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# New Hampshire Forests 2017



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## Abstract

The second full remeasurement of the annual inventory of the forests of New Hampshire was completed in 2017 and covers more than 4.7 million acres of forest land, with an average volume of over 2,300 cubic feet per acre. The data in this report are based on 1,162 plots located across New Hampshire. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 52 percent of total forest land area. Of the forest land, 64 percent consists of large diameter trees, 25 percent contains medium diameter trees, and 11 percent contains small diameter trees. The volume of growing stock on timberland has continued to increase since the 1980s and currently totals nearly 9.5 billion cubic feet. The average annual net growth of growing stock on timberland from 2012 to 2017 was over 180 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, species composition, regeneration, and forest health. Sets of supplemental tables are available online at <https://doi.org/10.2737/NRS-RB-119> and contain: 1) tables that summarize quality assurance and 2) a core set of estimates for a variety of forest resources.

## Acknowledgments

The authors would like to thank inventory crew members from New Hampshire for their help during the 2008–2017 inventory years: Aaron Clark, Robert Gregory, John Higham, Katherine Locke, Jason Morrison, Joyce Quinn, Bryan Tirrell, and Ashley Zickefoose. Thanks also to Susan Francher and Paul Frederick for serving as external reviewers and providing insightful, constructive comments.

Cover: View of the Presidential Range of the White Mountains. Photo by Randall Morin, USDA Forest Service.

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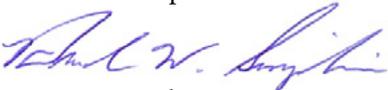
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# Foreword

The landscape of New Hampshire has undergone many changes during its history. One of the constants has been a working forest landscape that provides goods and services through stewardship, management, and conservation. We depend upon the forest for timber, maple syrup, and firewood, along with values and services such as watershed protection, wildlife habitats, carbon sequestration, outdoor recreation opportunities, and scenic beauty. Forests dominate the landscape of New Hampshire; decisions we make and actions we take today to care for those lands need to be informed by accurate and timely data.

The New Hampshire Division of Forests and Lands is pleased to be a partner of the U.S. Forest Service in the Forest Inventory and Analysis (FIA) inventory of New Hampshire forests. The more we know and understand the resources of our forests, the better we can sustain our forests. Sustainable forests begin with healthy forests, and we encourage you to become familiar with information contained in this publication.

Brad W. Simpkins



New Hampshire State Forester

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Online at <a href="https://doi.org/10.2737/NRS-RB-119">https://doi.org/10.2737/NRS-RB-119</a>	



Wooded stream in Franconia State Park. Photo by Elizabeth Morin, used with permission.

# Highlights

## On the Plus Side

- New Hampshire is the second most forested state in the United States.
- Participation in New Hampshire's current use taxation has increased, which may reduce the amount of forest land converted to other uses.
- Changes in stand stocking toward more moderately and fully stocked stands suggest that forest management practices over the past three decades have improved the general stocking condition across New Hampshire.
- Most forest carbon in New Hampshire is found in moderate-aged stands dominated by relatively long-lived species, suggesting that forest carbon stocks will continue to increase as stands mature and accumulate carbon in aboveground and belowground components.
- Timber resources in New Hampshire are at near-record levels since inventories began in 1948.
- The mortality rate (0.7 percent) for the 2017 inventory is slightly lower than what was reported for the 2012 and 2007 inventories.
- Tree crowns are generally healthy and stable across the State.
- The ratio of growth to removals of 1.9:1.0 in New Hampshire indicates that growth is adding nearly twice as much volume annually as is getting removed by harvesting.

## Areas of Concern

- Commercial and residential development of forest land, particularly in the southern quarter of the State, has resulted in reductions in forest land use. New Hampshire lost forest land at a rate of about 0.4 percent per year between 2012 and 2017.
- The expected transfer of 1.6 million acres of family forest land foreshadowed by the advanced age (65+) of many owners is an important trend to monitor as the fate of forests is most likely to change when forest land is passed to the next generation of owners.
- The total volume of sawtimber in New Hampshire has decreased slightly since 2012, mostly due to the decrease in forest land.

- Timber volume peaked in 2012 and the rate of growth has leveled off as the forest matures, a trend that is likely to continue into the future.
- The dominance of beech and noncommercial tree species in the sapling size class raises concerns about the future species composition in New Hampshire.
- The proportion of ash basal area with poor crowns has more than doubled since 2012, but the relative amount is still low (6 percent).
- The presence of nonnative invasive plant species has remained stable since the 2012 inventory.

## **Issues to Watch**

- The small parcels held by many landowners and the trend toward more landowners with smaller parcels complicate the economics of forest management and the delivery of government programs.
- The trend toward more area of large diameter and less area of small and medium diameter trees in New Hampshire needs continued monitoring.
- Although wood volume continues to accumulate as the forests mature, only a small fraction of the accumulated material is available for use as wood products.
- The total volume of timber resources in New Hampshire has started to decrease for the first time since the Forest Service's Forest Inventory and Analysis program began doing inventories in the State in 1948. The slight decrease in timberland area along with a slowing rate of increase in growing-stock volumes has resulted in this reduction in total timber volume. Growth rates may decrease further as the forest ages.
- If the current species composition remains constant as saplings mature, the future forest overstory will have more red maple and balsam fir trees and less eastern white pine, eastern hemlock, and northern red oak than today.
- Although the proportion of high grade volume has remained relatively stable, changes in species composition point toward potential reductions in overall sawtimber quality into the future.
- An important consideration for those landowners actively managing their land is the ability of the primary wood products industry to retain pulp mills, sawmills, and veneer mills within a distance that allows for a sustainable market for the harvested material.

