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West Virginia Forests 2018: Summary Report

Citation

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Abstract

This report summarizes the third full annualized inventory of West Virginia forest land. The inventory was conducted from 2012 to 2018 by the Forest Inventory and Analysis program of the U.S. Department of Agriculture, Forest Service, Northern Research Station in cooperation with the West Virgina Division of Forestry. West Virginia has nearly 12 million acres of forest land with an average of 507 trees (at least 1.0-inch in diameter) per acre. Hardwoods are the dominant tree species in West Virginia. Forest land is dominated by the oak/hickory forest type group, which occupies 73 percent of the total forest land area (8.8 million acres). Sound tree volume of live trees averages 2,775 cubic feet per acre. Growing stock net growth exceeds removals resulting in a growth to removals ratio of 2:1, meaning that timberland is accumulating volume. Fragmentation and parcelization, aging forest cover, as well as threats from native and non-native plants and pests are major issues that will impact the future of West Virginia's forests. Information from the National Woodland Owner Survey and the Timber Products Output studies are also presented in this summary document.
For further information about the FIA program, including methods and raw data, please visit the National FIA program website. A detailed interactive report is available at https://doi.org/10.2737/NRS-RB-133-INT, and supplemental information, including (1) tables summarizing quality assurance, (2) a core set of tabular estimates for a variety of forest resources, and (3) user and database guides for P2 and P2+ protocols, can be accessed at https://doi.org/10.2737/NRS-RB-133.

KEYWORDS: inventory, land use, fragmentation, forest land, timberland, forest ownership, urban forests, volume, growth, removals, mortality, carbon, forest regeneration, invasive plants, forest health, forest products

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Cover Photo: Eastward view from Rich Mountain, Randolph County, West Virginia. USDA Forest Service photo by Karen Kubly.

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West Virginia Forests 2018: Summary Report

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Contact author:
Randall S. Morin
randall.s.morin@usda.gov
717-718-4174

About the Authors

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

Thomas A. Albright is a forester with the FIA Program, Northern Research Station, Williamsport, PA.

Brett J. Butler and Jesse Caputo are research foresters with the FIA program, Northern Research Station, Amherst, MA.

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

James D. Garner is an ecologist with the FIA program, Northern Research Station, St. Paul, MN.

Thomas C. Goff is a forester with the FIA program, Northern Research Station, Columbia, MO.

Cassie M. Kurtz and Brian F. Walters are foresters with the FIA program, Northern Research Station, St. Paul, MN.

Rachel Riemann is a research forester with the FIA program, Northern Research Station, Troy, NY.

Sjana Schanning is a forester with the FIA program, Northern Research Station, Hayward, WI.

Christopher W. Woodall is a research forester with Northern Research Station, Durham, NH.

Foreword

West Virginia, the third most heavily forested state in the nation, has come to rely greatly on the benefits of its abundance of forestlands. The State's ability to provide year around outdoor activities has made it a frequent destination for travelers looking to enjoy the great outdoors. Therefore, it is imperative that we, as stewards of the forest, do everything possible to ensure its sustainability.

West Virginia forests are generally considered multi-purpose forests. Not only do they serve as an important ecosystem necessary for the survival of many plant and animal species, but they also serve as an important natural resource designed to protect the atmosphere from the release of harmful greenhouse gases. Unfortunately, for far too many years, the volume of timber harvested on state-owned forest lands was insufficient to promote forest health and sustainability. The properties had simply become over-mature to the point that the State was at risk of losing all beneficial value of the properties. In 2017, the West Virginia Division of Forestry (WVDOF) began implementing an aggressive, but sound, silvicultural management plan that provided for the removal of over-mature, diseased, and inferior-quality species while allowing younger, healthier trees to continue to grow. While this project is still ongoing, I believe that it has already proven to be a great benefit to the sustainability of our forest lands.

Although the WVDOF is solely responsible for the sound, silvicultural and sustainable management of state-owned forest lands, it is important to note that we do not do it alone. The Division often works collaboratively with numerous state and federal agencies, higher education institutions, nonprofit organizations, and the forest-products industry on various initiatives designed to assure that the State's beautiful forest lands are well-managed and sustained. The compilation of the information contained in this book is an example of a successful working relationship and collaboration between the WVDOF and the Forest Inventory Analysis program of the U.S. Department of Agriculture, Forest Service, Northern Research Station. I am confident that this publication will serve as an invaluable tool for everyone interested in properly maintaining the forests and their important contribution to our society for generations to come.

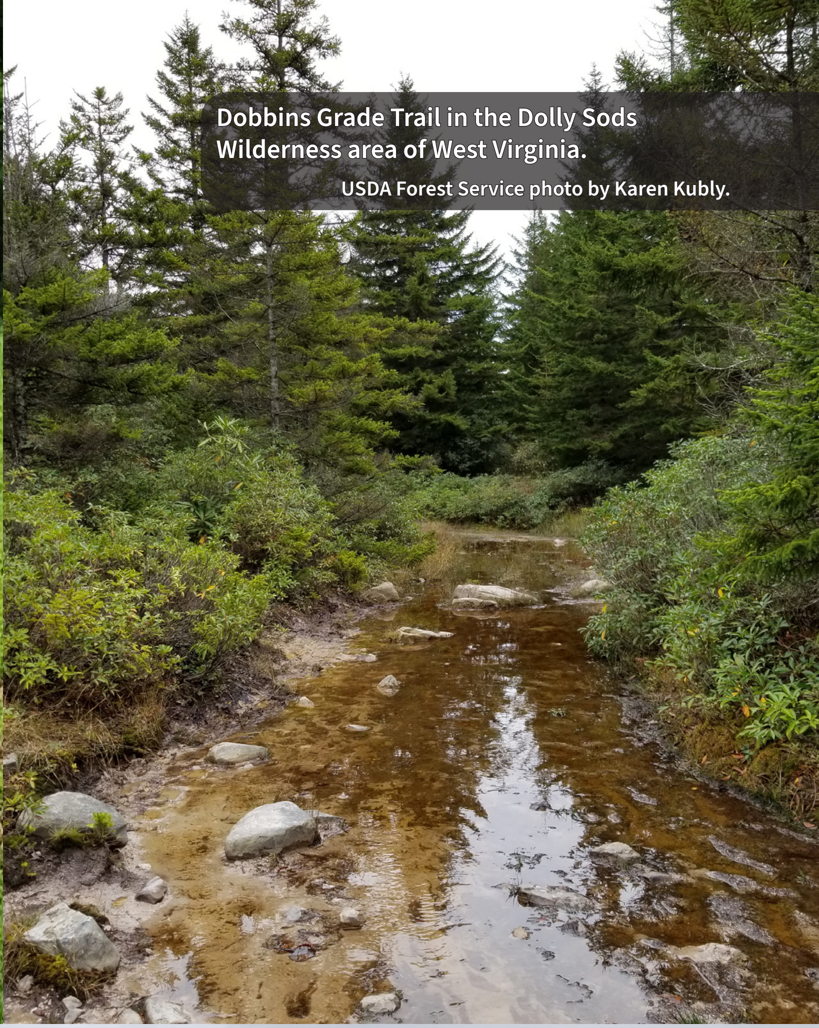
Tom Cover

Director/State Forester (retired)
West Virginia Division of Forestry

Contents

Deer and turkey in Doddridge County, West Virginia.

USDA Forest Service photo by Karen Kubly.



Dobbins Grade Trail in the Dolly Sods Wilderness area of West Virginia.

USDA Forest Service photo by Karen Kubly.

Lindy Point, Tucker County, West Virginia.

USDA Forest Service photo by Karen Kubly.

Highlights

On the Plus Side

- West Virginia is the third most forested state, with 78 percent of its land base forested.
- Timberland makes up 97 percent of West Virginia forest land.
- Due to the continuing increases in volume, West Virginia timber resources are at record levels since the first forest inventory in 1949.
- Most of the forest carbon in the region is found in medium-aged stands dominated by relatively long-lived species. This suggests that carbon stocks will continue to increase in the State as stands mature and accumulate carbon in aboveground and belowground components.
- The ratio of growth to removals is 2:1 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 2008.
- Tree crowns remain generally healthy and stable based on the low occurrence of crown dieback.
- Many of the wood-processing facilities in the State 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 has begun to increase after major declines that began in 2007.

Concerns

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Background

What is FIA?

The U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) program, is often referred to as the Nation's forest census. FIA is a national program that conducts and maintains a comprehensive inventory of forest resources in the United States and its territories. Key definitions, data collection methods, and estimation procedures are summarized in this report. For more detailed information, see Statistics and Quality Assurance for the Northern Research Station Forest Inventory and Analysis Program.

Visit the National FIA program website for additional information.

What is this report?

This report summarizes the findings of the eighth survey of the forest resources of Indiana conducted between 2012 and 2018. This report will refer to these years as the 2018 inventory. This report is broken into chapters that focus on forest features, forest resource attributes, health indicators, and socioeconomics. It includes graphics which summarize data to make comparisons as well as maps to reflect forest attribute estimates. The summary report and additional resource materials are available online at https://doi.org/10.2737/NRS-RB-133.

More detailed results are available in the West Virginia Forests 2018: Interactive Report StoryMap collection (Fig. 1). It includes interactive maps, charts, and dashboards that summarize data and illustrate trends, making it easy for readers to compare between inventory periods, geographic locations, or ecological divisions. This document offers a summary of those results.

West Virginia Forest Inventories

Information on the condition and status of forests in Indiana was obtained from the USDA Forest Service, Northern Research Station, Forest Inventory and Analysis (NRS-FIA) program. Periodic inventories were completed in 1949 (Wray 1952), 1961 (Ferguson 1964), 1975 (Bones 1978), 1989 (DiGiovanni 1990), and 2000 (Griffith and Widmann 2003). Previous annual inventory cycles were completed in 2008 (Widmann et al. 2012) and 2013 (Morin et al. 2016).

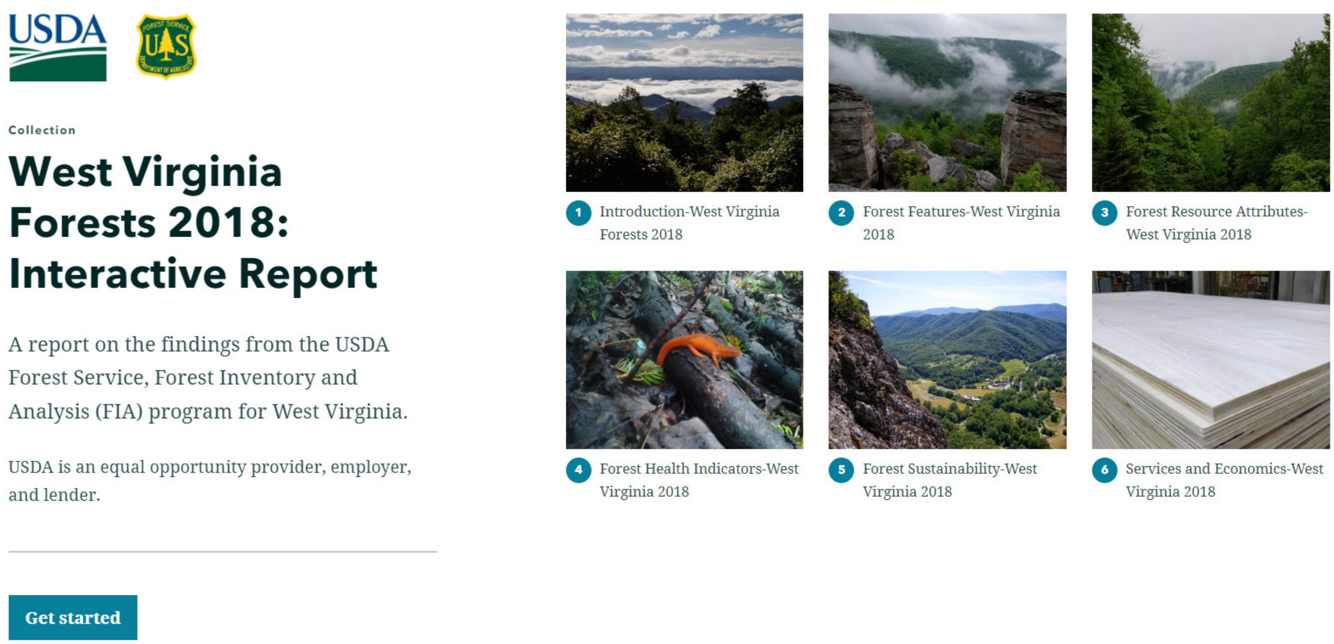

Figure 1.—The West Virginia Forests 2018: Interactive Report contains a series of StoryMaps (collection) that focus on different forest aspects. Select the Get Started button or one of the photos to view an individual StoryMap within the collection.

FIA switched from periodic to annual inventories starting after the 1998 periodic inventory. West Virginia began annual inventories in 2004. Under the annual inventory system, approximately one-fifth of all field plots were measured each year. This resulted in a completed inventory every 5 years, with estimates being produced using a 5-year moving average. In 2014, NRS-FIA changed to a 7-year inventory cycle, wherein one-seventh (14.3 percent) of the plots are measured annually. For the 2018 inventory, estimates such as forest area, volume, and biomass are based on 2,070 forested field plots collected from 2013 to 2018. The 2018 change variables, such as net growth, removals, and mortality, are based on 2,027 plots collected in 2007 to 2013 and resampled in 2013 to 2018. Data used in this publication were accessed from the FIA database from May 2019 to May 2020. Information published in this report and in related tables is based on Forest Inventory and Analysis Database (FIADB), collected under NRS field guides 4.0 to 7.2 and compiled in the National Information Management System (NIMS). Version 7.2 of the FIA field methods guide was released October 2017. It describes the current set of nationally consistent core field procedures used by all FIA units for projects that begin after the date of release. This version of the field guide covers all core and core optional measurements collected on Phase 2 plots (the standard base FIA sample grid, each sample location represents approximately 6,000 acres). See Bechtold and Patterson (2005) and Gormanson et al. (2023) for definitions and technical details. FIA estimates, tabular data, and maps may be generated using the various applications in the FIA Data and Tools page.

