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Delaware Forests 2018: Summary Report

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Abstract

This summary report provides an overview of findings from the fourth annualized inventory of Delaware forests based on data collected from 2012 to 2018. Forest land area remained stable at 359,000 acres, and 51 percent of forest land is in the oak/hickory forest-type group. Forests in the State continue to mature, with 76 percent in large diameter stands and 65 percent in stands older than 60 years of age. Total live-tree net volume on timberland is 907 million cubic feet, and 92 percent of that volume is in growing-stock trees. Annual gross growth of 29 million cubic feet less annual mortality of 11 million cubic feet resulted in an annual net growth of 18 million cubic feet on timberland. Additional information on land use change, fragmentation of forest land, ownership, urban forests, species composition, stand structure, forest carbon, down woody material, regeneration, invasive plants, forest pests, tree health, and timber products output are also presented. A detailed interactive report is available at https://doi.org/10.2737/NRS-RB-129-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-129.

KEY WORDS: 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: Cape Henlopen State Park, Sussex County, Delaware. Photo by Randall Morin, USDA Forest Service.

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Foreword

Delaware forests play a critical role in maintaining a healthy environment and are a vital part of the State's natural green infrastructure. Healthy trees absorb and store carbon dioxide and release pure oxygen into the atmosphere and in the process filter out pollutants, thus greatly improving air quality. Forests protect aquifers and watersheds, thereby improving the quality of the water that we drink and the water that is so important to the health and functionality of natural ecosystems. Forests produce wood and related products that we use every day in our places of work and in our homes. Many wildlife species depend on large blocks of forested habitat for their very survival. And forests provide every citizen with recreational opportunities along with aesthetic enjoyment and a general sense of well-being.

With all the natural benefits provided by healthy forests, it should be no surprise that the mission of the Delaware Forest Service is "to conserve, protect, and enhance Delaware's forests through education, management, and professional assistance." Protecting and conserving Delaware's remaining forest lands is of utmost importance. The updated 2020 Delaware Forest Action Plan outlines a number of steps that our foresters, support staff, and cooperating partners will take over the next 10 years to (1) improve forest health and functionality, (2) help develop new forest markets, (3) encourage all forest landowners to practice sustainable forest management, and (4) expand public awareness and appreciation of the forests in Delaware. Our goals are measurable and attainable as we seek to conserve this renewable resource for generations to come.

The Delaware Forest Service partners with many agencies, both public and private, in an effort to improve efficiency in reaching the ultimate desired goal: healthy, sustainable forests. Our most significant partner is the U.S. Department of Agriculture, Forest Service as this Federal agency supports many of our core landowner assistance programs, including urban and community forestry, forest health management, forest stewardship, and wildland fire protection. A key component in planning future management activities for our precious forests is an overall assessment and measurement of the forest resources in Delaware. This is where the Forest Service's Forest Inventory and Analysis (FIA) program plays a crucial role. FIA specialists completed comprehensive statewide inventory reports for Delaware forests in 1957, 1972, 1986, 1999, 2008, 2013, and most recently in 2018. These continually updated data enable us to detect trends in the forest resource, for better or for worse, and to apply such knowledge to sound forest management recommendations. It is in the interest of all Delawareans to safeguard the vitality of our forests. The data contained in this most recent FIA report offer detailed and valuable information that will help all of us with the future challenges we face in conserving, protecting, and enhancing Delaware forests.

Michael A. Valenti, Ph.D., State Forester

Delaware Department of Agriculture, Delaware Forest Service

Contents

Loblolly pine plantation post-thinning. Photo by Stephen Potter, USDA Forest Service.

Highlights

On the Plus Side

- The area of forest land in Delaware remains stable at 359,000 acres, ensuring the continued delivery of valuable timber products and critical ecosystem services.
- Despite the State's small size and limited geography, the forests of Delaware are relatively diverse, with the latest inventory tallying 55 individual tree species and 30 individual forest types.
- Total forest ecosystem carbon stocks in Delaware were an estimated 38.7 million tons in 2018, and carbon density was an estimated 108 tons per acre on forest land.
- Sound tree volume increased 3 percent from 2013 to 2018 to 1.1 billion cubic feet and timberland accounted for 94 percent of that volume.
- In the process of milling industrial roundwood in the State's primary wood-using mills, only 2 percent of mill residues produced were not further utilized for other secondary uses such as mulch or animal bedding.

Issues to Watch

- A majority of the forest land (79 percent) in the State is privately owned, yet only 14 percent of landowners with more than 10 acres received management advice and just 11 percent had a written management plan.
- By 2020, 168,000 acres of Delaware forest land will have been in wildland-urban interface conditions for at least 30 years, making this area more likely to exhibit changes commonly associated with urbanized forests.
- Invasive plant species were detected on more than half of the plots monitored for their presence in 2018, with Japanese honeysuckle being the most commonly observed.
- Over one-third of all timberland stands in the State were more than 80 years old in 2018, and 77 percent of timberland was in large diameter stands. While a mature forest resource offers an abundant supply of volume for utilization, the lack of successional diversity can have negative implications for sustainability and wildlife habitat.
- Delaware forest land had an average 13 dead trees (snags) per acre but only 1 large (17 inches diameter at breast height or greater) snag per acre in 2018. Although there is an abundance of snags in the State, the lack of large diameter snags is cause for concern and may not meet the needs of certain forest-associated wildlife species.