- Invasive insect pests that are likely to impact abundant tree species in New Hampshire in the future include hemlock woolly adelgid, emerald ash borer, and Asian longhorned beetle.
- The risk of catastrophic economic and ecological loss of forest resources could increase due to forest maturity and more extreme weather-related events, including hurricanes, droughts, and floods caused by a changing climatic regime.
- Two highly valuable commercial species, eastern white pine and red oak, are nearly absent in the smaller size classes in New Hampshire.
- A maturing forest structure continues to limit pioneer and other shade-intolerant species that thrive in sunnier forested conditions.
- Frequent tree damage (25 percent of trees) and internal decay on 11 percent of trees in New Hampshire may be an indication of reduced tree health and timber quality.
- Urbanization is affecting an increasing amount of forest area in New Hampshire. A total of 1.3 million acres (28 percent of New Hampshire forest land) was in wildland-urban interface (WUI) conditions by 1990, and between 1990 and 2010 forest land was converted to WUI conditions in the majority of counties at rates greater than 5 percentage points per decade.



# Background



View of the Presidential Range of the White Mountains. Photo by Randall Morin, USDA Forest Service.

# Data Sources and Techniques

The forests of New Hampshire are one of northern New England's most valuable assets due to their importance to the economy and quality of life for residents. Accurate and statistically defensible information is critical for understanding the current conditions, interpreting trends over time, and projecting future scenarios. This report highlights the current status and trends observed in the forests of New Hampshire and is the culmination of the second complete remeasurement of the inventory using the USDA Forest Service Forest Inventory and Analysis (FIA) program's annualized forest inventory system. Data are based on 1,162 plots located across New Hampshire. Previous forest inventories in New Hampshire were completed in 1952 (USDA Forest Service 1954), 1960 (Ferguson and Jensen 1963), 1973 (Frieswyk and Malley 1985, Kingsley 1976), 1983 (Frieswyk and Malley 1985, Frieswyk and Widmann 2000), 1997 (Frieswyk and Widmann 2000), 2007 (Morin et al. 2011), and 2012 (Morin et al. 2015a). The annualized system was implemented in New Hampshire in 2002 to provide updated forest inventory information every year. The FIA program is the only source of data collected from a permanent network of ground plots from across the Nation that allows for comparisons to be made among states and regions. The most recent inventory period was conducted from 2011 through 2017 and hereafter is referred to as the 2017 inventory.

The FIA sampling design is based on a tessellation of the United States into hexagons approximately 6,000 acres in size with at least one permanent plot established in each hexagon. In Phase 1 (P1), the population of interest is stratified and plots are assigned to strata to increase the precision of estimates. In Phase 2 (P2), tree and site attributes are measured for forested plots established in each hexagon. Phase 2 plots consist of four 24-foot fixed-radius subplots on which standing trees are inventoried. This sampling design results in 1,162 long-term inventory plots in New Hampshire. In Phase 3 (P3), field crews visited a subset of P2 plots to obtain measurements for an additional suite of variables associated with forest and ecosystem health. P3 has been replaced by Phase 2+ (P2+), in which fewer data are collected per plot but more plots are sampled. Otherwise, P2+ follows the same paradigm as the retired P3, focusing on forest and ecosystem health. Detailed information on the sampling protocols can be found in the report on statistics and quality assurance (Gormanson et al. 2018). A glossary of terms commonly used in FIA reports is available at <https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary>. Supplemental tables summarizing the results reported for New Hampshire are available at <https://doi.org/10.2737/NRS-RB-119>.

# An Overview of Forest Inventory

## What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. FIA defines a tree as any perennial woody plant species that can attain a height of 15 feet at maturity. A list of the tree species mentioned in this report is included in the appendix. Throughout this report, the size of a tree is usually expressed as diameter at breast height (d.b.h.), in inches. This is the diameter, outside the bark, at a point 4.5 feet above the ground.

## What is a forest?

A forest is a collection of trees and most people would agree on what a forest is. But in order for statistics to be reliable and comparable, a definition must be created to avoid ambiguity. FIA defines forest land as land that has at least 10-percent tree cover and is not currently developed for nonforest use. Generally, the minimum area for classification as a forest is 1 acre in size and 120 feet in width. There are more specific criteria for defining forest land near streams, rights-of-way, and shelterbelt strips (USDA Forest Service 2016).

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

From an FIA perspective, there are three types of forest land: timberland, reserved forest land, and other forest land. In New Hampshire, approximately 94 percent of all forest land is classified as unreserved and productive timberland and 6 percent is reserved or unproductive (or both) forest land.

- Timberland is unreserved forest land that meets the minimum productivity requirement of 20 cubic feet per acre per year.
- Reserved forest land is land withdrawn from timber utilization through legislative regulation without regard to productive status (e.g., state parks, natural areas, national parks, and Federal wilderness areas). All reserved forest land is in public ownerships.
- Other forest land is commonly found on low-lying sites or high craggy areas with poor soils where the forest is incapable of producing at least 20 cubic feet per acre per year. In earlier inventories, FIA measured trees only on timberland plots and did not report volumes on all forest land. Since the implementation of the annual inventory, FIA has been reporting volume on all forest land.

- With the second remeasurement completed, comparison of three sets of growth, mortality, and removals data, as well as analysis of trends on forest land, is now possible. However, because some of the older periodic inventories reported only on timberland, much of the trend reporting in this publication is still focused on timberland.

## **How many trees are in New Hampshire?**

Forest land in New Hampshire contains approximately 927 million live trees that have a d.b.h. of at least 5 inches. The exact number of trees cannot be determined because the estimate is based on only a sample of the total population. The frequency estimates are calculated from field measurements of 1,047 forested plots. For information on sampling errors, see the report on statistics and quality assurance (Gormanson et al. 2018).

## **How do we estimate a tree's volume?**

To estimate a live tree's volume, FIA uses volume equations developed for each tree species group found within the northeastern United States. Individual tree volumes are based on species, diameter, and height. FIA reports volume in cubic feet and board feet (International ¼-inch rule). Board-foot volume measurements are applicable only for sawtimber-size trees. Some wood products are often measured in cords (a stack of wood 8 feet long by 4 feet wide and 4 feet high). A cord of wood consists of about 79 to 85 cubic feet of solid wood and the remaining 43 to 49 cubic feet are bark and air.