Forest Features

Forest Area and Land Use

West Virginia's diverse forests are dominated by oak/hickory and maple/beech/birch forest-type groups, but spruce/fir and pine forest-type groups 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 the Forest Inventory and Analysis program's estimates of numbers of trees, wood volume, and biomass.

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 and has remained relatively stable (Fig. 2).

Forests are the dominant land cover across most of West Virginia. The percentage of forest cover is highest in the Cumberland Mountains which are dominated by the Monongahela National Forest. FIA groups contiguous counties that have similar forest cover, soil, and economic conditions into geographic units, referred to in this report as FIA units or inventory units: Northwestern, Southern, and Northeastern (Fig. 3).

Figure 2.—Area of forest land and timberland by year, West Virginia. Error bars represent a 68 percent confidence interval.

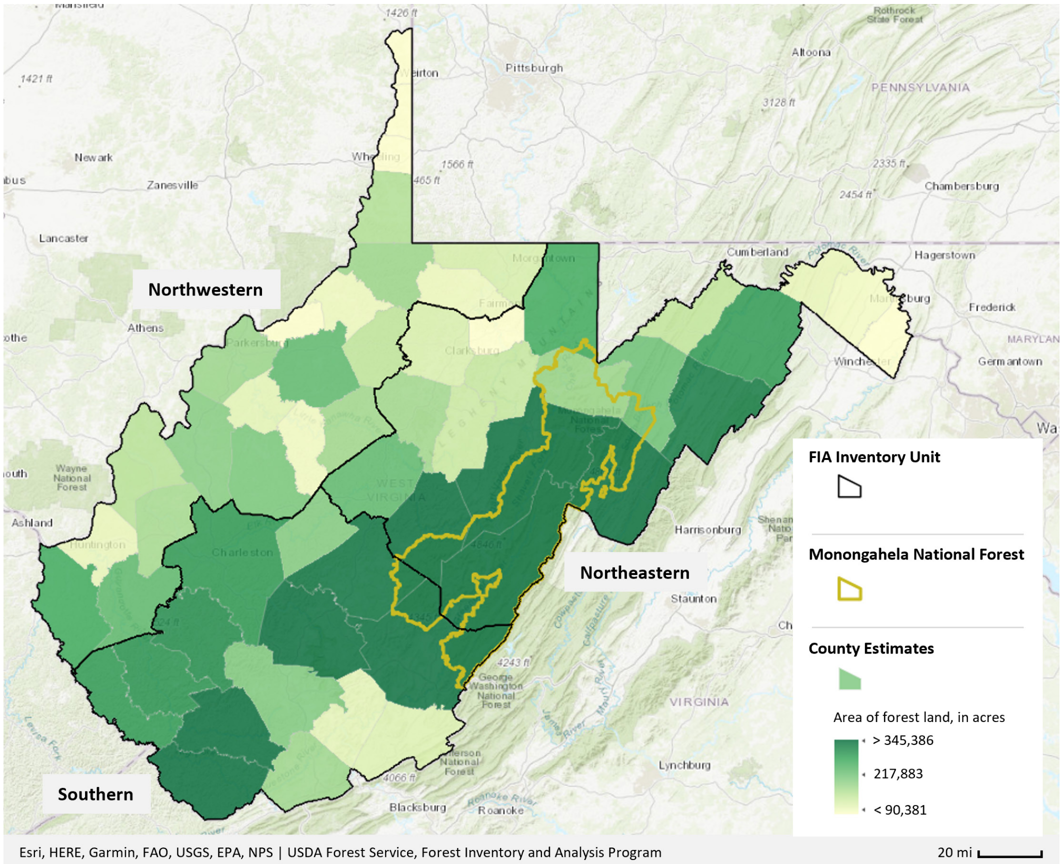

Figure 3.—Area of forest land by county, West Virginia, 2018.

West Virginia is the third most forested state, with 78 percent of its land base forested. The current statewide estimates of forest land have remained stable since 1989. Future changes in the West Virginia forest land base will depend on the pace of land development as well as the economics of farming and the oil and gas industries, and the composition of future forests will depend on many factors including disturbance, management, and climate regimes.

Land-Use Change

Although the total area of forest land in West Virginia has remained relatively stable between 2013 and 2018, some areas of the State have experienced forest loss while other areas have seen increases in forest land. To better understand West Virginia 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 (or diversion), and the conversion of nonforest land to forest is known as gross forest gain (or reversion). 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 forest resources and helps land managers make informed policy decisions.

Forest losses and gains are happening occur across much of the State with losses particularly evident in northern West Virginia. However, the area containing the Monongahela National Forest has had very little change in forest land. The amount of forest that diverted to nonforest land (221,000 acres) was more than double the amount of nonforest that reverted to new forest (106,000 acres), leading to net loss in total forest land area (Fig. 4). Developed land was the predominant land use associated with both forest loss (119,000 acres) and forest gain (54,000 acres).

The net loss of forest land reported in this inventory is due to gross loss exceeding gross gain. Gains and losses from multiple causes are driving forest land-use change dynamics in West Virginia. 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. Thus, some reported changes are not necessarily permanent.

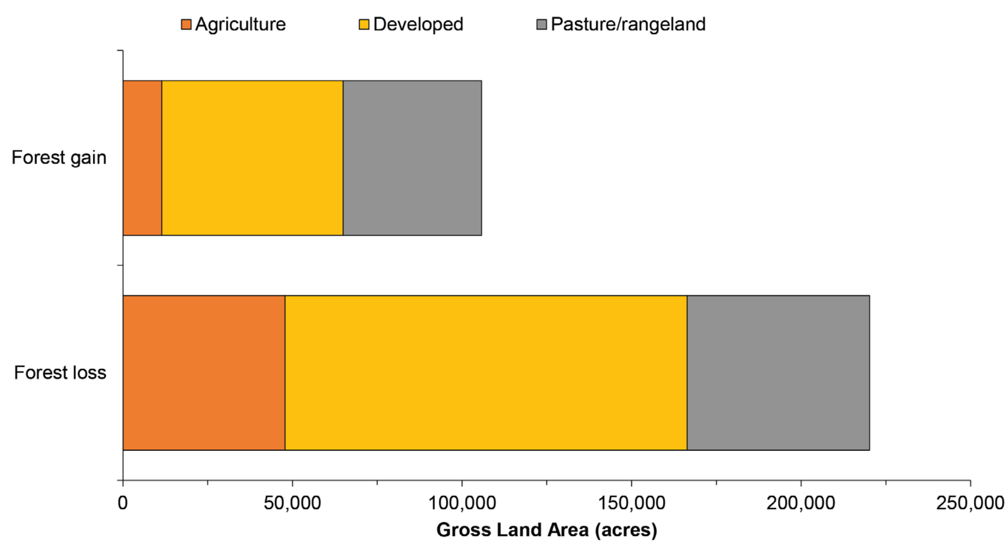

Figure 4.—Gross area forest gain and forest loss by land use category, West Virginia, 2013 to 2018. Gross area forest loss and forest gain due to rights-of-way, water, and other nonforest land was negligible.

Availability and Productivity

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 landowners 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.

Ninety-seven percent of West Virginia forest land meets the definition of timberland, and 89 percent of that timberland is in private ownership. The current estimates of timberland have remained relatively unchanged since 1989 (Fig. 2). Most of the land in the reserved class is designated wilderness 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. 5).

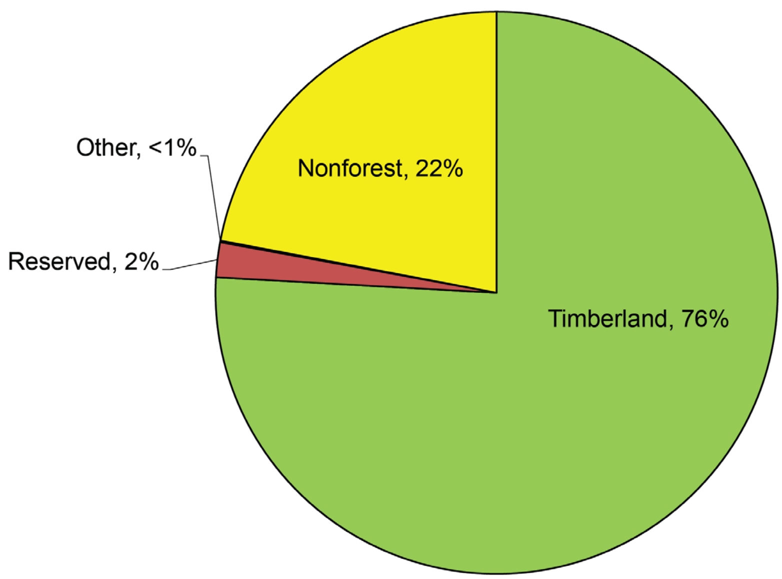

Figure 5.—Land area by major category, West Virginia, 2018.

Volume

The assessment of the volume of live trees provides information on trends in the resource, the potential uses of that wood, and its economic value. Current volumes and changes in volume over time can characterize forests and reveal important resource trends. FIA reports volume for trees at least 5.0 inches in diameter, measured as diameter at breast height (d.b.h.), by several categories including: sound, net, growing stock, and sawtimber. Sound volume is the total volume less deductions for rotten and unsound wood. Net volume is sound volume minus additional deductions for roughness and form defects and is computed for the central stem from the 1-foot stump to a 4.0-inch top diameter. Growing-stock volume excludes rough or rotten cull trees and non-commercial species. Volume estimates for sound, net, and growing stock are reported in cubic feet. Trees classified as rough cull either have two-thirds of their volume not meeting merchantable requirements with the majority of that volume being rough cull, or they are not a commercial species. Rotten cull trees have two-thirds of their volume as cull and the majority is unsound or rotten cull. While rough and rotten cull trees may not be available for timber utilization, they provide critical wildlife habitat and carbon storage. Estimates of sawtimber volume are reported in board feet (International ¼-inch), from stump for hardwoods, minimum 11.0 inches d.b.h. to a 9-inch top diameter, and from stump for softwoods, minimum 9.0 inches d.b.h. to a 7-inch top diameter.

Sound volume on forest land increased 3 percent from 2013 to 2018 to 33.2 billion cubic feet, and 95 percent of that volume was in hardwood species. Timberland accounted for 97 percent (32.1 billion cubic feet) of total sound volume, also increasing 3 percent over the same time period. Reserved forest land saw a 6 percent rise in sound volume to 1.1 billion cubic feet. Net volume on timberland was 28.2 billion cubic feet, a 3 percent increase, and 93 percent of net volume was in growing-stock trees (Fig. 6). The proportion of net volume in growing stock decreased from 95 percent in 2008 to 93 percent in 2013 and remained at that level in the most recent 2018 survey. Similarly, the proportion of net volume in rough cull increased from 4 percent in 2008 to 6 percent in 2013 and 2018 while rotten cull remained static over that time period. Interestingly, the proportion of net volume in growing stock, rough cull, and rotten cull trees is essentially the same on public-owned and private-owned timberland.

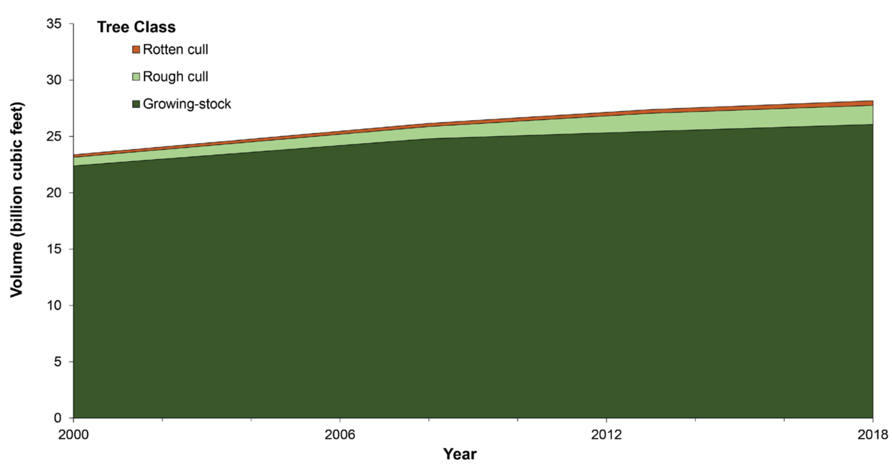

Figure 6.—Net volume on timberland by tree class and year, West Virginia.

Sawtimber volume on timberland increased 12 percent between 2008 and 2018 to 97.3 billion board feet (International ¼-inch). Yellow-poplar[1] alone accounts for 19 percent of that volume and saw an increase of 17 percent to 18.3 billion board feet over the same time period (Fig. 7). Red maple and black cherry also experienced notable gains since 2008, increasing 20 percent and 29 percent respectively. Although estimates for sawtimber volume have decreased for some species, all of these changes are within the margin of error.