An Overview of Forest Inventory

What is this Report?

This report summarizes findings of the 2018 survey of Delaware forest resources. Data for this survey were collected from 2012 through 2018 and are referred to as the 2018 inventory throughout this report. The inventory was conducted by the U.S. Department of Agriculture's Forest Service, Forest Inventory and Analysis program in cooperation with the Delaware Department of Agriculture, Delaware Forest Service. The summary report and additional resource materials are available online at https://doi.org/10.2737/NRS-RB-129.

The results presented in the interactive StoryMap collection are divided into sections that focus on different forest aspects, such as carbon, sustainability, health, and timber trends (Fig. 1). Graphics, including interactive maps, charts, and dashboards, summarize data and illustrate trends that make it easy for readers to compare between inventory periods, geographic locations, or ecological divisions. This document offers a short summary of select results

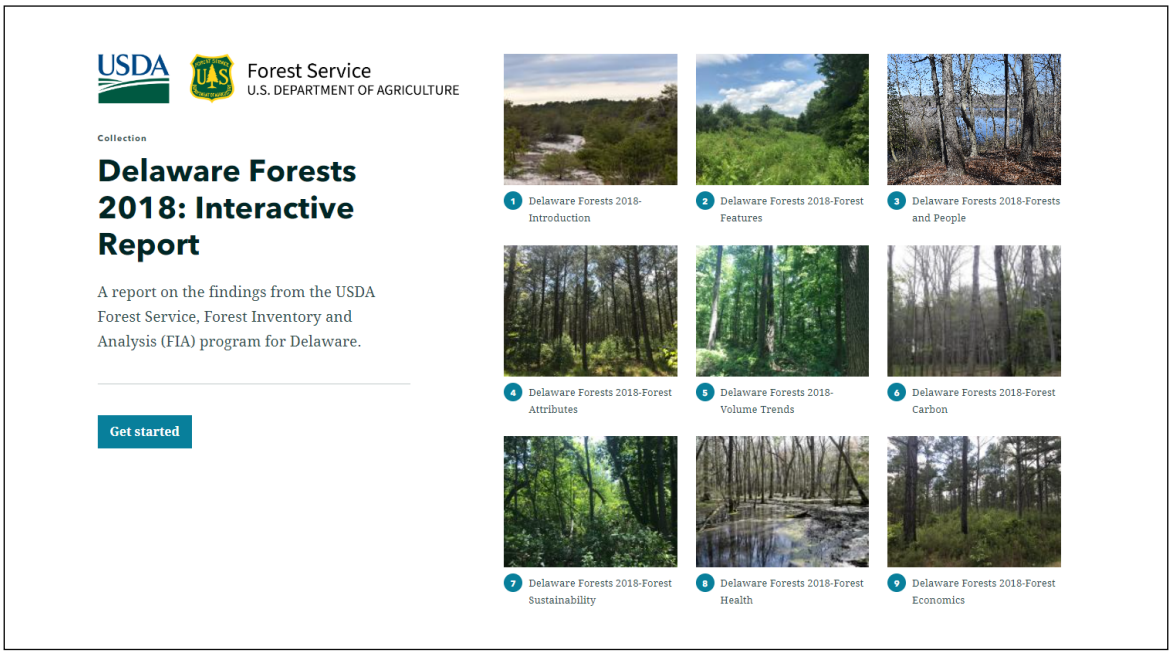

Figure 1.—The Delaware Forests 2018 StoryMap collection contains a series of StoryMaps that focus on different forest aspects. Click on "Get started" to enter the collection or click on one of the photos to view an individual StoryMap within the collection.

What is FIA?

The USDA Forest Service's 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 the following paragraphs. For more detailed information, see "Statistics and Quality Assurance for the Northern Research Station Forest Inventory and Analysis Program" (Gormanson et al. 2018) and supplemental resources available online at https://doi.org/10.2737/NRS-RB-129.

Delaware Forest Inventories

FIA has been conducting inventories of Delaware forest resources since 1957. Prior to 1999, inventories were conducted periodically, or approximately once every 10 to 20 years. Periodic inventories were completed in 1957 (Ferguson 1959), 1972 (Ferguson and Mayer 1974), 1986 (Frieswyk and DiGiovanni 1989), and 1999 (Griffith and Widmann 2001). In 1999 an annual inventory system was implemented, wherein a percentage of plots were measured each year and an entire inventory cycle completed every 5 years. Previous annual inventories were completed in 2008 (Lister et al. 2012), and 2013 (Lister et al. 2017). In 2014 FIA went from a 5-year cycle completing 20 percent of the plots annually to a 7-year cycle completing 14 percent of the plots annually. FIA maintains a 5-year reporting period and each report covers a full data cycle. This creates a yearly moving window of 5-year cycles, composed of plots from up to 7 years, which are identified by the last year in a given full cycle. For this report, plots measured from 2012 through 2018 are collectively referred to as the 2018 inventory.