## **How is forest biomass estimated?**

Specific gravity values for each tree species or group of species were developed at the Forest Service's Forest Products Laboratory (Miles and Smith 2009) and were applied to FIA tree volume estimates to determine merchantable tree biomass (weight of tree bole). Total aboveground live-tree biomass is calculated by adding the biomass for stumps, limbs, and tops (Woodall et al. 2011). Live biomass for foliage is currently not reported. FIA inventories report biomass weights as oven-dry short tons. Oven-dry weight of a tree is the green weight minus the moisture content. Generally, 1 ton of oven-dry biomass is equal to 1.9 tons of green biomass.

## **How do we compare data from different inventories?**

New inventories are commonly compared with older datasets to analyze trends or changes in forest growth, mortality, removals, and ownership acreage over time

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

Before the Component Ratio Method (CRM) was implemented, volume and biomass were estimated using separate sets of equations (Heath et al. 2009). With CRM, determining the biomass of individual trees and forests has become an extension of FIA volume estimates, allowing biomass estimates for tree growth, mortality, and removals to be obtained not only for live trees, but also for belowground coarse roots, standing dead wood, and down woody debris.

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

## **A word of caution on suitability and availability**

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



# Forest Features



A moose (*Alces alces*) and her baby near a spruce/fir forest. Photo by Randall Morin, USDA Forest Service.

# Dynamics of the Forest Land Base

## Background

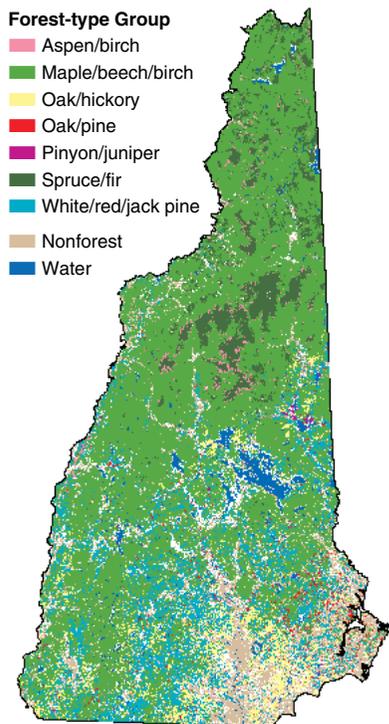
New Hampshire's diverse, forested landscape includes the transition from maple/beechn/birch forests of the northeastern United States to the spruce/fir forests of northern New England. Because forests are essential for wood products, tourism, clean water, clean air, wildlife habitat, and wood energy, 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 because they have a direct effect on the amount of goods and services provided.

Forest type is determined by the stocking (relative density) that tree species contribute to a sampled area. The forest types used by FIA are based on the types presented by Eyre (1980). Related forest types are combined into groups. A map based on FIA plot attributes and ancillary data illustrates the spatial distribution of forest-type groups in New Hampshire (Fig. 1). This dataset is available for download at [https://data.fs.usda.gov/geodata/rastergateway/forest\\_type/index.php](https://data.fs.usda.gov/geodata/rastergateway/forest_type/index.php).

## What we found

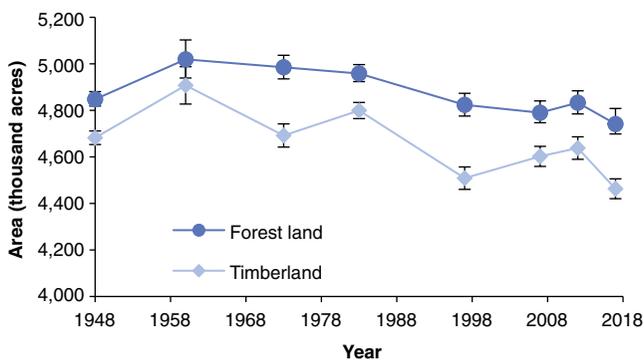
Forests dominate the land cover across most of New Hampshire. The percentage of forest cover generally increases from south to north in New Hampshire (Fig. 1), mostly due to more urbanization in the south. In 1948, when FIA completed its first inventory in New Hampshire, 84 percent of the State's area was forested. The 1960 inventory showed a small increase in forest cover (87 percent of land area). New Hampshire's forest land base then decreased at a slow rate between the 1960s and 2000s and dropped more precipitously between 2012 and 2017 (Fig. 2). Currently, forest covers 83 percent of New Hampshire's land base. Much of the nearly 280,000-acre decrease in forest land since 1960 is due to the development of land to meet the needs of a growing population, particularly in the southern part of the State because of population growth north of Boston, MA (Fig. 3).

The forest land base in New Hampshire is composed of predominantly hardwood forest types. The maple/beechn/birch forest-type group makes up 52 percent of the forest land in the State. Spruce/fir and oak/pine forest-type groups are also well represented (Fig. 1), and 64 percent of New Hampshire's forest land is in large diameter stands (Fig. 4).