Differences in hardwood sawtimber quality are clear when comparing public and private owned timberland (Fig. 8). On public-owned timberland, 43 percent of hardwood sawtimber volume meets the standard for grade 1, compared to 33 percent on private. The proportion of volume in the tie/timber grade was also significantly different between the two major ownership groups, 4 percent for public and 10 percent for private.

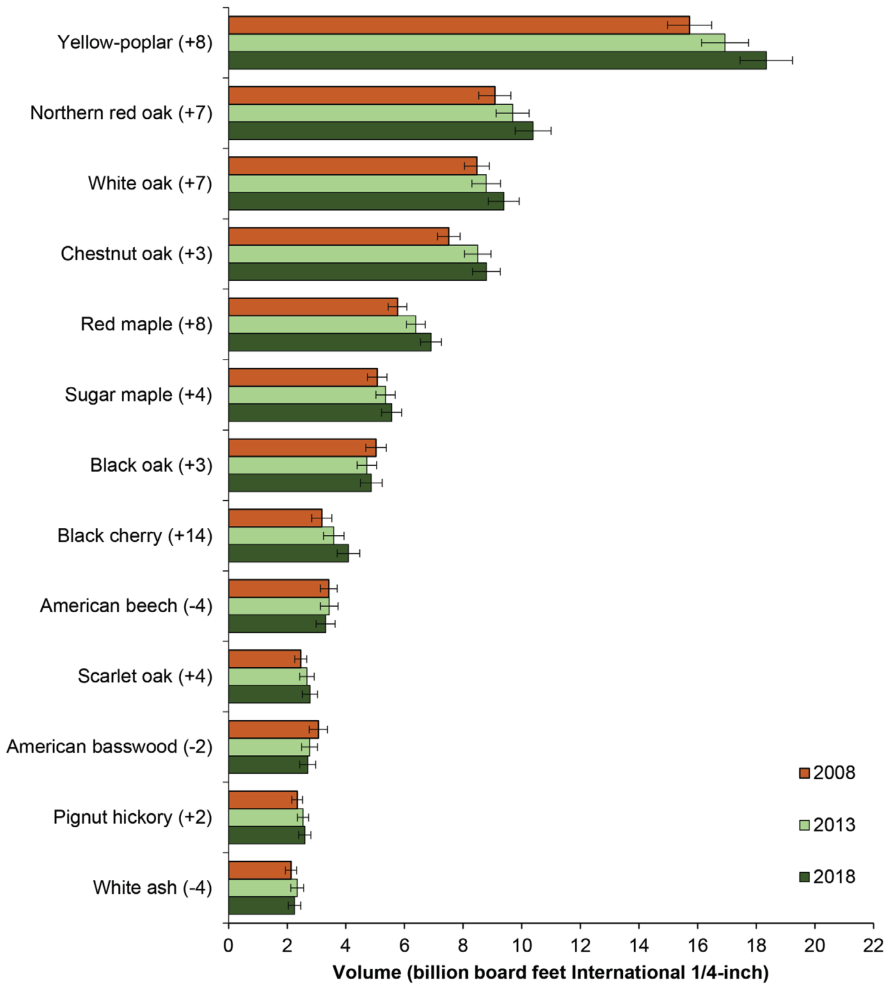

Figure 7.—Sawtimber volume on timberland of species having at least 2 percent of volume, by inventory year, with percentage change between 2013 and 2018 in parentheses, West Virginia. Error bars represent a 68 percent confidence interval.

[1] See list of tree species, seedling and larger, found on FIA plots in West Virginia in the 2018 inventory for a list of common and scientific names for each tree species.

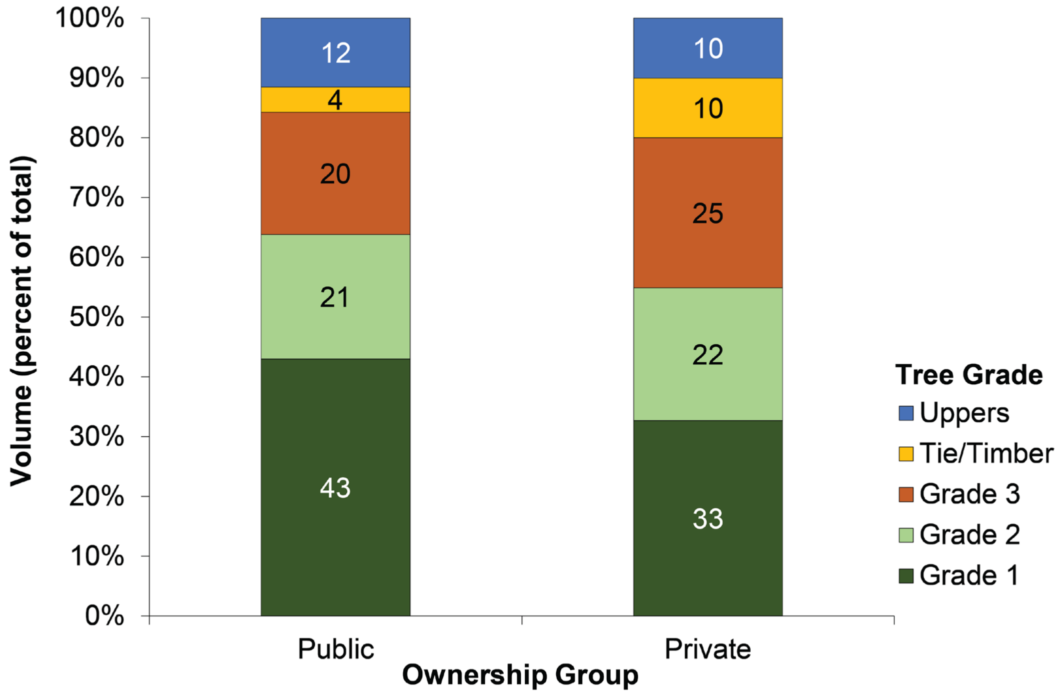

Figure 8.—Proportion of total hardwood sawtimber volume on timberland by tree grade and major ownership group, West Virginia, 2018. "Uppers" refers to trees containing a qualifying saw log outside the butt section.

Net sawtimber volume increased from 2013 to 2018. Ninety-three percent of net volume on timberland was in growing-stock trees in 2018, compared to 96 percent in the last periodic inventory in 2000. While the low proportion of net volume on timberland in cull trees is a positive indication of the State's overall timber quality, the steady increase of that proportion, specifically rough cull, is an important trend to monitor going forward.

West Virginia ranks third in the United States in proportional hardwood sawtimber volume in high-quality tree grades (grades 1 and 2) and second only to Pennsylvania in total board foot (International ¼inch) volume in these grades. Hardwood sawtimber volume on timberland increased 6 percent from 2013 to 2018 but 39 percent of that increase was in tie/timber grade trees compared to 20 percent in grade 1 trees (Fig. 9). Grade 1 volume increased 7.5 billion board feet from 2008 to 2013, then increased less than one billion board feet from 2013 to 2018. Changes in these trends will be important for foresters and policy makers to follow going forward to ensure the continued delivery of high-quality hardwood products from the State forests.

Timber quality overall is higher on public-owned land than on private owned land but 86 percent of hardwood sawtimber volume is on private land. The higher proportional volume in grade 1 trees on public-owned land coupled with the low number of family forest owners with a written management plan suggests that there is room for improvement where the management of private timberland is concerned.

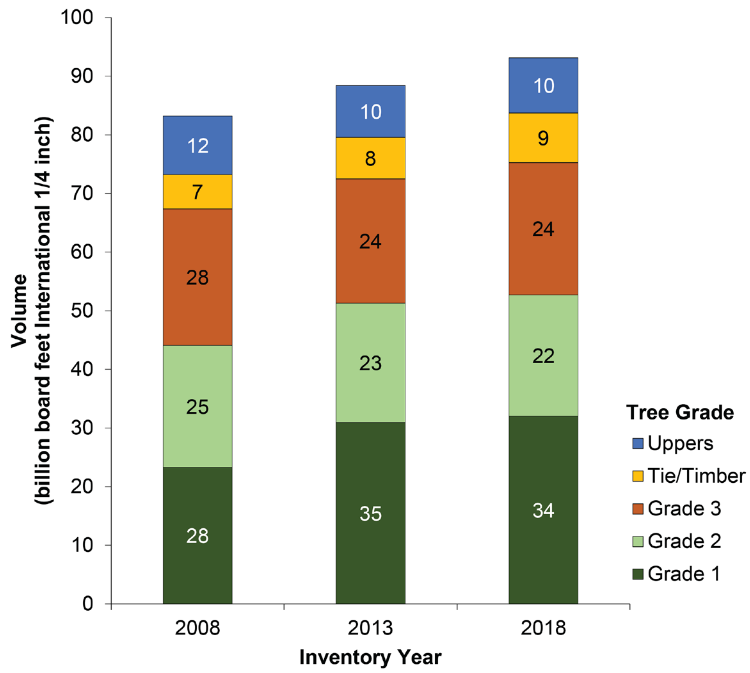

Figure 9.—Hardwood sawtimber volume on timberland, by tree grade and inventory year, with percentage of total hardwood sawtimber volume for each inventory year, West Virginia.

Forest Ownership

To a large extent, the availability and quality of forest resources are determined by landowners. It is the owners, working within biophysical, legal, and market constraints, who ultimately determine if the land will stay forested, how much timber will be supplied, what recreational opportunities will be available and to whom, and what types of wildlife habitat will be encouraged. By understanding the characteristics of forest landowners, the forest conservation community can better help owners meet their needs, and in so doing, help conserve the forests for future generations. FIA's National Woodland Owner Survey (NWOS) studies private forest landowner attitudes, management objectives, and concerns with a focus on families, individuals, and other unincorporated groups, collectively referred to as "family forest owners" (Butler et al. 2021).

Nearly nine out of every 10 acres of forest land in West Virginia are privately owned. The majority of the forest acres in the State, an estimated 6.1 million acres (50.8 percent of all forest land), are family-owned forests. Corporations own an estimated 4.1 million acres of forest land (34.5 percent). Other private owners, including conservation organizations and unincorporated clubs and partnerships, own an additional 131,000 acres. Public agencies (federal, state, and local) control 13.6 percent of West Virginia forest land. The Federal government manages 1.2 million acres, largely in the Monongahela National Forest. An estimated 330,000 acres are managed by state forest, park, and wildlife agencies. An additional 60,000 acres are managed by local government agencies (Fig. 10). Over the past decade, 2008 to 2018, the largest changes have been approximately a 500 thousand acre decrease in the acreage in family forest holdings and corresponding 700 thousand acre increase in the acreage in corporate forest holdings.

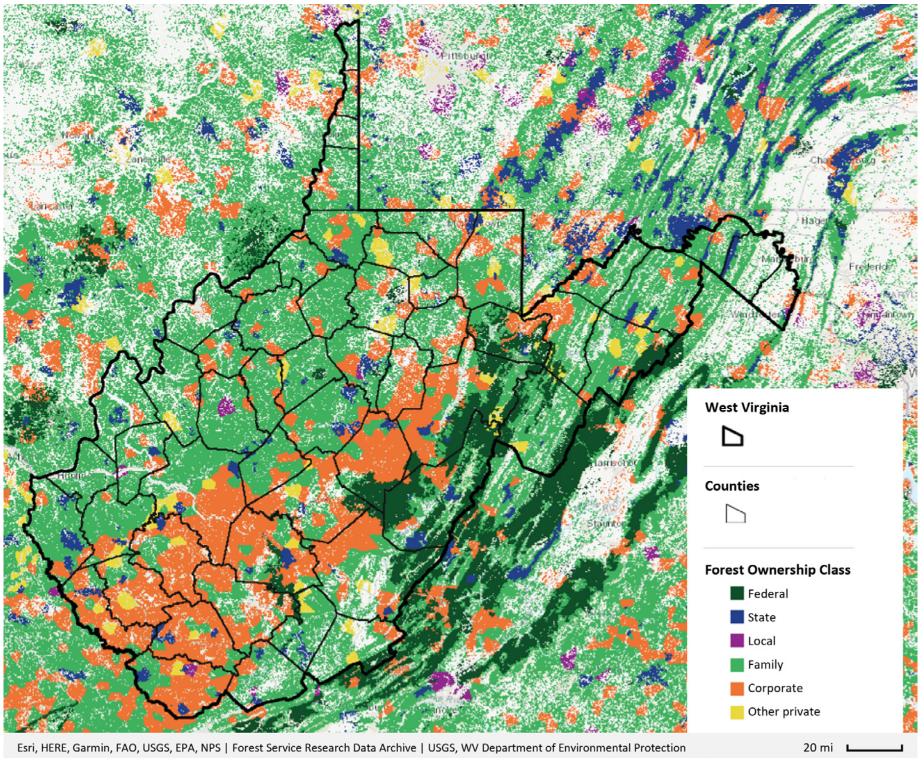

Figure 10.—Distribution of forest land by ownership class, West Virginia.

There are an estimated 96,000 family forest ownerships with 10 or more acres of forest land across West Virginia. An estimated 67.4 percent of these family forest ownerships own less than 50 acres of forest land, but 77.0 percent of the family forest land is in holdings of at least 50 acres. The average size of a family forest holding is 59.3 acres (Fig. 11).

Many family forest owners are active on their land. The most common activities are personal recreation, such as hiking or hunting, and cutting trees for personal use, such as firewood (Fig. 12). And the intentions for doing these activities in the future are even greater.