For the 2018 inventory, 436 plots in Delaware were selected for measurement. From that selection, 141 contained forest land, 256 were nonforest, and 39 were not sampled due to various reasons preventing access. Current estimates of forest area, composition, volume, and other statistics are based on 397 sampled plots. Estimates of change (e.g., forest area change, growth, mortality, and removals) are based on 374 plots that were measured both during the 2018 cycle and the previous cycle, which ended in 2013.

Forest Features

Area and Land Use

Forests cover 28 percent of Delaware; terrestrial nonforest land uses and water compose the remaining 67 percent and 5 percent of the surface area, respectively. Of terrestrial land uses, 29 percent of area is forest land, providing a critical resource and offering a wide range of benefits. FIA further characterizes land area by using several land use categories, which are aggregated for this report into agriculture, developed, forest, pasture/rangeland, water, wetlands, and other land (undeveloped beaches, nonvegetated lands, persisting snow and ice). The conversion of forest land to nonforest and water uses is referred to as gross forest loss (or diversion), and the conversion of nonforest land and water to forest is known as gross forest gain (or reversion). The difference between gross loss and gross gain is defined as net forest change. By comparing the land uses on current Delaware inventory plots (2012 through 2018) with the land uses recorded for the same plots measured during the previous inventory (2009 through 2013), hereafter referred to as 2018 and 2013, we can characterize forest land-use change dynamics. To better understand Delaware forest land dynamics, it is important to explore the underlying land use changes occurring in the State. Understanding land-use change dynamics is essential for monitoring the sustainability of Delaware's forest resources and helps land managers make informed policy decisions.

The first periodic inventory of Delaware forests in 1957 estimated an area of 392,000 acres of forest land. Forest land area declined between the 1986 periodic inventory and the completion of the first annual inventory in 2008 but has since stabilized (Fig. 2). The 2018 estimate of forest land is 359,000 acres, 96 percent of which is classified as timberland.

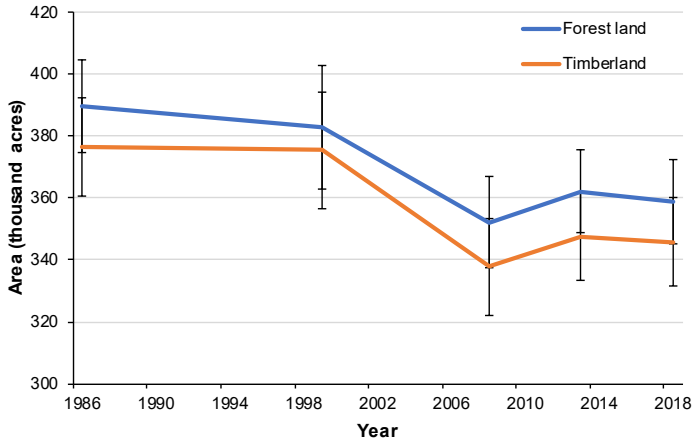

Figure 2.—Area of forest land and timberland by inventory year, Delaware. Error bars represent a 68 percent confidence interval.

Trends in forest land area resulting from land use change can be more closely examined by limiting the comparison to only plots that were measured at both times. Between 2013 and 2018, 27 percent of the land in Delaware remained forested, 72 percent remained in a nonforest land use, and 1 percent of land area underwent change as forest diversions or reversions (Fig. 3).

The net loss of forest land reported in this inventory is small. Gains and losses from multiple causes are driving forest land-use change dynamics in Delaware. 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.

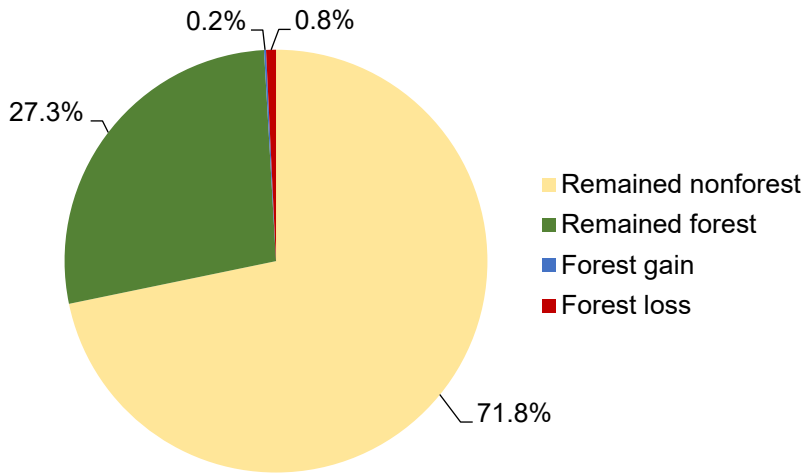

Figure 3.—Land use dynamics showing percentage of unchanged land, forest loss, and forest gain, Delaware, 2013 to 2018.