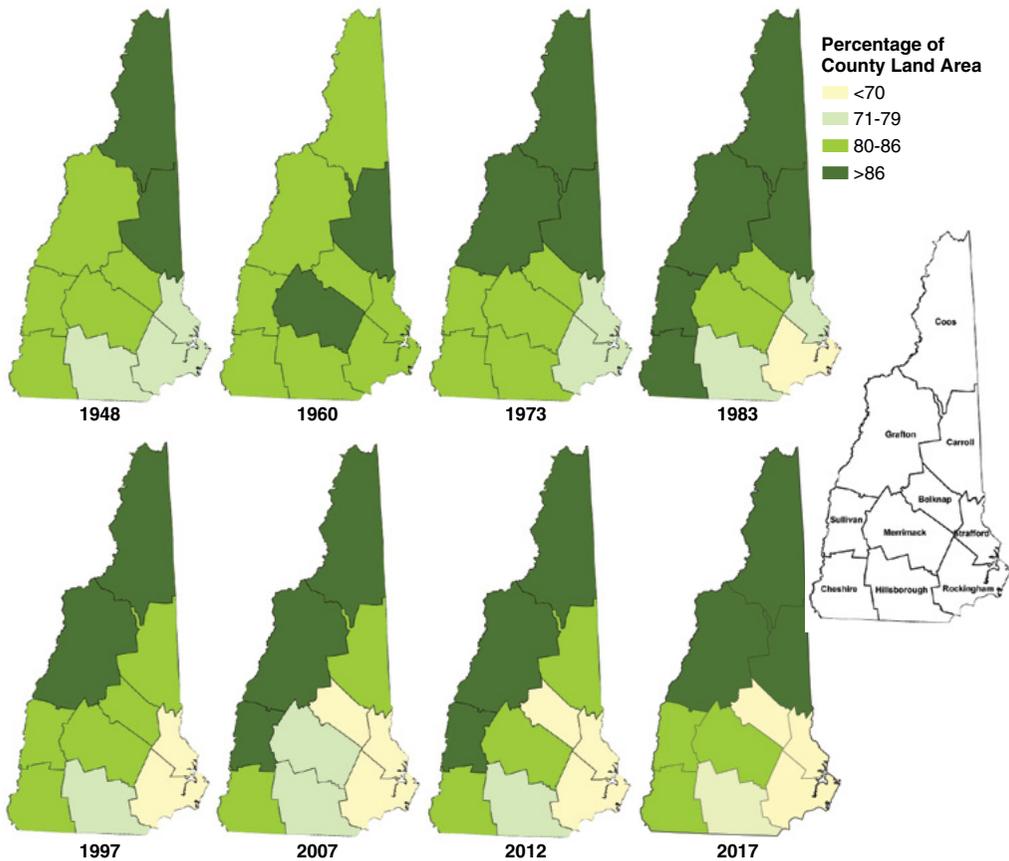


Projection: New Hampshire State Plane, NAD83.  
 Sources: USDA Forest Service, Forest Inventory and Analysis program, 2008;  
 NLCD 2006 (Fry et al. 2011).  
 Geographic base data are provided by the National Atlas of the USA®.  
 FIA data and Tools are available online at <https://www.fia.fs.fed.us/tools-data/>.  
 Cartography: R.S. Morin, USDA Forest Service, April 2019.

**Figure 1.**—Distribution of forest-type groups, New Hampshire, 2008.

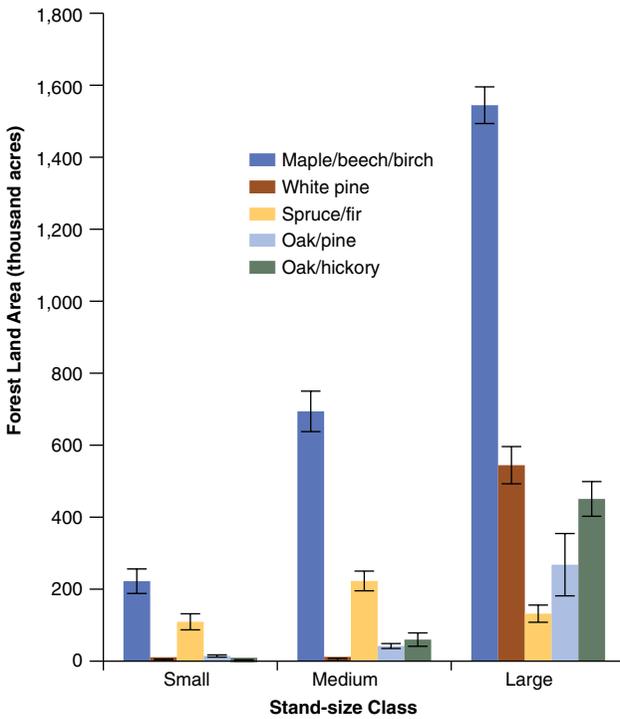


**Figure 2.**—Area of forest land and timberland by inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



Projection: New Hampshire State Plane, NAD83.  
 Sources: USDA Forest Service, Forest Inventory and Analysis program, 1948, 1960, 1973, 1983, 1997, 2007, 2012, and 2017 data.  
 Geographic base data are provided by the National Atlas of the USA®.  
 FIA data and Tools are available online at <https://www.fia.fs.fed.us/tools-data/>.  
 Cartography: R.S. Morin, USDA Forest Service, April 2019.

**Figure 3.**—Distribution of relative area of forest land by county and inventory year, New Hampshire.



**Figure 4.**—Area of forest land for the five most abundant forest-type groups by stand-size class, New Hampshire, 2017. Error bars represent a 68 percent confidence interval around the mean.

## What this means

With forests covering 83 percent of the land, New Hampshire is the second most forested state, but statewide estimates of forest land have decreased by about 2 percent over the last two decades. The largest proportional losses in forest land over this period occurred in Merrimack and Belknap Counties. Future changes in New Hampshire’s forest land base will depend on the pace of land development, particularly in the southern part of the State.

# Availability and Productivity of Forest Land

## Background

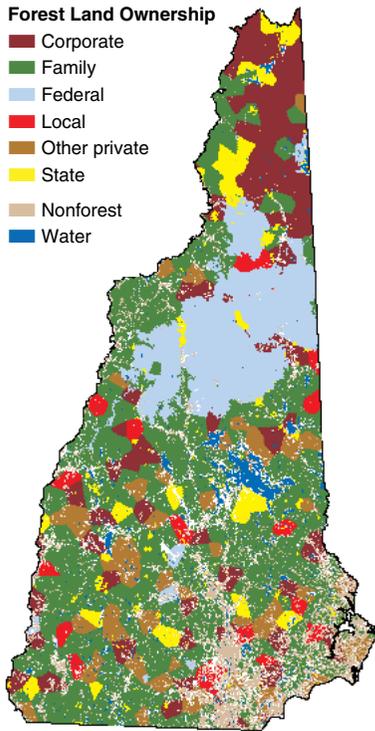
FIA divides forest land into three categories—timberland, reserved forest land, and other forest land—to clarify the availability of forest resources and type of forest management planning. Two criteria are used to make this determination: reserved status (unreserved or reserved) and site productivity (productive or unproductive). Forest land that is capable of accumulating wood volume 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. A final category, other forest land, is made up of forest land that is unreserved and low in productivity.

## What we found

Ninety-four percent of the forest land of New Hampshire meets the definition of timberland (Fig. 2), and 77 percent of that timberland is in private ownership. Estimates of the amount of timberland have decreased by 1 percent since 1997 (Fig. 2). Most of the land in the reserved class is in designated natural areas and is located on the White Mountain National Forest (see Federal Ownership in Fig. 5). Other forest land (i.e., unreserved and unproductive) is rare and accounts for less than 1 percent of total land (Fig. 6).