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. The percentage of ownerships who have received advice and who have written forest managements plans is well under 50 percent and there are significant opportunities to help owners increase their engagement and stewardship of their lands.

Another important trend to watch is the aging of the family forest owners. Given the average age of family forest owners in West Virginia, 63 years, many acres of land will be passing on to the next generation in the not-too-distant future.

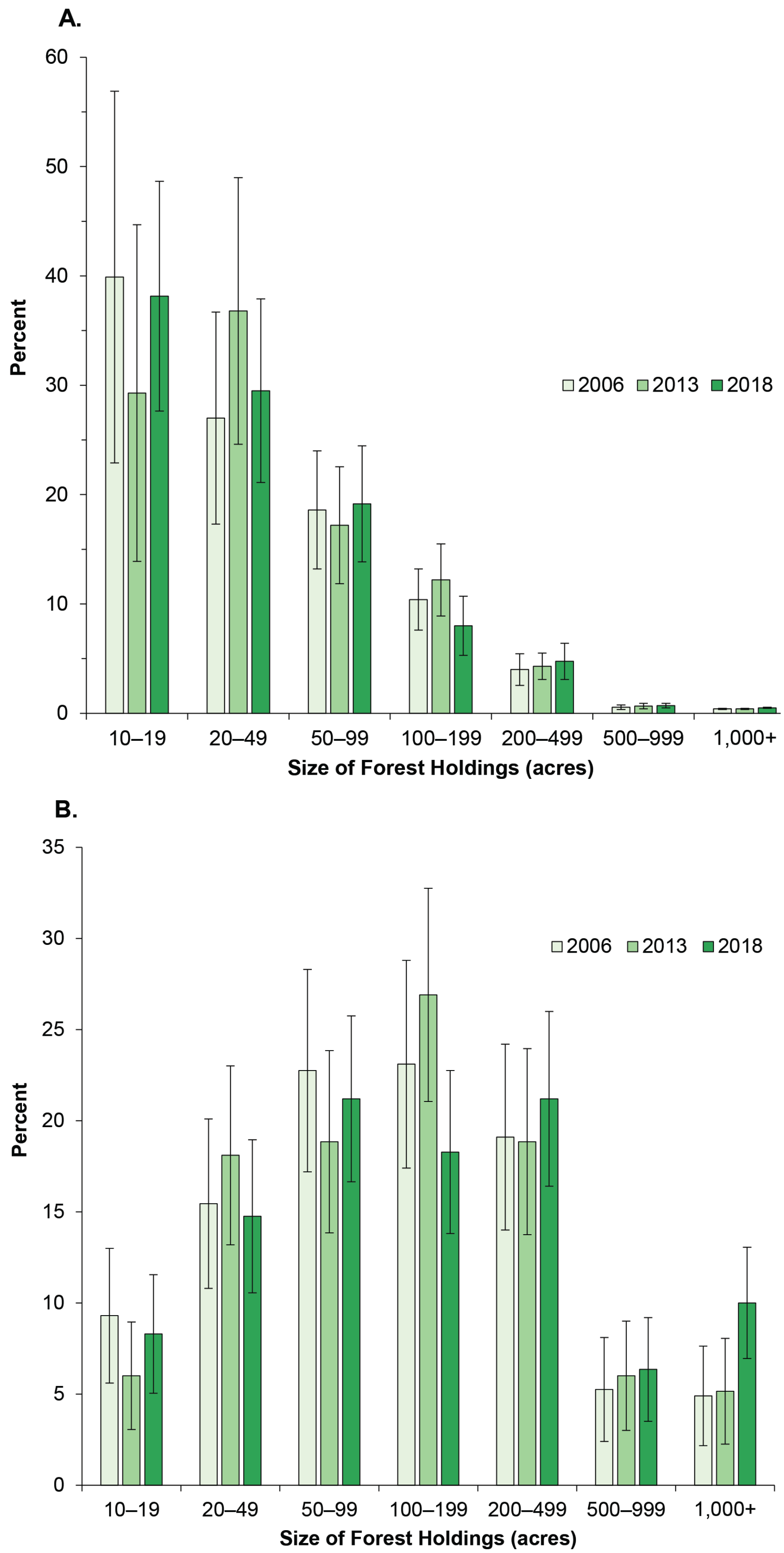

Figure 11.—Percent of (A) family forest ownerships and (B) family forest acreage by size of forest holdings and inventory year, West Virginia. Error bars represent a 95 percent confidence interval

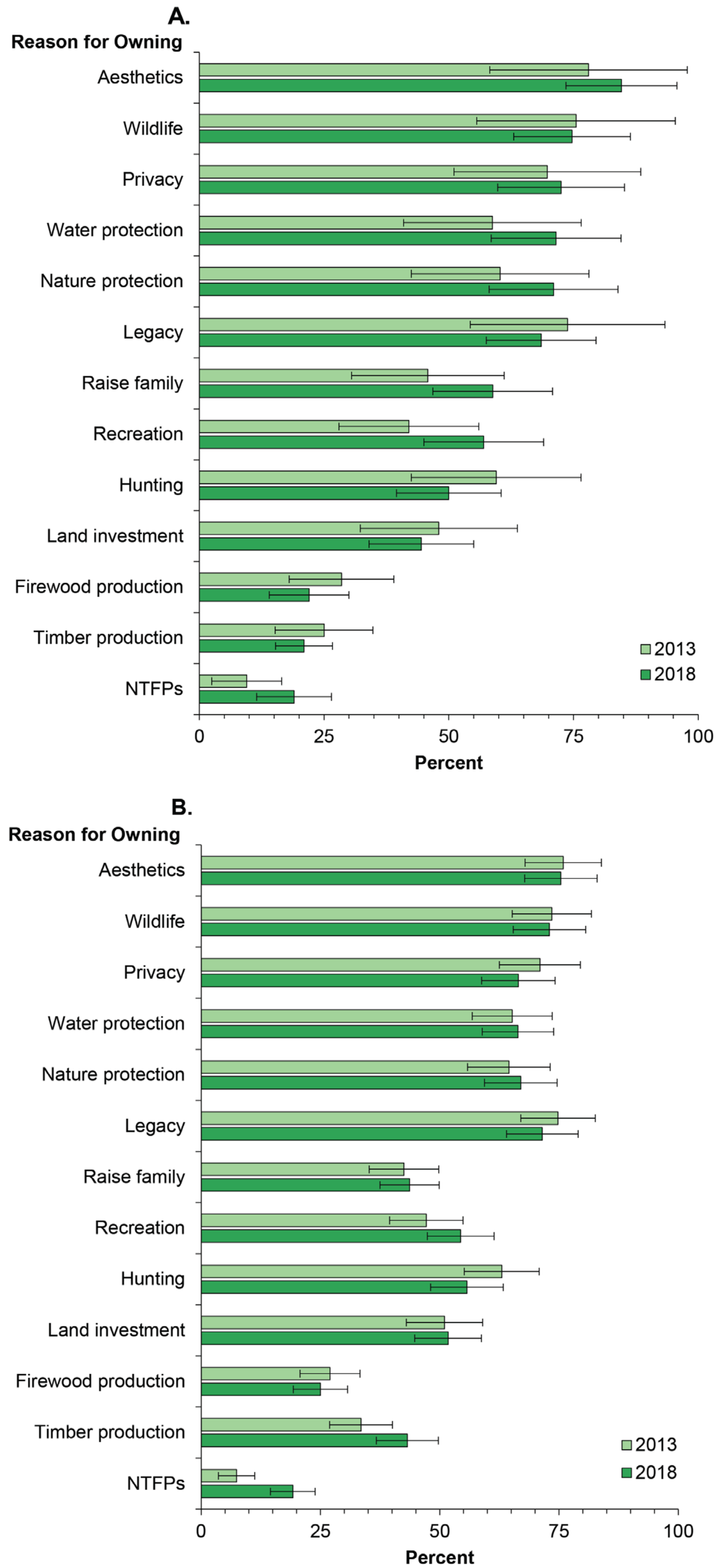

Figure 12.—Family forest (10+ acres) (A) ownerships and (B) acreage by reason for owning by inventory year, West Virginia. Error bars represent a 95 percent confidence interval. NTFPs are non-timber forest products.

Forest Resource Attributes

Forest-Type Groups

The composition of forests can be described at varying levels, from the numbers of individual species of seedlings, saplings, and trees, to a broader view of the resource categorizing land based on shared characteristics. The broad-scale delineation of forest land is expressed as forest types which comprise tree species that generally coexist together in a forested setting. Similar forest types are collectively known as forest-type groups.

Over 91 percent of West Virginia's 12 million forest land acres was composed of just two forest-type groups (Fig. 13). Oak/hickory accounted for nearly three-quarters of all forested acres with 8.8 million acres (73 percent). Maple/beech/birch occupied 2.2 million acres of forest land in 2018, or 18 percent of the total. Only one other forest-type group exceeded 2 percent of forested area: 278,000 acres were categorized as oak/pine. Though the two primary forest-type groups are dominant across the State, regional differences in the abundance of forest-type groups were apparent. The Northwestern and Southern units were 79 and 82 percent oak/hickory, respectively. Maple/beech/birch accounted for a higher proportion of forest land in the Northeastern unit where it reached 28 percent (1.3 million acres) and oak/hickory was only 61 percent of the unit's forested area.

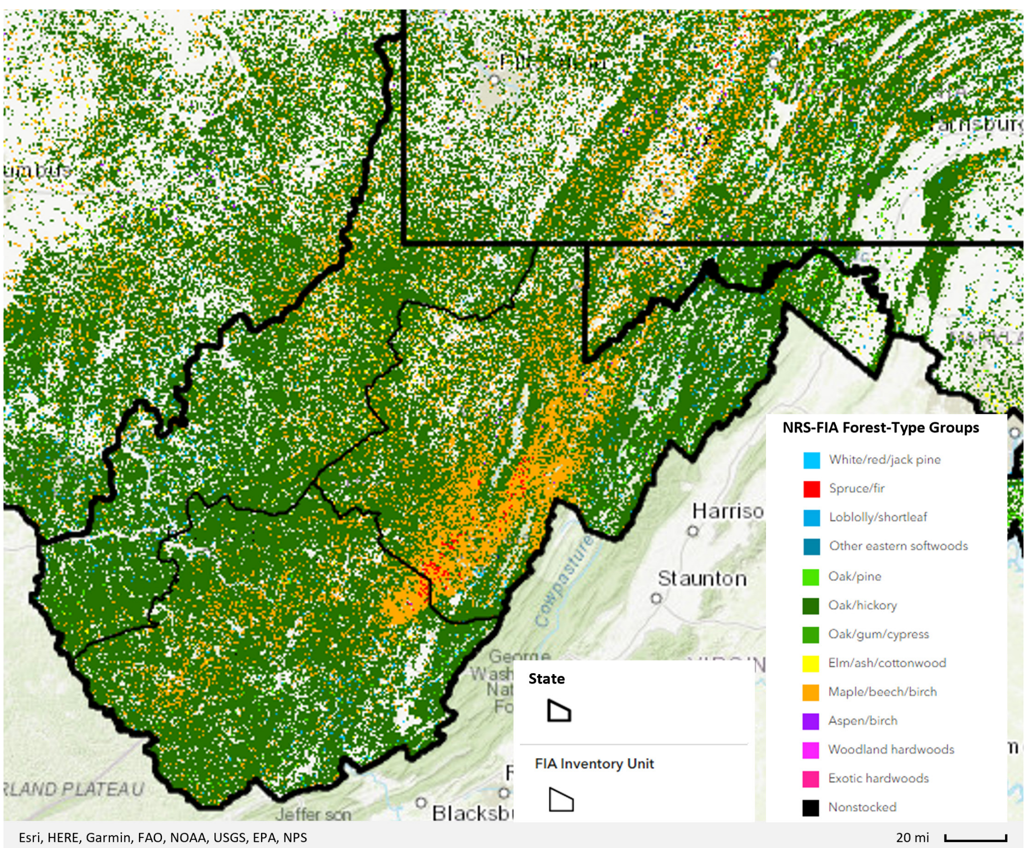

Figure 13.—Distribution of forest-type groups by inventory unit, West Virginia, 2018.

Though changes in the extent of forest-type groups are generally slow, some trends can be identified in the data of the past 10 years. The dominance of oak/hickory has decreased slightly since 2008 when it was 74.5 percent of forest land. This loss is equal to 130,000 acres over 10 years. A substantial portion of the oak/hickory loss of acreage was taken up by maple/beech birch which increased from 17.8 percent of forest land in 2008 to 18.3 percent in 2018, a gain of 52,000 acres. Elm/ash/cottonwood, while still a relatively small part of overall forest acreage, also saw an increase in proportion from 1.2 percent in 2008 to 1.9 percent in 2018, a 91,000-acre gain. Over 60,000 of the new elm/ash/cottonwood acreage was classified as oak/hickory in the last inventory cycle. It is unclear whether the trends of the last 10 years will continue. Ongoing analysis over successive inventory cycles will add clarity to the issue.

Tree Species Composition

Forest composition is constantly evolving. Influenced by the presence or absence of disturbances such as timber management, recreation, wildfire, ice storms, episodic precipitation, and invasive species, the current state of tree species composition is a reflection of historical and environmental trends across landscapes and within individual forests. As a result, the composition of tree species in a forest is an indicator of forest health, growth, succession, disturbance, and management. Knowledge of the distribution of species within a stand allows for the measurement and prediction of change.