Fragmentation and Urbanization

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 this designation was 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 such as the loss and fragmentation of native species, the introduction and spread of nonnative species (Riitters et al. 2018), increases in nonnative insect and disease invasions (see e.g., Guo et al. 2018), and impacts on water quality and quantity from impervious surfaces and increased pollution (Bar-Massada et al. 2014). The 2018 report from the Mid-Atlantic Climate Change Response Framework on Mid-Atlantic forest ecosystem vulnerability (Butler-Leopold et al. 2018) identified fragmentation and land use change as one of the seven most serious current major stressors and threats to forest ecosystems, and three of the other major threats—invasion by nonnative species, forest diseases and insect pests, and herbivory—are themselves heavily influenced by forest fragmentation and urbanization.

In previous reports we summarized forest spatial integrity using a spatial integrity index that combined forest patch size, local forest density, and connectedness to core (intact) forest land; included maps of the pervasiveness of roads throughout forested areas; and introduced the additional and extensive effect that 2010 levels of housing density had on forest land (see e.g., Albright et al. 2017, Lister et al. 2017). Although the spatial integrity index represents just one of the characteristics of fragmentation affecting forest ecosystems, examining the landscape using the index provides a scale-dependent but relatively robust way of looking at where forest remains the most spatially intact (core and high integrity forest) and where, due to either urban or agricultural development, the forest is more fragmented (Riemann, n.d.).

The ownerships with the greatest proportion of their forest land area remaining as non-WUI forest were Federal (100 percent) and State (84 percent) ownerships. The county and local government ownership group had the lowest proportion of its forest land remaining in non-WUI conditions in 2010 (0 percent), followed by the private ownership group (30 percent). However, the large amount of forest land in private ownership in Delaware meant that it had more acres remaining in non-WUI conditions in 2010 than all the other ownerships combined (Fig. 4). Almost all the forest land undergoing a change in WUI status between 1990 and 2010 was in private ownership.

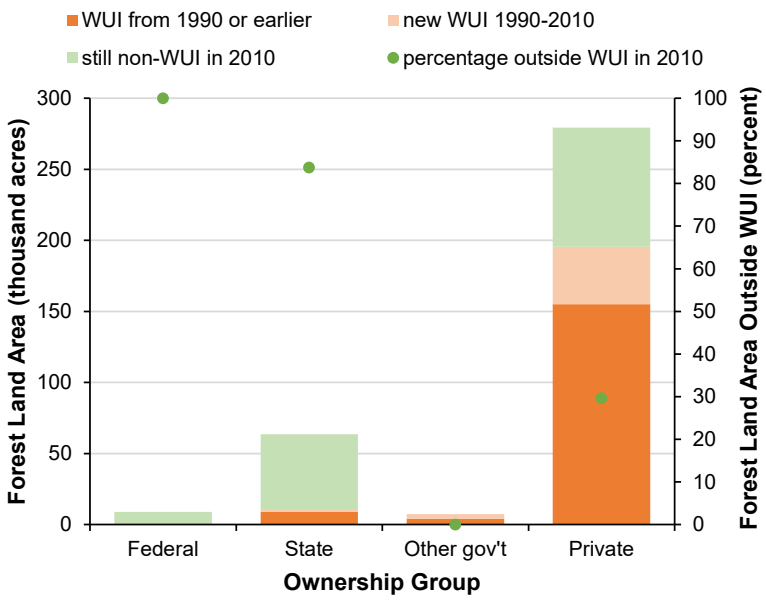

Figure 4.—Forest land area by ownership group and wildland-urban interface (WUI) change group, Delaware, 1990 to 2010. Forest land acreage is from Delaware, 2013.

Urbanization is affecting an increasing amount of forest area in Delaware, including unfragmented forest land in otherwise core or high spatial integrity situations. A total of 168,000 acres (46 percent of Delaware forest land) was in WUI conditions by 1990, and between 1990 and 2010 forest land was still being converted to WUI conditions. In Sussex County the rate averaged greater than 5 percentage points per decade.

Increasing urbanization has the potential to change how Delaware forests function, affecting their vulnerability to threats such as insect pests and diseases, nonnative species proliferation, and loss of native species. This greater vulnerability 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, to name a few. Many of the previously mentioned changes in forest ecosystems happen over time and thus forest land which has only recently become WUI may not look different yet. Forest land that has been in WUI conditions for over 30 years is more likely to exhibit changes.