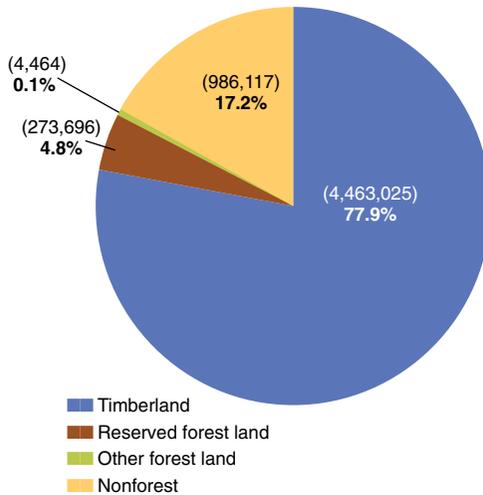
## What this means

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



Projection: New Hampshire State Plane, NAD83.  
 Sources: PAD v4.6, 2013; FIA 2009; ALP 2006.  
 Geographic base data are provided by the National Atlas of the USA®.  
 FIA data and Tools are available online at <https://www.fia.fs.fed.us/tools-data/>.  
 Cartography: R.S. Morin, USDA Forest Service, April 2019.

**Figure 5.**—Distribution of forest land by owner group, New Hampshire, 2014.



**Figure 6.**—Distribution of land by land use, New Hampshire, 2017. Values in parentheses are acreages.

# Ownership of Forest Land

## Background

How land is managed is primarily the owner's decision. Therefore, to a large extent, landowners determine the availability and quality of forest resources, including recreational opportunities, timber, and wildlife habitat. By understanding the priorities of forest landowners, the forest conservation community can better help owners meet their needs, and in so doing, help conserve the State's forests for future generations. The National Woodland Owner Survey (NWOS; <https://www.fia.fs.fed.us/nwos>), conducted by FIA, studies private forest landowners' attitudes, management objectives, and concerns. It focuses on the diverse and dynamic group of owners that is the least understood—families, individuals, and other unincorporated groups, collectively referred to as “family forest owners.” The NWOS data reported here are based on the responses from 146 family forest ownerships from New Hampshire that participated between 2011 and 2013 (Butler et al. 2016).<sup>1</sup> Where available, these results are compared to the previous iteration of the NWOS implemented between 2002 and 2006. For comparisons of forest land by ownership category, data are also included for the most recent, 2011 through 2017, FIA inventory.

## What we found

### General Ownership Patterns

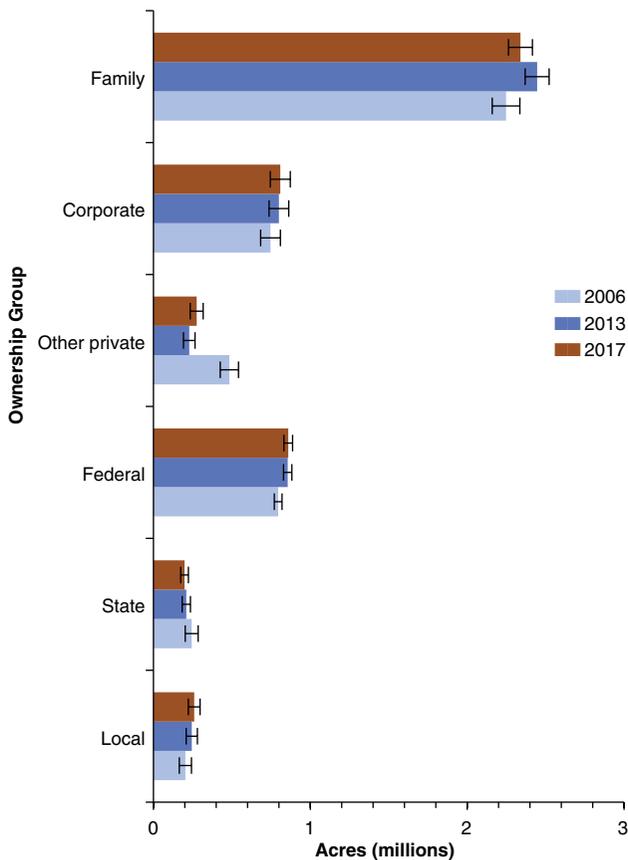
Nearly 3 out of every 4 acres (72.2 percent) of the forest land in New Hampshire are privately owned. Most of this private forest land, an estimated 2.3 million of the 3.4 million acres, is owned by family forest owners. Details about this group are discussed in the next section. Corporations own an estimated 809,000 acres. Other private owners, including conservation organizations and unincorporated clubs and partnerships, own an estimated 276,000 acres.

Public owners control 27.8 percent of New Hampshire forest land. The Federal government manages an estimated 859,000 acres of forest land, largely in the White Mountain National Forest. State forest, park, and wildlife agencies are stewards of an estimated 198,000 acres of forest land. Local governments control an estimated 260,000 acres of forest land in the State.

Between 2006 and 2017 the estimated forest acreage owned by other private owners decreased by 208,000 acres, and State-owned forest acreage decreased by 56,000 acres. The estimated areas for all other ownership categories showed net increases ranging from 50,000 to 100,000 acres (Fig. 7).

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<sup>1</sup> Data for the 2017–2018 NWOS are currently being collected with results anticipated for release in late 2019.