The forest land in West Virginia contains over 6 billion trees (at least 1.0 inch d.b.h.) representing more than 100 different tree species. Red maple is the most abundant tree totaling over 900 million stems across the State (Fig. 14). The other top species by number are sugar maple, American beech, and yellow-poplar. Across successive inventories since 2008, the abundance across tree species has remained rather stable with slight decreases for red maple and sugar maple and substantial increases in American beech and yellow-poplar.

Approximately 11 percent of West Virginia trees are of sawtimber size (639 million) representing more than 70 different tree species (Fig. 15). Sawtimber size trees are at least 9.0 inches d.b.h. for softwoods and at least 11.0 inches d.b.h. for hardwoods. The top sawtimber species are dominated by yellow-poplar, chestnut oak, white oak, and red maple. Across successive inventories since 2008, the abundance of most of the important sawtimber species such as yellow-poplar, oak spp., red maple, and sugar maple have shown slight increases.

Timber resources in West Virginia are at record levels since FIA inventories began in 1949 but there is some indication that the rate of increase has leveled off. This rate may continue to decrease as the average of forest land in the State continues to increase. Despite the rate of increase leveling off, the forests of West Virginia continue to add value due to growth that is occurring on the higher valued sawtimber-sized trees. The forest products industry as well as landowners 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.

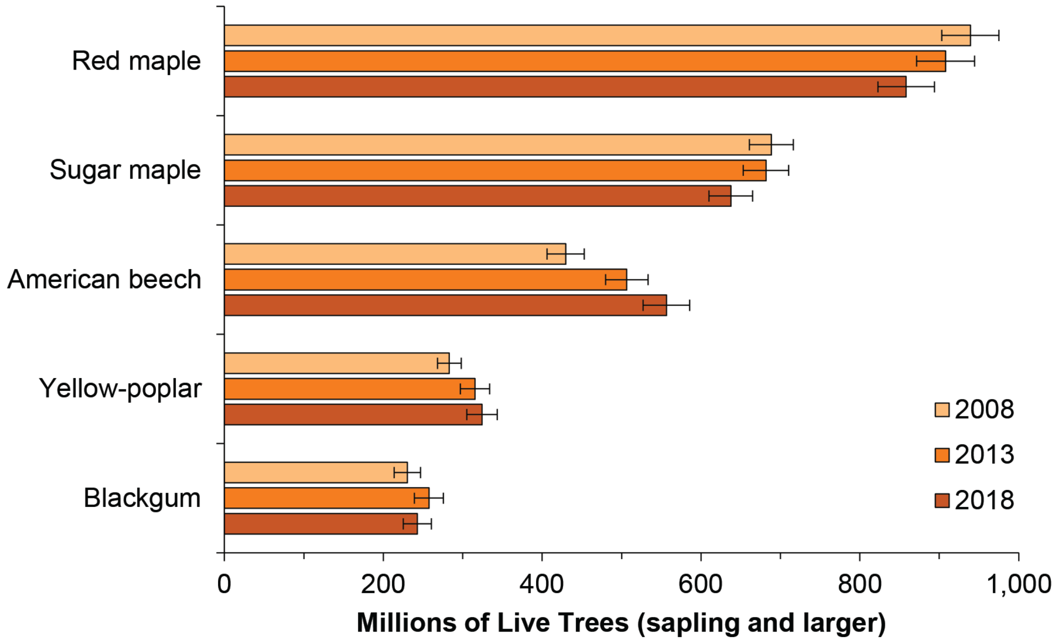

Figure 14.—Number of live sapling or larger trees on forest land by species and inventory year, West Virginia. Error bars represent a 68 percent confidence interval.

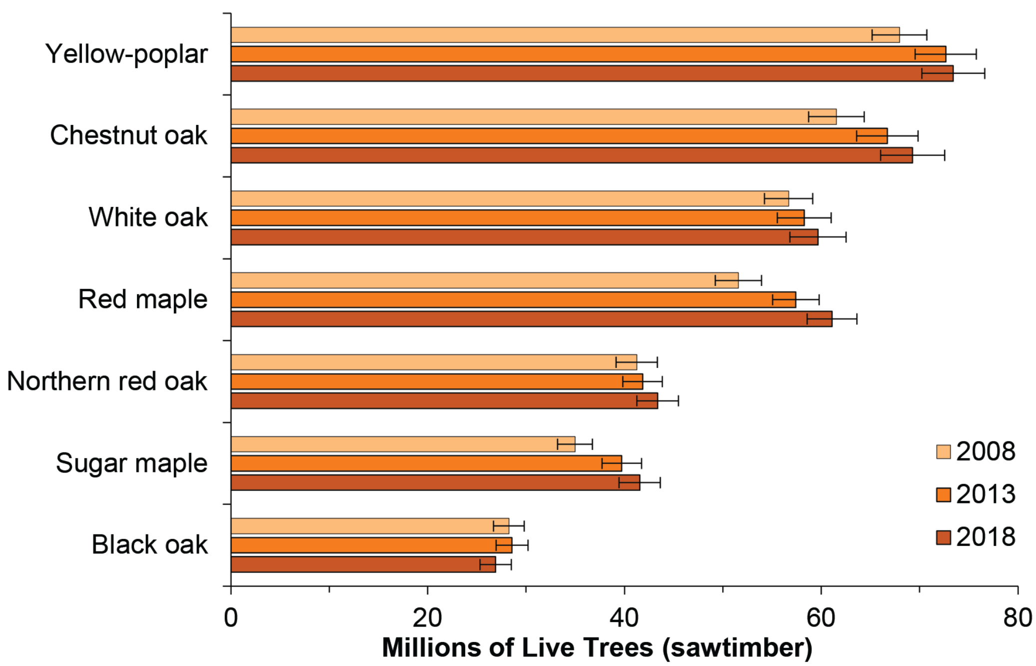

Figure 15.—Number of live sawtimber-sized trees on forest land by species and inventory year, West Virginia. Error bars represent a 68 percent confidence interval.

Stand Structure

The relationships between forest type, stand size, and stand age provide insight about overall forest composition and structure. Although stand size and stand age are closely related, examined separately, they can each provide valuable information about different aspects of a forest. While stand size may provide information important for timber products development and ecosystem services, stand age may help to better understand habitat availability and forest succession. Information about the presence of standing dead trees also provides insight regarding wildlife habitat, carbon storage and overall forest structure. Forest structure is discussed by examining the relationship between stand size, stand age, forest type and the presence of standing dead trees.

Three classes are used to describe the stand size of forested conditions. The seedling/sapling (small) size class is assigned to stands where at least half of the total stocking present is in seedlings and saplings (trees less than 5.0 inches d.b.h.). The poletimber (medium) stand-size class describes stands where at least half of the stocking is of trees at least 5.0 inches d.b.h. but less than the diameter standards for a softwood or hardwood sawtimber tree. When the majority of stocking volume in a stand is made up of softwoods at least 9.0 inches d.b.h. and hardwood species at least 11.0 inches d.b.h., the sawtimber (large) stand-size class is assigned. For timberland these simple classifications allow for easy comparisons of young, maturing, and mature forests.

The proportion of timberland classified as large diameter stands has been steadily increasing (Fig. 16). Although the total area of timberland has decreased slightly overall, since 1989 the acreage of large diameter stands has increased by nearly 2 million acres as small- and medium-sized stands grow and shift into the larger stand-size class.

Accounting for nearly a quarter (24 percent) of all timberland in West Virginia, the balance of stand-size classes within the white oak/red oak/hickory forest type is skewed heavily toward sawtimber stands with 91 percent of stands classified in the large size class and only a single percent in the seedling/sapling category. This is a notable shift from 1989 when sawtimber stands made up just 56 percent of the white oak/red oak/hickory and a full 14 percent were seedling/sapling stands (Di Giovanni 1990).

Timberland across the State continues to grow and shift from small and medium stands into the large stand-size class. Although these shifts suggest maturing forests, they alone do not indicate a lack of regeneration. Stands that classify as sawtimber include trees of a full range of sizes and the large number of saplings across all stand-size classes suggests that recruitment is occurring in the understory resulting in dynamic, multi-aged, and multi-sized stands. The continued decline of timberland qualifying as small and medium sized stands does, however, suggest a reduction in the diversity of habitat available across the State.

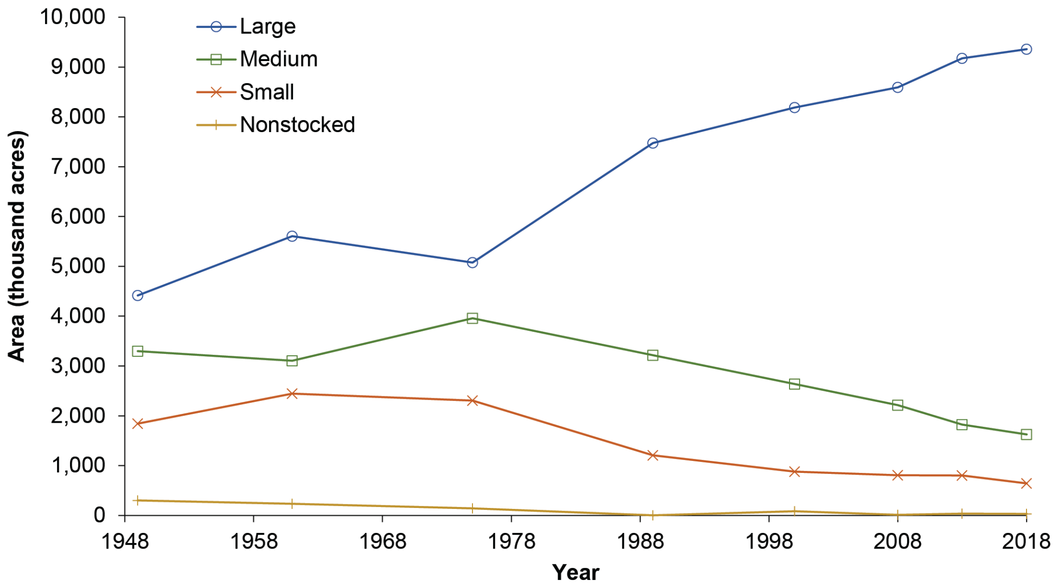

Figure 16.—Area of timberland by stand-size class and year, West Virginia.

Forest Health Indicators

Insects and Diseases

Insects and disease pathogens help shape the structure and composition of forest ecosystems. Monitoring their status provides a measure of forest health and is crucial in assessing the current state and changing trends in West Virginia forests. Mortality caused by insect and disease activity can be hard to differentiate from other causes and natural senescence. The ratio of mortality-to-gross growth has been used as a national indicator of mortality; ratios above 0.6 are considered high and may be indicative of an acute forest health issue if forests are not senescing (Ambrose 2019). Further, a high mortality-to-gross growth ratio, in combination with high average annual mortality as a percentage of live volume suggests an increased likelihood of a serious threat to forest health.

Over the 2018 inventory cycle, West Virginia forests have been impacted by a variety of native and introduced insects and diseases, including spongy moth (*Lymantria dispar*), sycamore anthracnose, oak decline, beech bark disease, emerald ash borer (*Agrilus planipennis*), and hemlock woolly adelgid (*Adelges tsugae*). At the time the data in this report were gathered (2012 through 2018), spotted lanternfly (*Lycorma delicatula*) had not yet been reported in West Virginia. However, it was introduced in 2019 and now poses risks to grapes, hops, and a variety of fruit trees. Continued research on hosts will determine if spotted lanternfly is a viable pest of West Virginia tree species beyond the invasive tree, ailanthus. Two major insect species of concern, emerald ash borer (EAB) and hemlock woolly adelgid (HWA), are discussed further.

Emerald ash borer, a wood-boring beetle native to Asia, was first detected in southcentral West Virginia in 2007 and within 10 years, EAB was found in every county (Fig. 17). As EAB is difficult to detect at low-levels, natural spread was enhanced by human-mediated transportation of infested materials; subsequently, spread of EAB has outpaced detection, with population establishment averaging 4 to 6 years prior to identification (McCullough 2020). All North American ash species are hosts of EAB; however, host preference appears to vary by species, with consistently high observations of green ash and black ash mortality and variable white ash mortality (Herms and McCullough 2014, McCullough 2020). Although EAB shows some preference for stressed trees, all trees 1.0 inch in diameter or greater are susceptible regardless of vigor.

Ash trees are an important component of the West Virginia forest resource. The high mortality-to-gross growth ratio indicates that current statewide mortality of ash exceeds ash growth, and in combination with a high mortality rate, suggests that ash forests are experiencing a forest health issue. While the presence of EAB cannot be directly linked to ash mortality, the rising mortality-to-gross growth ratio since EAB's introduction suggests that EAB is likely the main driver. Additionally, as greater than 50 percent of the State had identified EAB infestations by 2013, the increase in mortality since 2018 is likely to be largely influenced by EAB activity. The loss of ash in forested ecosystems will affect species composition and alter community dynamics. Continued monitoring will help to identify the long-term impacts of EAB.