Forests and People

Forest Ownership

To a large extent, landowners determine the quantity and quality of forest resources, including recreational opportunities, timber supply, and wildlife habitat. By understanding the priorities of forest land owners, 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 FIA program's National Woodland Owner Survey (NWOS) studies private forest owners' attitudes, management objectives, and concerns with a focus on the families, individuals, and other unincorporated groups collectively referred to as "family forest ownerships." The NWOS results reported here are from studies completed in 2013 (Butler et al. 2016), and 2018 (Butler et al. 2020). Due to a small sample size, data from the 2006 NWOS (Butler 2008) are not included. The results presented here are for family forest ownerships with 10 or more acres of forest land.

Seventy-nine percent of Delaware forest land is privately owned (Fig. 5). Most of these private acres, an estimated 198,000 acres, are family forests. Corporate ownerships have an estimated 68,000 acres across the State and other private owners, including conservation organizations and unincorporated clubs and partnerships, own an additional estimated 16,000 acres. Federal, State, and local governments are responsible for the other 21 percent of the forest land in the State. Most of this public forest land is managed by State forestry, parks, and wildlife agencies. The area of forest land by ownership group has stayed relatively constant since 2013.

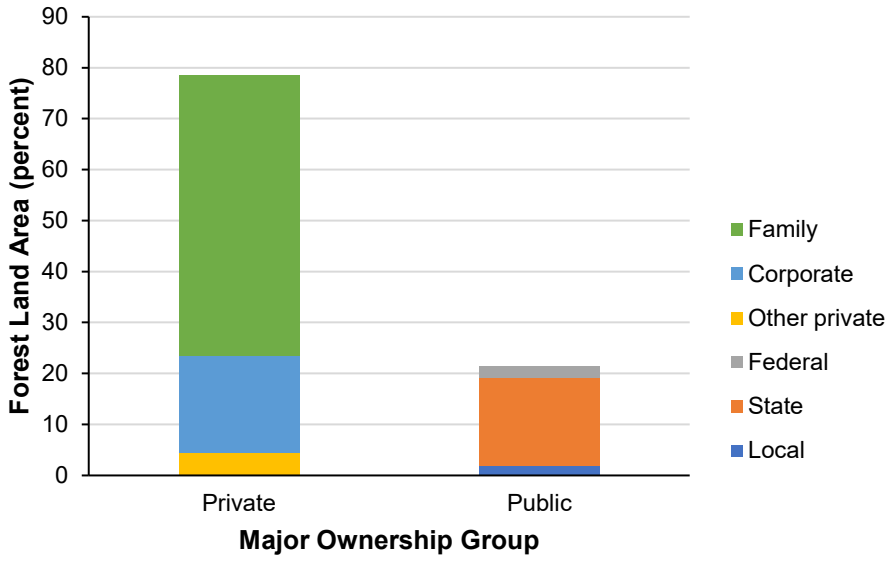

Figure 5.—Percentage of forest land area by major ownership group and ownership class, Delaware, 2018.

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 owners of land whose fate is arguably the most uncertain—we see that they own their land primarily for amenity reasons, but many are actively doing things with their land. The percentage of ownerships that have received advice and that have written forest management 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 the State, 64 years, many acres of land will be passing on to the next generation in the not too distant future.

Forest Attributes

Species Composition

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 occur together in a forested setting. Similar forest types are collectively known as forest-type groups.

The forested acres of Delaware are relatively diverse given the small size and limited geographic variation of the State. Half of the eight forest-type groups identified have at least 5 percent of total forest land area. Oak/hickory was the most prominent forest-type group with 184,000 acres, accounting for 51 percent of the total (Fig. 6). The loblolly/shortleaf pine forest-type group had 19 percent of area, the oak/gum/cypress forest-type group had 16 percent, and the oak/pine forest-type group had 7 percent.

Shifts in the extent of forest-type groups are generally slow to appear; however, a comparison of the latest cycle with 2008 makes some changes evident. The proportion of all forest land classified as oak/hickory has decreased 3 percentage points over 10 years. Conversely, a 3-point increase was seen in both loblolly/shortleaf pine and oak/gum/cypress forest-type groups.