**Figure 7.**—Area of forest land by ownership group and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.

### Family Forest Ownerships

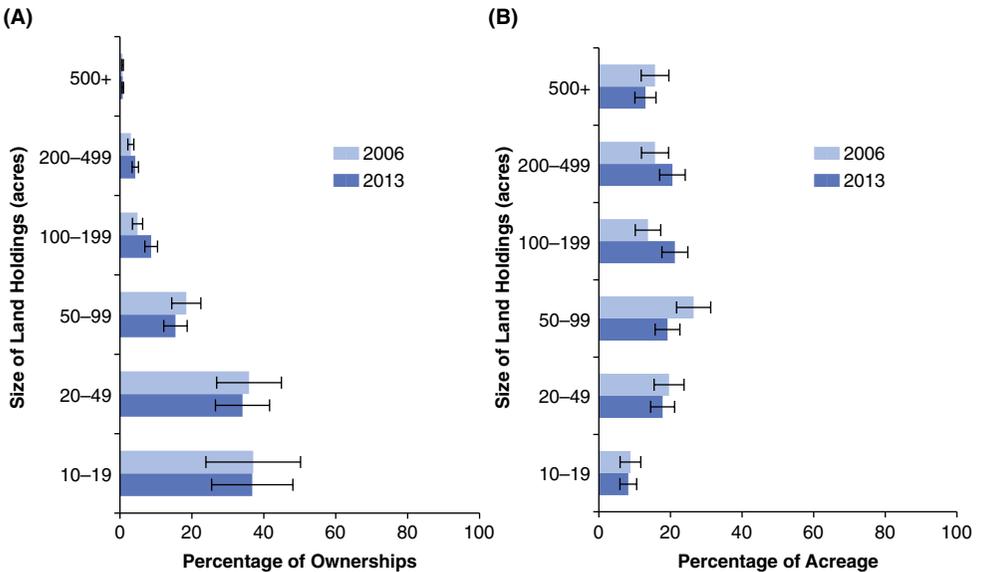
As of 2013, the date of the latest available data,<sup>1</sup> there are an estimated 39,000 family forest ownerships (standard error [SE] = 6.9 percent) across New Hampshire that each own at least 10 acres of forest land. The number of family forest ownerships remained virtually unchanged since 2006, but the acreage increased by an estimated 135,000 acres. The average forest holding size of this group in 2013 was 56.1 acres per ownership (SE = 11.4 percent). This is slightly higher than in 2006, but the estimates are not statistically different. As of 2013, 70.9 percent of these family forest ownerships own less than 50 acres of forest land, but 74.0 percent of the family forest land is in holdings of at least 50 acres (Fig. 8).

The primary reasons for owning forest land are related to amenity values, such as aesthetics, nature, privacy, and wildlife (Fig. 9). Objectives related to financial values, including timber production and land investment, are rated as dominant ownership

reasons much less frequently. The most common activities on family forest land are personal recreation, such as hunting and hiking, and cutting trees for personal use, such as firewood (Fig. 10). Due to changes in the wording of the questions, it is not possible to directly compare responses to the 2013 NWOS questions on ownership objectives to those in the 2006 NWOS.<sup>2</sup>

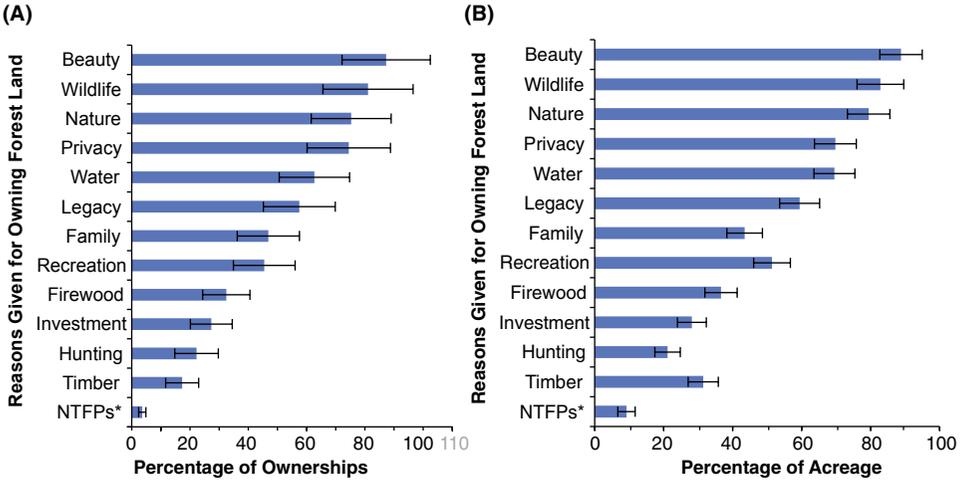
The majority of family forest ownerships report participating in the State’s tax program and participation is increasing, but far fewer report participating in other assistance programs or traditional forestry management activities (Fig. 11). Twenty-six percent of the ownerships in New Hampshire, owning 46 percent of the family forest land, report receiving forest management advice in the previous 5 years. Fifteen percent of the ownerships, owning 41 percent of the family forest land, report having a written forest management plan. Fewer than 10 percent of the ownerships report participating in easement, cost sharing, or certification programs. Again, comparisons between the 2006 and 2013 iterations of the NWOS are not feasible due to changes in question wording.<sup>2</sup>

The average age of family forest owners in New Hampshire is 61.4 years (SE = 5.4 percent). Forty-seven percent of the private forest land, or 1.6 million acres, is owned by people 65 or older (Fig. 12). Between 2006 and 2013, there was a decrease in the percentage of owners 65 or older and a marked increase in owners between 55 and 64 years old.

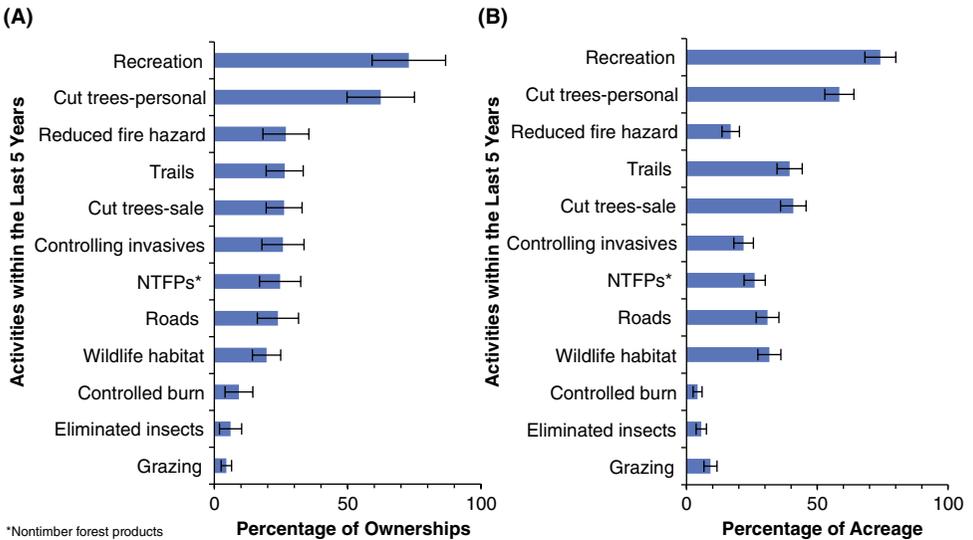


**Figure 8.**—Percentage of family forest (A) ownerships and (B) area of forest land by size of forest land holdings and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.