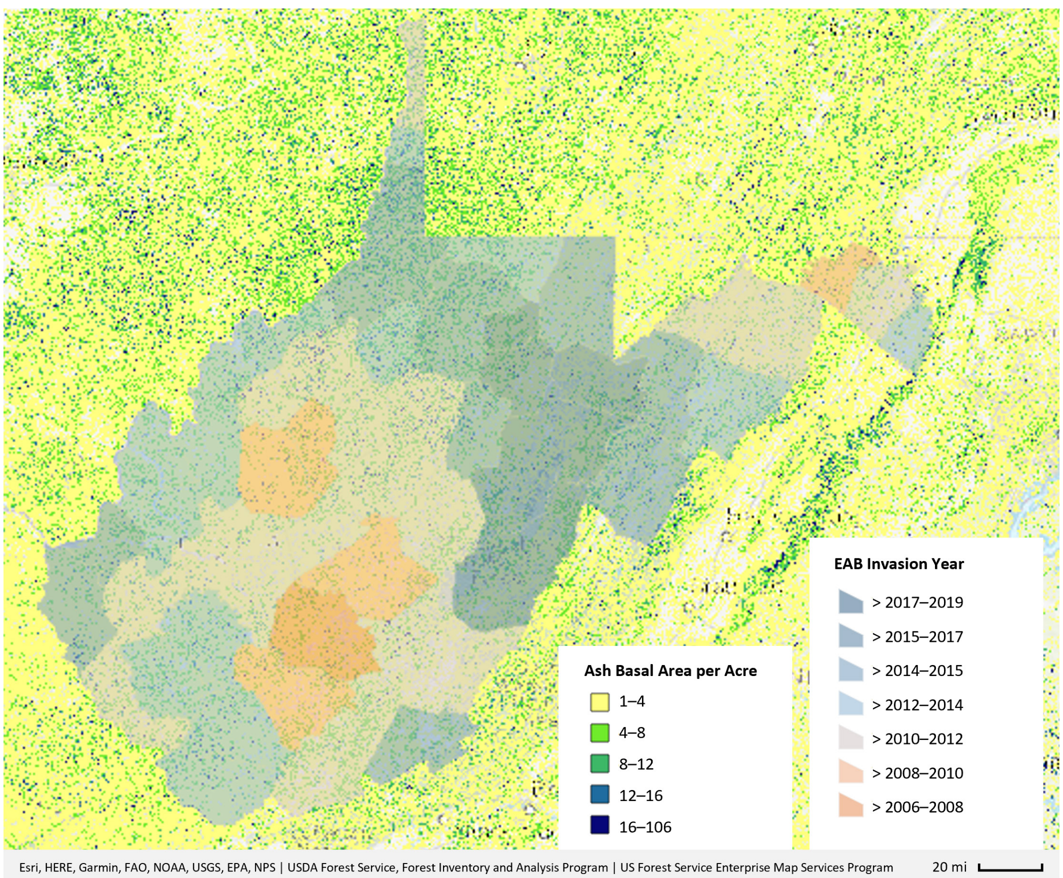

Figure 17.—Year of first detection of emerald ash borer by county overlayed on ash basal area per acre of forest land, West Virginia.

First reported in Virginia in 1951, hemlock woolly adelgid was identified in West Virginia in 1992. Subsequent spread has yielded HWA detections in eastern hemlock trees in nearly every county in the State (Fig. 18). Eastern hemlock has played a significant role in the historical development of eastern forests in North America (Ellison et al. 2018). Identified as a foundation species, the widespread distribution and abundance of hemlock underpins the surrounding forest ecosystem, and its associated plants, animals, and processes (Ellison 2014, Ellison et al. 2018). Loss of hemlock will have implications for plant diversity, ecosystem dynamics, wildlife habitat, soil stability along streams, invertebrate habitat, water temperature and quality, and timber products availability.

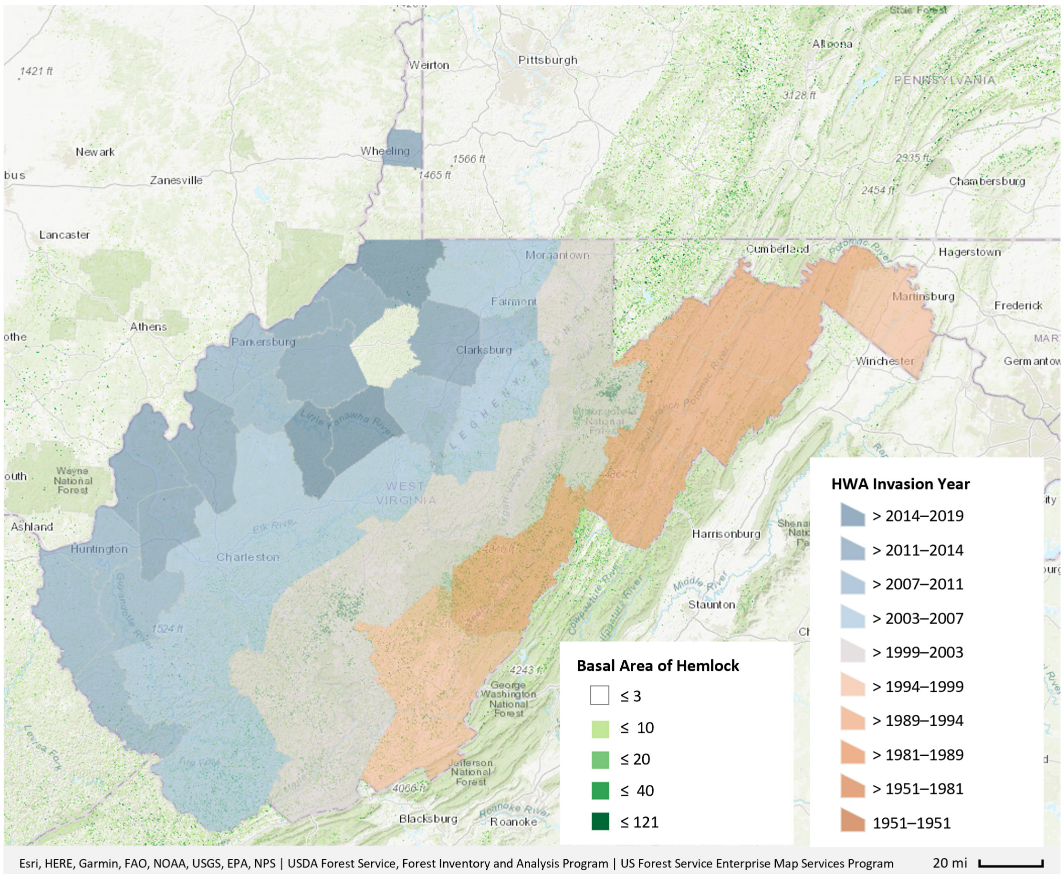

Figure 18.—Year of first detection of hemlock woolly adelgid by county overlayed on hemlock basal area per acre of forest land, West Virginia.

Forest Sustainability

Growth, Removals, and Mortality

Forests are a renewable resource if they are managed to provide a constant supply of useful products without diminishing long-term productivity. The rate of growth is an indicator of the overall condition of a stand as well as forest health, 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. Negative net growth occurs when mortality exceeds gross growth and is indicative of a serious forest health issue and results in a reduction of total inventory volume. Average annual net growth estimates are based on the change in volume of growing stock on timberland between inventories. The terms average annual net growth and net growth are used interchangeably. A useful measure to assess growth is the ratio of annual net growth to current inventory volume.

Mortality is a natural part of stand development in healthy forest ecosystems. Many factors contribute to mortality, including competition, succession, insects, disease, fire, human activity, and severe weather events. Mortality is often started by one causal agent (inciting factor) that is followed by other contributing stress factors, making it difficult to identify the underlying cause. Although mortality is a natural event in a functional forest ecosystem, dramatic increases in mortality can be a sign of forest health problems. Average annual growing-stock mortality estimates represent the average cubic-foot volume of sound wood that dies each year between inventories.

Since 2008, average annual net growth of growing stock on timberland has decreased in West Virginia while average annual mortality has increased and removals have been relatively stable (Fig. 19). Net growth of growing-stock trees on timberland averaged 408 million cubic feet annually as of 2018, and the ratio of net growth-to-removals (2.0:1.0) decreased substantially from what was reported for 2008 (3.6:1.0).

In comparison to previous inventories, annual net growth of growing stock on timberland as a percentage of growing-stock volume has been generally decreasing since 2008. By contrast, annual mortality of growing stock on timberland averaged 112 million cubic feet as of 2018 and as a percentage of growing-stock volume mortality has been generally increasing since 2008. However, net growth still outpaces removals by more than two to one annually.

The growthtoremoval ratio of growing stock on timberland in West Virginia remains above 1.0:1.0 although it has decreased since 2008 (3.6:2.0). Net growth of growing stock on timberland has continued to decrease since 2008 after increasing substantially between 1975 and 2008. Fortunately, all recorded removal volume was due to harvesting and not land-use change. Trees can be expected to regenerate if the land is not developed. A comparison of the growth-to-removals ratios of individual species to the average for all species is an indicator of sustainable harvesting. The high growth-to-harvest removals ratios of yellow-poplar, white oak, sugar maple, and red maple (above 2.0:1.0) suggest that these species should continue to increase in volume. In contrast, white ash, sassafras, and basswood have growthtoharvest removals ratios near or below 1.0:1.0 which indicate that those species may be decreasing in abundance.

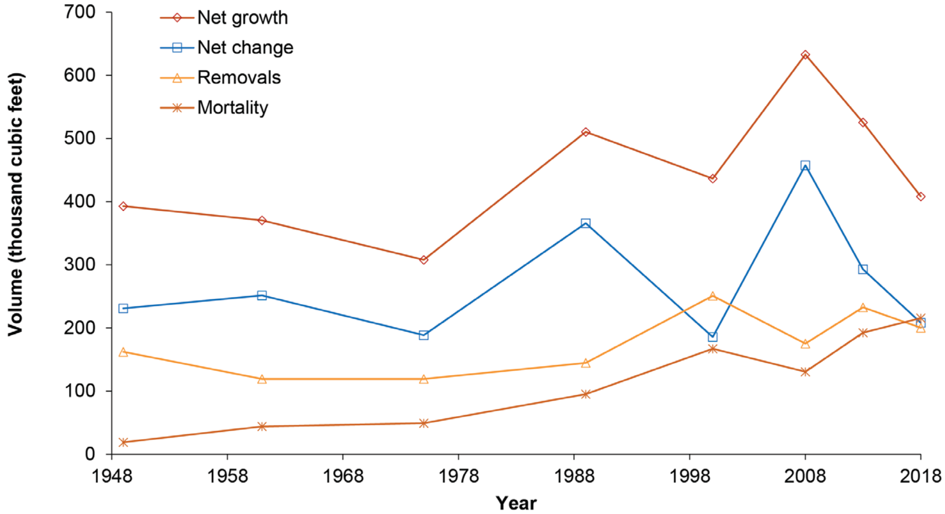

Figure 19.—Net growth, total removals, mortality, and net change of growing stock on timberland by inventory year, West Virginia. Includes land-use change.

Fragmentation

The wildland-urban interface (WUI) is the zone where human development meets or intermingles with undeveloped wildland vegetation, and it is the fastest-growing land use type in the conterminous United States (Mockrin et al. 2019, Radeloff et al. 2018). Although originally created to identify the area where wildfires pose the greatest risk to people, the WUI is associated with a variety of consequential human-environment conflicts. The 2014 report from the Central Hardwoods Climate Change Response Framework on Ecosystem Vulnerability (Brandt et al. 2014) identified fragmentation and land-use change as one of the top six current major stressors and threats to forest ecosystems, and two of the other threats—invasion by nonnative species and forest diseases and insect pests—are themselves heavily influenced by forest fragmentation and urbanization.

With the recent completion of a temporally consistent census block-level dataset capable of accurately comparing block-level change in housing densities from 1990 to 2010 (Mockrin et al. 2019, Radeloff et al. 2017), changes in housing density and forest land are analyzed at a finer spatial resolution and with more accuracy than was previously possible. The data is used to identify FIA forest land and changes in WUI status via the following categories: forest land in census blocks that have had housing densities above established wildland-urban interface thresholds for 30 plus years (from 1990 or before), forest that became WUI in the 1990s, forest that became WUI in the 2000s, forest that experienced change in WUI density both decades, and forest land that still remained in non-WUI census blocks in 2010 (Fig. 20). Forest land is depicted in the map using the 2011 National Land Cover Dataset (Homer et al. 2015) to mask out nonforest areas, however all forest land statistics reported are summarized from the FIA inventory data.

A total of 2.1 million acres (17 percent of West Virginia forest land) was in WUI conditions by 1990. Conversion to WUI conditions between 1990 and 2010 occurred at the highest rates in twelve of the fifty-five counties at rates greater than 5 percentage points per decade (Fig. 21).