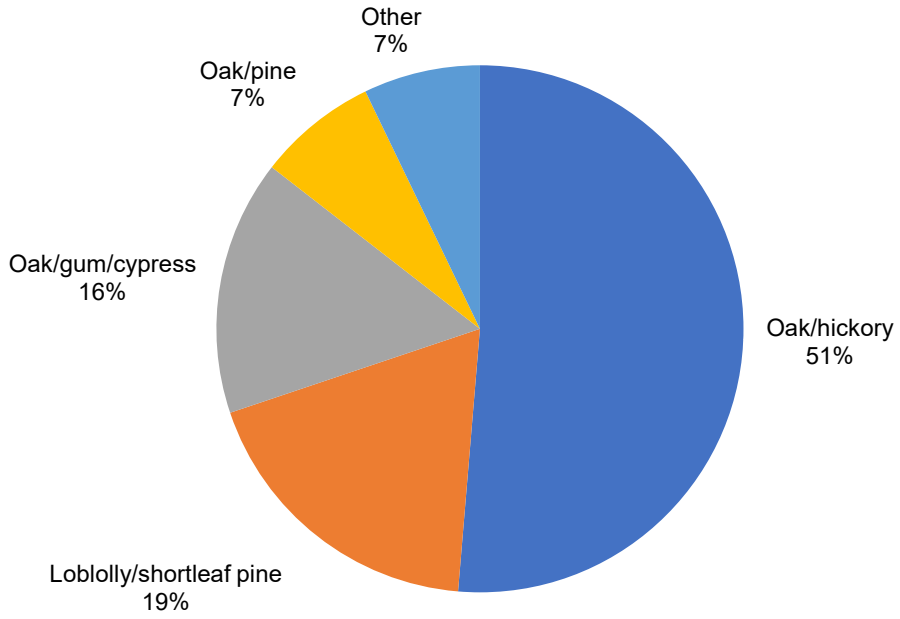

Figure 6.—Percentage of forest land area by forest-type group, Delaware, 2018.

Stand Structure

The relationships between forest type, stand size, and stand age provide insight into overall forest composition and structure. Although stand size and stand age are closely related, they can each provide valuable information about different aspects of a forest when examined separately. 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.

Stand Size

Three classes are used to describe the stand size of forested conditions. Since 1986 the proportion of timberland classified as large diameter stands has been steadily increasing (Fig. 7). Although the total area of timberland remained relatively unchanged, the acreage of large diameter stands increased by 33,000 acres as stands of small and medium diameter trees grew and shifted into the larger class. Although this trend continued, it appears to have slowed around 2008 and the area of small, medium, and large size class stands has remained relatively stable since.

Timberland across the State continued to grow and shift from small and medium stands into the large stand-size category. Although these shifts suggest maturing forests, they alone do not indicate a lack of regeneration. Stands that are classified as sawtimber can include trees of a full range of sizes and recruitment may be occurring in the understory, resulting in dynamic multiaged and multisized stands. Further investigation of individual tree diameters, stocking, and seedling data in these maturing stands could provide answers about whether these forests will sustain themselves in the years to come.

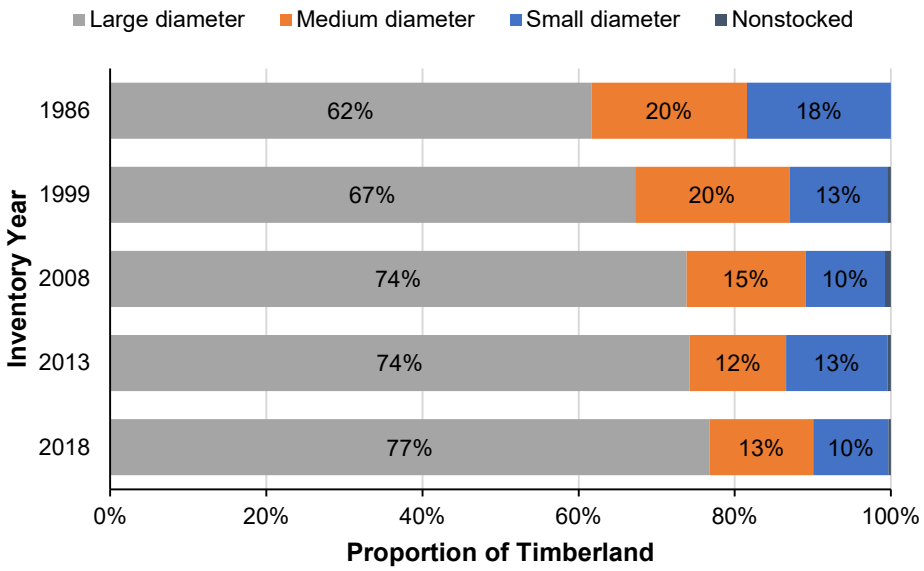

Figure 7.—Percentage of timberland area by stand-size class and inventory year, Delaware.

Stand Age

Stand age is assigned to forested areas based on the average age of trees in the predominant stand-size class that are not overtopped. "For a given forest-type, age class is correlated with stand height, tree density, basal area, volume, biomass, and carbon per acre" (Shifley and Ek 2019). An examination of trends and current conditions can provide an overview of changing forest dynamics related to succession, disturbances, and forest management.

Although a direct acreage comparison cannot be made between the periodic inventories (1986, 1999) and the annual inventories (2008, 2013, 2018) due to a change in protocol, general trends can be identified over this period. As suggested by the increased proportion of sawtimber stands, an investigation of stand age showed increasing acreage of timberland stands over 60 years old (Fig. 8). Since the first annual inventory in 2008, the acreage of timberland greater than 80 years old increased by 54,000 acres. This 76 percent increase meant that by 2018 over one-third (36 percent) of all timberland stands were more than 80 years old, compared to 21 percent in 2008. During the same time period, the total acreage of stands in the 61–80 year age class remained stable as stands at the high end of the class aged out and younger stands aged in to fill the gap. A steep decline in area covered by 41–60 year stands continued and the acreage of these stands decreased by nearly half, from 90,000 acres in 2008 to 48,000 acres just 10 years later. Notably, loblolly pine stands made up only 19 percent of all timberland in 2018 yet accounted for 40 percent of all stands age 40 years and younger.