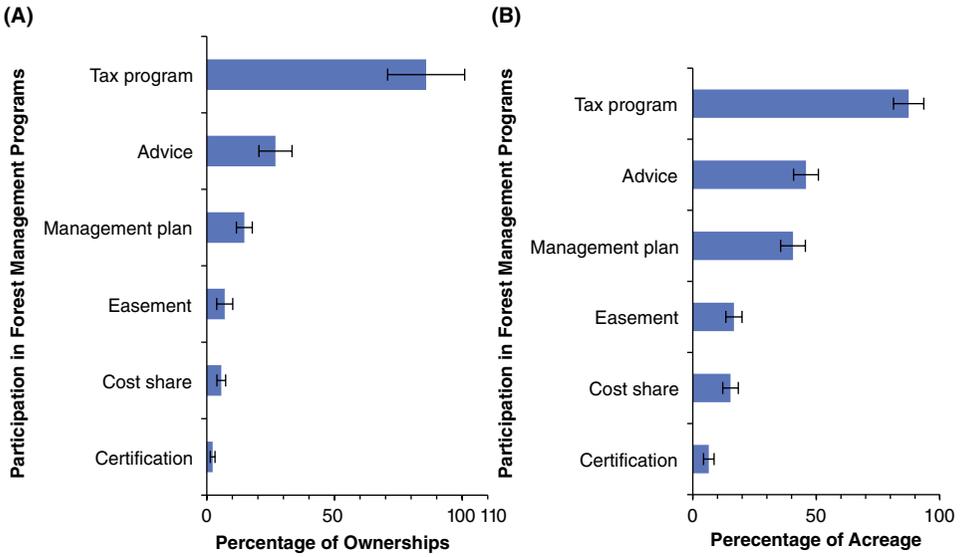
<sup>2</sup> More concerted efforts were made to keep the questions as consistent as possible between the 2013 and forthcoming 2018 iterations of the NWOS to allow for more accurate analyses of changes over time.



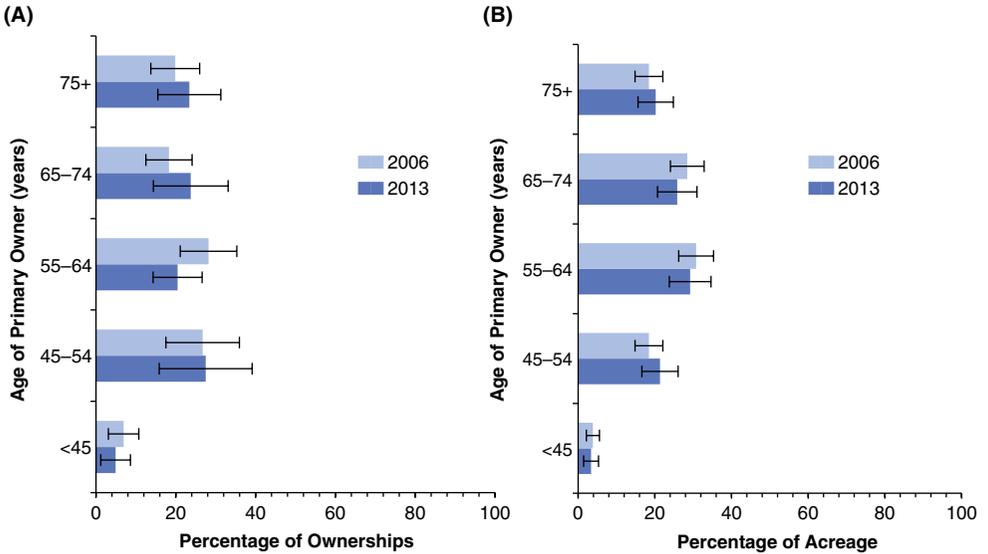
**Figure 9.**—Percentage of family forest (A) ownerships and (B) area of forest land by reasons given for owning forest land ranked as very important or important, New Hampshire, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the mean.



**Figure 10.**—Percentage of family forest (A) ownerships and (B) area of forest land by activities in the past 5 years, New Hampshire, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the mean.



**Figure 11.**—Percentage of family forest (A) ownerships and (B) area of forest land by participation in forest management programs, New Hampshire, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the mean.



**Figure 12.**—Percentage of family forest (A) ownerships and (B) area of forest land by age of primary owner and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.

## What this means

The fate of the forests lies primarily in the hands of those who own and control the land. It is therefore critical to understand forest owners and what policies and programs can help them conserve the forests for current and future generations. Family forest ownerships are the owner group that is the least understood, and the fate of their land is arguably the most uncertain. They own their land primarily for amenity reasons, but many are actively doing things with their land. Although the percentages of ownerships that have received advice and that have written forest management plans are higher compared to most other states, there are still significant opportunities to help these owners increase their engagement and stewardship of their lands. The small parcels held by many landowners and the trend toward more landowners with smaller parcels complicate the economics of forest management and the delivery of government programs. However, programs such as Tools for Engaging Landowners Effectively (<http://www.engaginglandowners.org>) can help the conservation community develop and implement programs more effectively and efficiently. Another important trend to watch is the aging of the family forest owners. With many of them being relatively advanced in age, this portends many acres of land passing on to the next generation in the not too distant future. There are programs such as Your Land Your Legacy (<http://masswoods.net/monthly-update/your-land-your-legacy-deciding-future-your-land>) and Ties to the Land (<http://tiestotheand.org>) that are being implemented to help owners meet their bequest goals, but it is uncertain who the future forest owners will be and what they will do with their land.