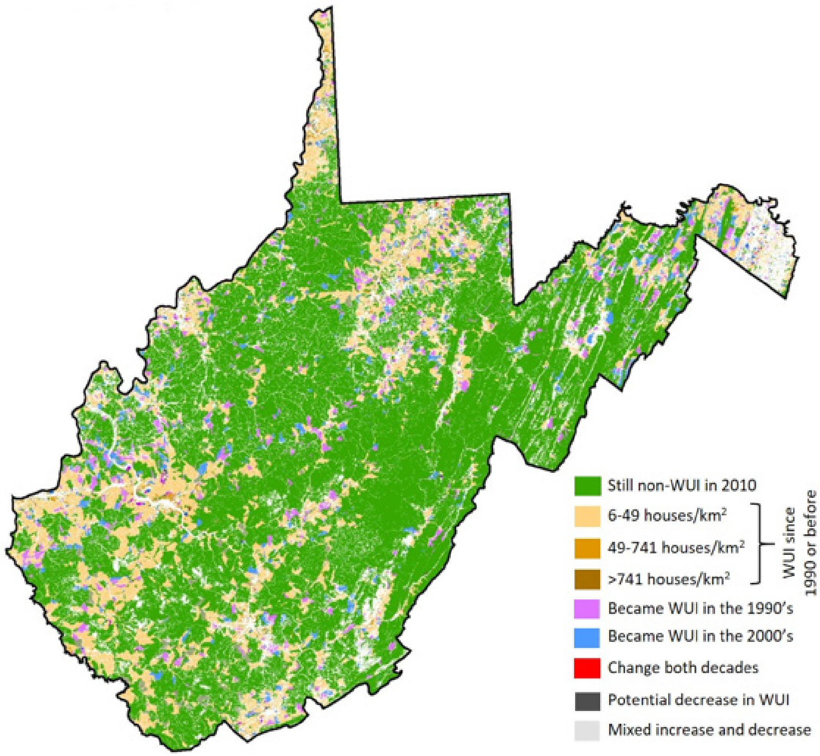

Figure 20.—National Land Cover Database forest by census block-level change in wildland-urban interface (WUI) status West Virginia, 1990–2000. Sources: Radeloff et al. 2017 and Homer et al. 2015.

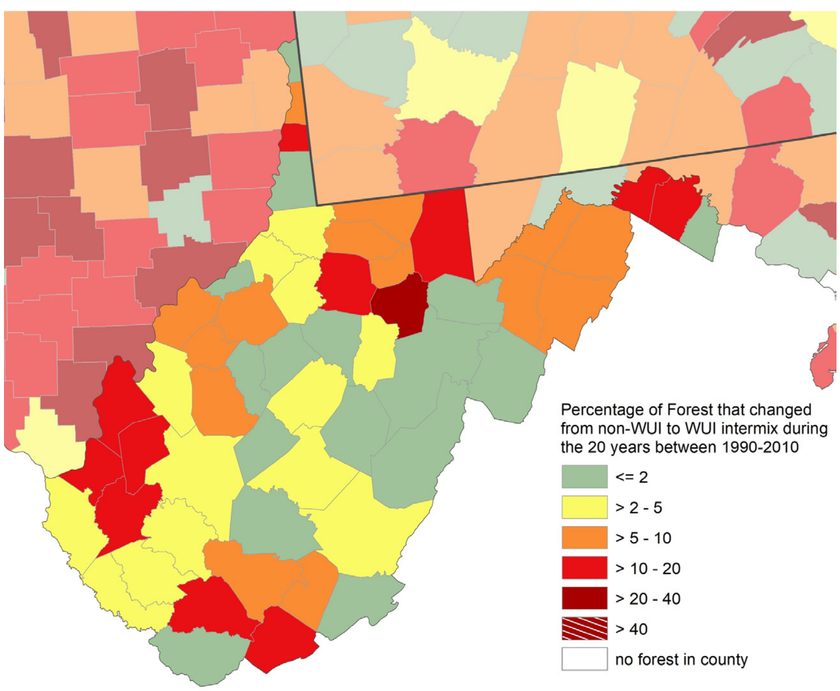

Figure 21.—Proportion of FIA forest in each county that changed from non-wildland-urban interface (non-WUI) to WUI intermix during the 20 years between 1990 and 2010, West Virginia. Source: Radeloff et al. 2017.

Increasing urbanization has the potential to change how forests function, affecting their vulnerability to threats such as insect pests and diseases, nonnative species proliferation, and loss of native species, all of which hinders their overall resilience in the face of both these threats and the additional changes and disturbances expected due to climate change. Such changes also affect the inherent ecosystem services provided by forest land such as clean water, flood protection, clean air, wildlife habitat, and forest products. Many of the above changes in forest ecosystems happen over time and thus forest land which has only recently become WUI may not look different immediately. Forest land which has been in WUI conditions for over 30 years is more likely to exhibit observable changes.

Regeneration

The species composition, abundance, and structure of tree regeneration is an important indicator of the future sustainability and trajectories of numerous forest ecosystem attributes, such as live tree stocking, resilience to disturbance events, or both. Various facets of FIA's inventory can quantitatively address tree regeneration including the abundance of advanced tree regeneration on all plots and the abundance of all seedlings measured on a subset of plots.

From 2008 through 2018 the abundance of advanced tree seedlings (less than 1.0 inch d.b.h and at least 6 inches in length for softwoods and 12 inches in length for hardwoods) has declined to approximately 1,700 per acre (Fig. 22). At the same time, the percent of West Virginia forest classified as young (less than 20 years in age) has remained relatively stable around 5 percent. During the 2018 inventory, over 19 percent of West Virginia forest land was assessed as having very low to low ungulate browse impact on seedlings. In contrast, more than 15 percent of West Virginia forest land was identified as suffering from high to very high impact of seedling browse.

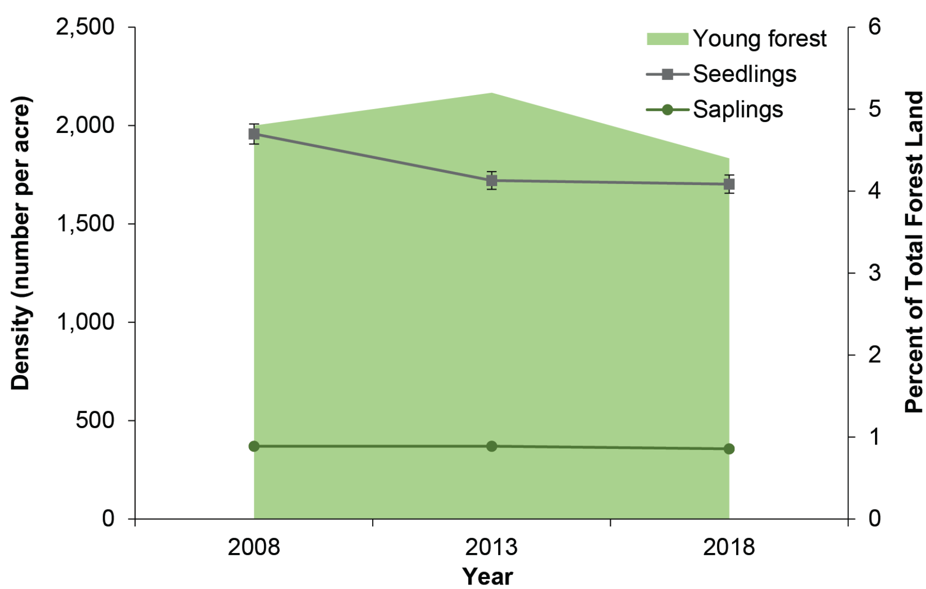

Figure 22.—The percent of young forest (less than 20 years in age) and number of seedlings (at least 6.0 inches in length for softwoods and at least 12.0 inches for hardwoods) and saplings (1.0 to less than 5.0 inches d.b.h.) per acre of forest land by inventory year, West Virginia. Error bars represent a 68 percent confidence interval.

Additional regeneration assessments on a subset of plots (phase 2+, or P2+) classify seedlings by height and estimated the total number of all established seedlings at over 84 billion with an average of over 7,000 seedlings per acre of forest land. Red maple, white ash, and sugar maple were the most abundant tree seedlings across all height classes (Fig. 23). American beech, red maple, and yellow-poplar were the most abundant species in the largest seedling height class (at least 5.0 feet in height). In terms of the difference between the abundance of the smallest versus largest seedling size classes, red maple had the greatest disparity with an average of over 2,000 small seedlings per acre (2.0 to less than 12.0 inches in height) across all of West Virginia forest land but approximately 25 per acre for the largest height class (at least 5.0 feet). In contrast, American beech had over 74 small seedlings compared to 64 per forest land acre that were 5.0 feet in height or taller.

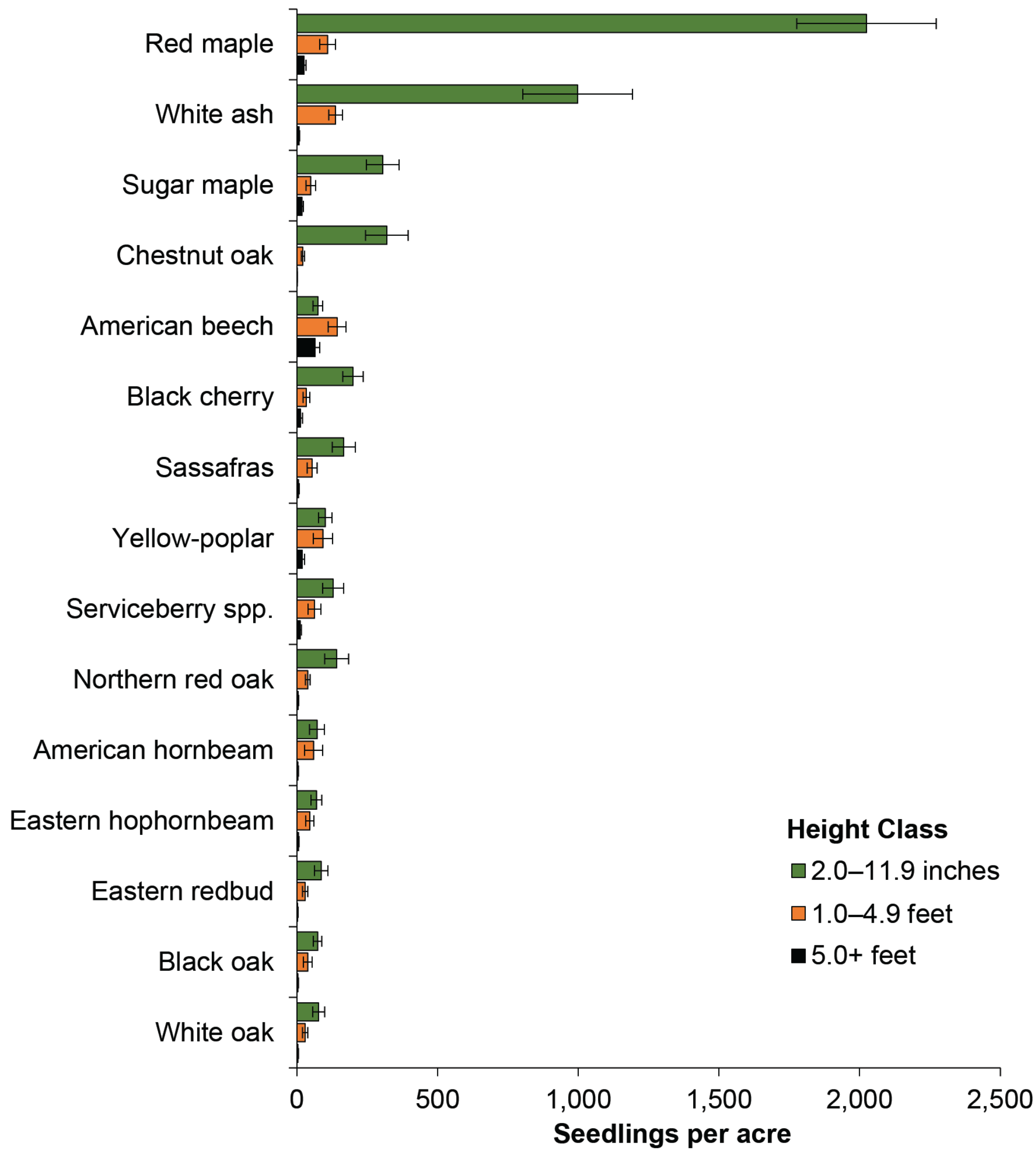

Figure 23.—Seedlings per acre for the fifteen most abundant tree seedling species across three height classes on forest land, West Virginia, 2018. Error bars represent a 68 percent confidence interval.

Like many states in the eastern United States, there is a lack of younger aged forests across West Virginia despite an abundant understory of seedlings. Additionally, the majority of West Virginia forests have experienced moderate to heavy browsing of tree seedlings which can impede effective tree regeneration. The abundance of seedling species across height classes can indicate a variety of forest stand dynamics such as stand senescence or changing successional directions. Only American beech appears to have abundant populations of the smallest seedlings with recruitment into the larger height classes. In contrast, species like white ash, sugar maple, and chestnut oak have appreciable abundance of the smallest sized seedlings but hardly any larger sized seedlings. Although not as commercially important nor critical for ensuring future sustainability, red maple had the largest number of the smallest seedlings among all tree species. Overall, the lack of young forest and moderate levels of browse will remain a problem for select forest types dependent on relatively open conditions or disturbance for regeneration such as oaks. The prevalence of red maple in the understory coupled with the lack of diversity across abundant tree seedling species (especially oaks) points to further species shifts in the future.

Invasive Plants

Invasive plant species (IPS) are both native and nonnative species that can negatively affect ecosystems. Several factors contribute to the success of IPS such as rapid growth, prolific seed production, survival in harsh environments, and vegetative propagation. Humans, hoofed mammals, fragmentation, and disturbance promote the spread of IPS. Once established, they can quickly take over an area, displacing native species, and affecting habitat suitability. IPS often form dense monocultures that alter light, nutrient, and water availability. Invasive plants can negatively affect the suitability of wildlife habitat. In forests, infestations may increase runoff and limit food, cover, and nesting sites (Kurtz 2013). For example, infestation by nonnative bush honeysuckles can form a shrub layer so dense that it completely shades out understory plants. If nonnative bush honeysuckles gain hold during initial stages of stand development, they can eliminate tree regeneration and critical components of future forests. Cavity dwellers dependent on snags are then displaced. By reducing the number of trees, IPS can impact the carbon cycle. Additionally, they affect aesthetic beauty which influences tourism and local economies.