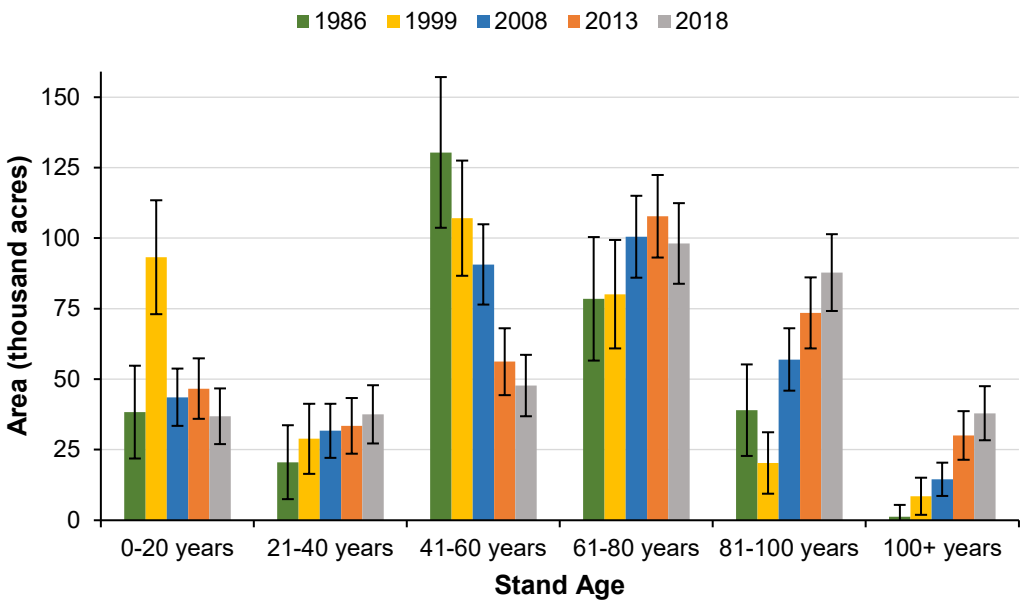

Figure 8.—Timberland area by stand-age class and inventory year, Delaware. Error bars represent a 68 percent confidence interval.

Delaware forests are maturing and the presence of older and larger stands generally implies lower natural and anthropogenic disturbances. As with stand size, the age of a stand is determined based on the plurality of stocking and does not in itself imply a lack of recruitment; therefore, regeneration may still be occurring in the understory of larger and older stands. While older forests supply valuable habitat and maintain the potential to supply needed forest products, it is preferable to maintain both early and late successional habitats for all forest-associated species.

In 2018 the proportion of stands 40 years and younger (22 percent) was nearly equal to the proportion of small and medium diameter stands (23 percent). That these stands of younger and smaller diameter trees were disproportionately composed of loblolly pine stands suggests that other prominent forest types encompass a less diverse range of stand sizes and ages across the State.

Volume Trends

Tree 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. The FIA program reports volume for trees at least 5 inches in diameter 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 noncommercial 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 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 diameter at breast height (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 was 1.1 billion cubic feet in 2018 and timberland accounted for 94 percent (1.0 billion cubic feet) of that volume. Most of the remaining sound volume is found on reserved forest land; other forest land contains less than 1 percent of total sound volume. Net volume on timberland was 907 million cubic feet, and 92 percent of net volume was in growing-stock trees (Fig. 9). The proportion of net volume in growing stock decreased from 97 percent in 2008 to 92 percent in 2013 due to an increase in rough cull. The proportion of net volume in growing stock on public land is slightly higher than on private land, 94 percent and 92 percent, respectively. Rotten cull on public land was less than 1 percent of net volume in 2018.

Small sample size and associated error make reporting change in volume for a small state like Delaware difficult, particularly at the individual species level. The data suggest that the mature forest resources of the State continue to accumulate volume. Hardwoods accounted for 85 percent of total sound volume in 2018, but most of the within-error increases in volume appear to be driven by increases in softwood volume. Loblolly pine volume increased substantially from 2008 to 2018 with notable gains in net (39 percent), growing stock (38 percent), and sawtimber (50 percent).