In 2018 there were 215 plots monitored for IPS in West Virginia. Of the 20 invasive plants recorded, multiflora rose was the most commonly found, and Nepalese browntop showed the largest increase in relative occurrence. Multiflora rose was found on 112 plots (52.1 percent) and is present throughout the State except for Kanawha, Mineral, and Webster counties. It is the most commonly recorded invasive in the region, of the 40 species monitored. Also frequently recorded on plots in West Virginia were Nepalese browntop and black locust (40.9 and 33.5 percent of plots, respectively; Table 1).

Between the 2013 and 2018 inventories the total number of invasive plant species observed in West Virginia changed. There were 21 IPS on plots in 2013 and 19 in 2018. The species which were not recorded this inventory were only present on one plot in 2013 (Table 1). Additionally, one species observed in 2018 was not found in 2013 (glossy buckthorn, 1 plot). The percentage of plots in the State with invasive plants present remained nearly the same as in 2013 with roughly 79 percent of plots having one or more IPS.

Table 1.—Most commonly found invasive plant species, West Virginia, 2013 and 2018

Species	Observances, 2018	Percentage of plots, 2018	Observances, 2013	Percentage of plots, 2013
Multiflora rose (*Rosa multiflora*)	112	52.1	193	59.6
Japanese stiltgrass, Nepalese brown top (*Microstegium vimineum*)	88	40.9	118	36.4
Black locust (*Robinia pseudoacacia*)	72	33.5	122	37.7
Autumn olive (*Elaeagnus umbellate*)	52	24.2	75	23.1
Nonnative bush honeysuckle (*Lonicera* spp.)	42	19.5	53	16.4
Tree of heaven (*Ailanthus altissima*)	39	18.1	54	16.7
Japanese honeysuckle (*Lonicera japonica*)	36	16.7	53	16.4
Japanese barberry (*Berberis thunbergii*)	25	11.6	39	12.0
Garlic mustard (*Alliaria petiolata*)	23	10.7	29	9.0
European privet (*Ligustrum vulgare*)	14	6.5	10	3.1
Japanese meadowsweet (*Spiraea japonica*)	9	4.2	5	1.5
Oriental bittersweet (*Celastrus orbiculatus*)	9	4.2	21	6.5
Common barberry (*Berberis vulgaris*)	4	1.9	4	1.2
Bull thistle (*Cirsium vulgare*)	3	1.4	2	0.6
Creeping jenny (*Lysimachia nummularia*)	3	1.4	7	2.2
Japanese knotweed (*Polygonum cuspidatum*)	3	1.4	3	0.9
Princesstree (*Paulownia tomentosa*)	3	1.4	8	2.5
European cranberrybush (*Viburnum opulus*)	1	0.5	1	0.3
Glossy buckthorn (*Rhamnus frangula*)	1	0.5	--	--
Canada thistle (*Cirsium arvense*)	--	--	1	0.3
Dames rocket (*Hesperis matronalis*)	--	--	1	0.3
Giant knotweed (*Polygonum sachalinense*)	--	--	1	0.3

When looking at these trends it is important to note that the sample size was smaller in the 2018 inventory. In 2013, 324 plots were monitored for IPS while only 215 plots were monitored in 2018. Additionally, since the inventory only covers forested areas, areas with less forest land have fewer inventory plots. This is important to note with respect to species distribution.

Invasive plants can cause vast ecosystem and economic consequences. Invasive presence is influenced by time since introduction, forest fragmentation, and propagule pressure. Careful forest management will be important to mitigate spread. Since the majority of West Virginia forest land is held by private landowners, education and outreach can be important tools to increase awareness. The presence of IPS is concerning and future monitoring is necessary. With future measurements, changes in the percentage of plots with IPS in the State, species presence and distribution, newly observed invasives, and an increase in the number of IPS per plot are all key metrics to watch. Further analysis of the invasive plant data may also help reveal key site and regional trends.

Forest Carbon

Among terrestrial ecosystems, forests contain the largest reserves of sequestered carbon. The accumulation of carbon in forests helps to mitigate emissions of carbon dioxide to the atmosphere from sources such as wildfires or the burning of fossil fuels. Carbon accumulates in growing trees via the photosynthetically driven production of structural and energycontaining organic (carbon) compounds that primarily accumulate in trees as wood; approximately 50 percent of tree biomass is carbon (based on dry weight). Over time, carbon also accumulates in standing dead trees, down woody materials, litter, and forest soils. The FIA program uses a combination of field measurements and models to estimate forest carbon stocks. Procedures for the estimation of carbon are detailed in the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2017 (U.S. Environmental Protection Agency 2019). Forest carbon is often broken down into storage pools. The carbon pools and their components discussed here are defined as: live biomass (live trees at least 1.0 inch d.b.h. and live understory vegetation), dead wood (standing dead trees at least 1.0 inch d.b.h. and down dead wood), forest floor litter, and soil organic matter estimated to a depth of 1 meter (39 inches).

Total forest ecosystem carbon stocks in West Virginia are an estimated 1.2 billion tons, which has remained unchanged since 2013. Carbon density is an estimated 99 tons per acre of forest land. Soil organic carbon and live trees are the largest components; combined, these account for 92 percent of forest carbon stocks (Fig. 24).

While forest ecosystem carbon stocks have remained relatively stable in West Virginia, density has risen slightly as a result of maturing stands accumulating carbon in the live biomass pool coinciding with a loss of forest land area. Soil organic carbon stocks represent the largest pool in West Virginia and are important to long-term carbon storage. The carbon stocks in live biomass also represent a substantial amount of the total carbon and there are opportunities to increase carbon stocks in the near term, as this pool is most affected by forest management. One of the greatest threats to the carbon stocks of West Virginia forests is loss of forest land. As mitigating U.S. greenhouse gas emissions becomes increasingly important, an understanding of trends in carbon sequestration in the face of land-use change will be an essential tool for forest managers.

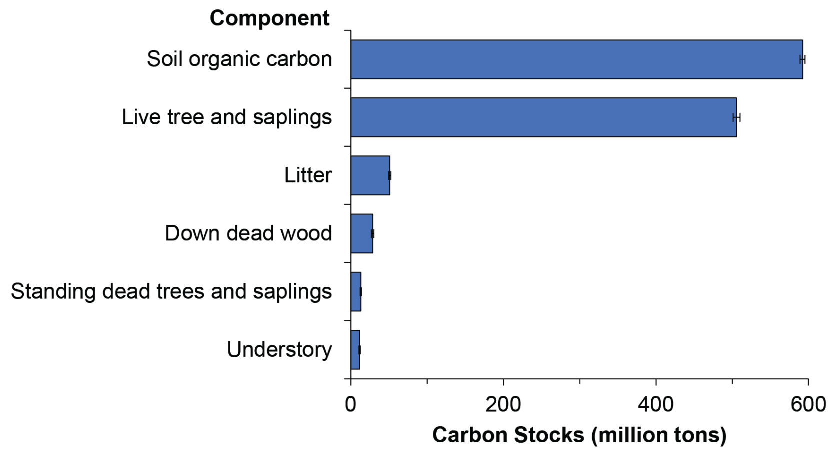

Figure 24.—Carbon stocks on forest land by component, West Virginia, 2018. Error bars represent a 68 percent confidence interval.

Timber Products Output

The harvesting and processing of timber products produces a stream of income shared by timber owner, managers, marketers, loggers, truckers, and processors. In 2017, the wood products and paper manufacturing industries in West Virginia employed 6,300 people with an average annual payroll of $248.6 million (U.S. Census Bureau 2019). To better manage the State forests, it is important to know the species, amounts, and locations of timber being harvested.

A canvass of West Virginia 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 2017. For this report, the 2017 survey is supplemented by the most recent surveys conducted in surrounding States that processed wood harvested from West Virginia. In 2017, there were 32 active primary wood-processing mills that processed a total of 75.7 million cubic feet of industrial roundwood. Eighty-five percent of the industrial roundwood processed by West Virginia mills came from the forest land of the State. In 2017, 123.4 million cubic feet of industrial roundwood was harvested from West Virginia forest land, a decrease of 35 percent since 2007 (Fig. 25). Nearly all of the decrease was observed in the saw log class.

Decreases in production occurred across all species groups from 2007 to 2017. The yellow-poplar species group continued to account for the largest proportion of roundwood production (20 percent) followed by the red oak and soft maple species groups (Fig. 26). Notably, soft maple production did not decrease over this period.

Industrial roundwood harvests provide West Virginia woodland owners an outlet to sell timber and manage their forest land. Decreases in the demand for industrial roundwood limit the opportunities for landowners to find markets for the timber they own. An important consideration for the future of the primary wood-products industry is its ability to retain industrial roundwood processing facilities. The loss of processing facilities makes it harder for landowners to find markets for the timber harvested from management activities on their forest land.

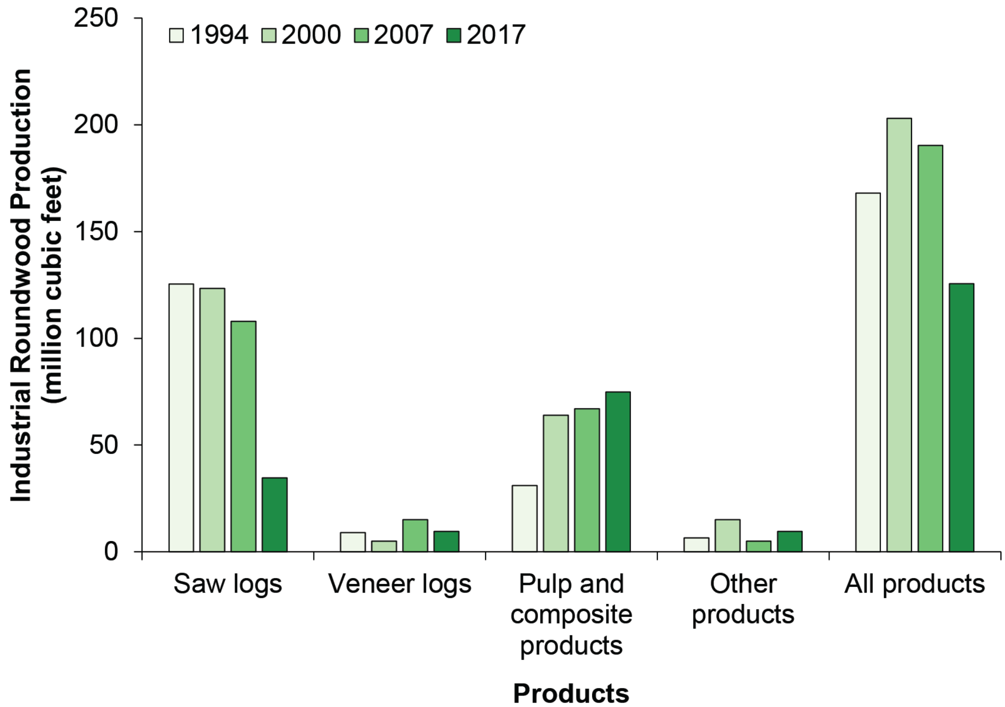

Figure 25.—Industrial roundwood production by product and year, West Virginia.

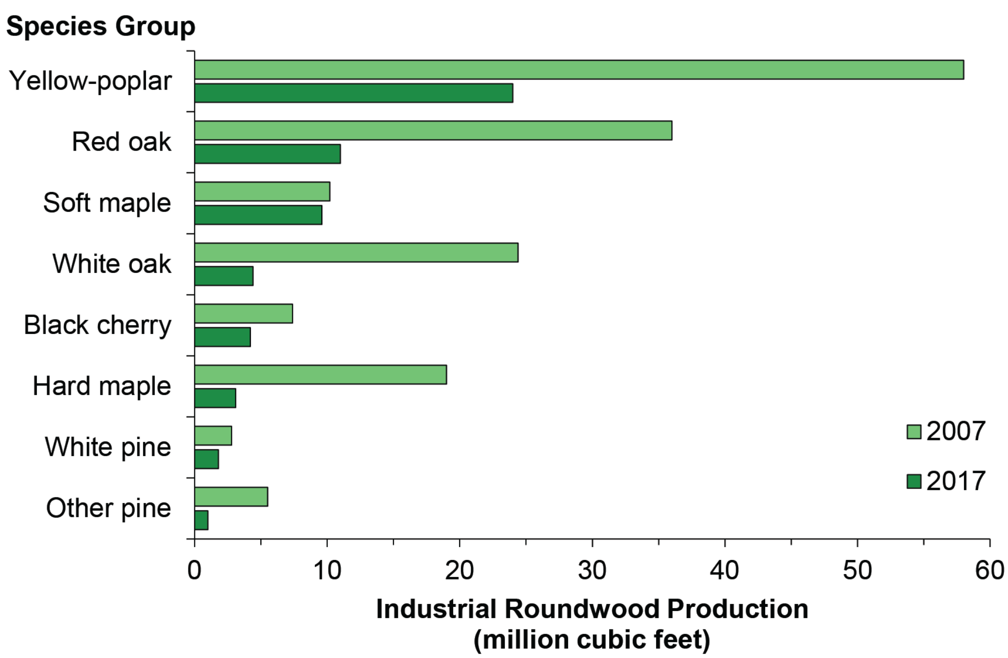

Figure 26.—Industrial roundwood harvested by species group, West Virginia, 2007 and 2017.

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