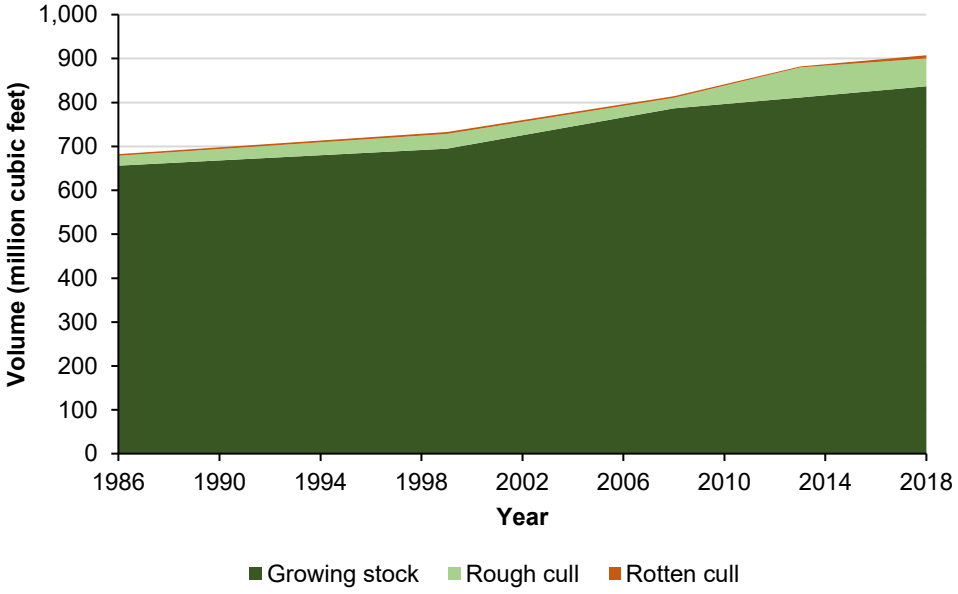

Figure 9.—Net volume of live trees on timberland by tree class and inventory year, Delaware.

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 and of 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. Negative net growth 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 initiated 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 an indication 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.

Gross growth on timberland was 29 million cubic feet in 2018. Mortality of 11 million cubic feet resulted in a net growth of 18 million cubic feet. Harvest removals were 11 million cubic feet, leaving a net change of 6 million cubic feet (Fig. 10). Relatively high sample error makes change comparisons uncertain, but the data suggest that increases in mortality and harvest removals from 2013 to 2018 led to decreases in net growth and net change, respectively.

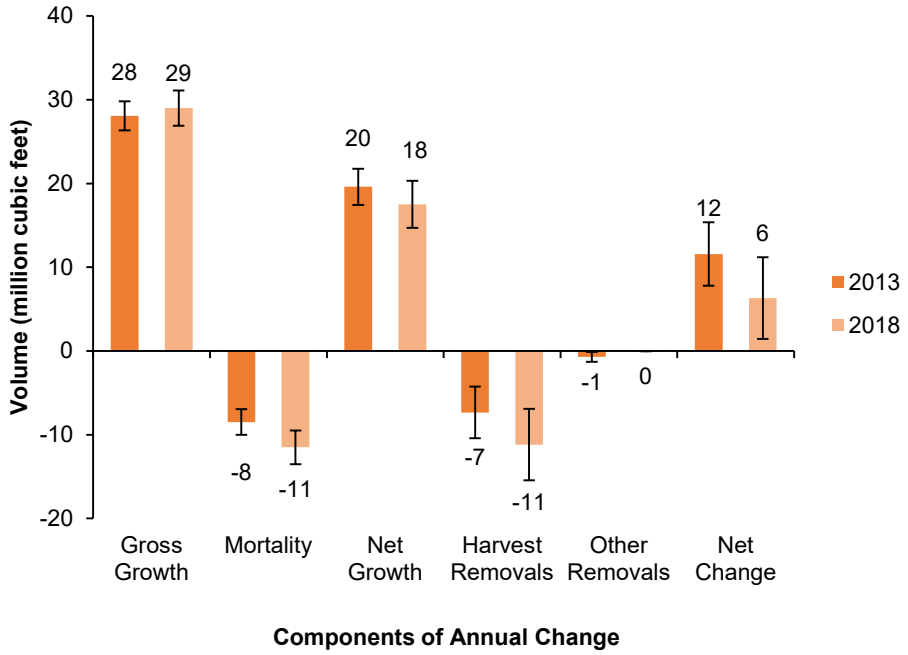

Figure 10.—Components of volume change on timberland by inventory year, Delaware. Error bars represent a 68 percent confidence interval.

The growth-to-removals ratio of growing stock on timberland in Delaware was estimated to be 1.7:1.0 in 2018 compared to 2.4:1.0 in 2013. Fortunately, all recorded removal volume was due to harvesting and not land use change. Trees can be expected to regenerate as long as 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, loblolly pine, sweetgum, white oak, and blackgum (above 2.0:1.0) suggest that these species should continue to increase in volume. In contrast, willow oak, southern red oak, black cherry, and scarlet oak have growth-to-harvest removals ratios near or below 1.0:1.0, which indicate that those species may be decreasing in abundance.

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