## Land Use Change

### Background

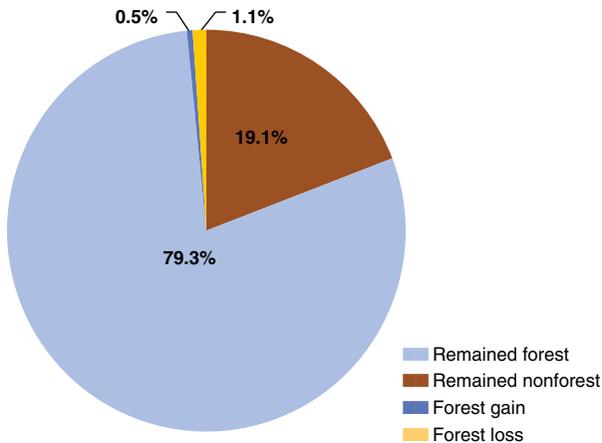
Forests cover 83 percent of the land area in New Hampshire, providing a critical resource and offering a wide range of benefits. FIA characterizes land area by using several broad land use categories: forest, rangeland, agriculture, water, developed, and other land (wetlands, undeveloped beaches, nonvegetated 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 New Hampshire inventory plots (2017) with the land uses recorded for the same plots measured during the previous inventory (2012) we can characterize forest land-use change dynamics. To better understand New Hampshire 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 New Hampshire’s forest resources and helps land managers make informed policy decisions.

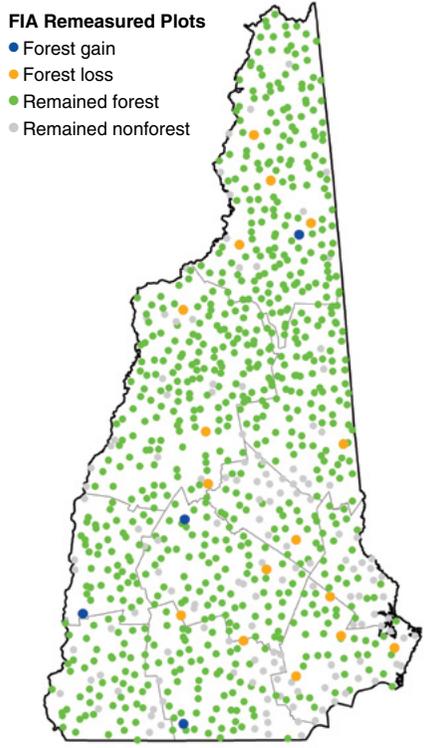
## What we found

Total land area in New Hampshire comprises about 5.9 million acres; agricultural land uses, along with urban, water, and other nonforest land uses, cover 1.2 million acres of the State’s surface area. Between 2012 and 2017 most of the land use in New Hampshire either remained forested (79.3 percent) or stayed in a nonforest land use (19.1 percent) (Fig. 13). The total area of forest land in New Hampshire declined gradually between recent decades, with a 0.4-percent average annual rate of decline since the previous inventory. Change plots—for mapping purposes, defined as those remeasured plots having land use gain or loss of at least 25 percent—are distributed throughout the State, and forest loss plots are more prevalent (Fig. 14).

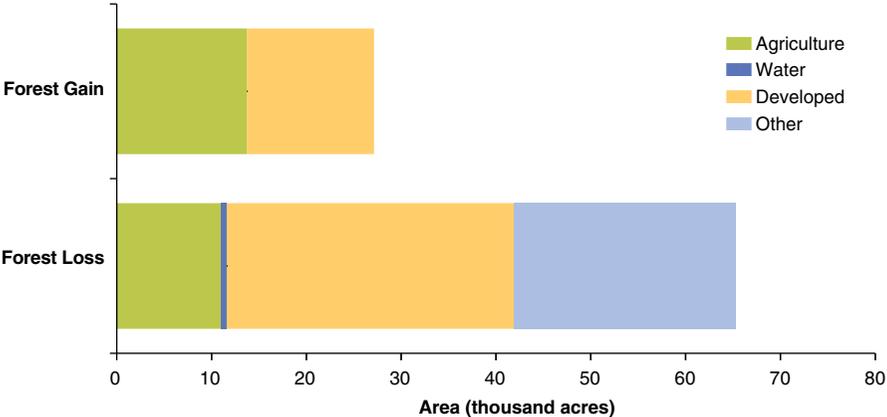
On the 1.6 percent of surface area where land use changed between inventories (Fig. 13), the amount of forest diverted to nonforest (65,000 acres) exceeded the amount of nonforest that reverted to new forest land (28,000 acres), leading to a slight net loss in forest land area (Fig. 15).



**Figure 13.**—Land use dynamics showing percentage of unchanged land, forest loss, and forest gain, New Hampshire, 2012 to 2017.



**Figure 14.**—Distribution of remeasurement inventory plots showing forest gain, forest loss, persisting forest, and persisting nonforest, New Hampshire, 2012 to 2017. Depicted plot locations are approximate.



**Figure 15.**—Gross forest loss and forest gain by land use category, New Hampshire, 2012 to 2017.

Forty-six percent of the gross forest loss, or about 30,000 acres, was due to diversion to developed land use (Fig. 15). Forest loss also resulted from forest land converted to agriculture (17 percent, or 11,000 acres), other land uses (36 percent, or 23,000 acres), and water (about 1 percent, or 500 acres). Fifty-one percent of forest gain in New Hampshire, or about 14,000 acres, was from agricultural land converting to forest. Developed land (49 percent, or about 13,000 acres) provided the remaining source of forest reversion (Fig. 15).

## What this means

The net loss of forest land reported in this inventory is small, but forest loss is only partially offset by forest gain. Gains and losses from multiple causes are driving land-use change dynamics in New Hampshire. 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. Such changes are generally not permanent and may be more prevalent in stands of small diameter trees.

# Stand Size and Structure—A Growing, Maturing Forest

## Background

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

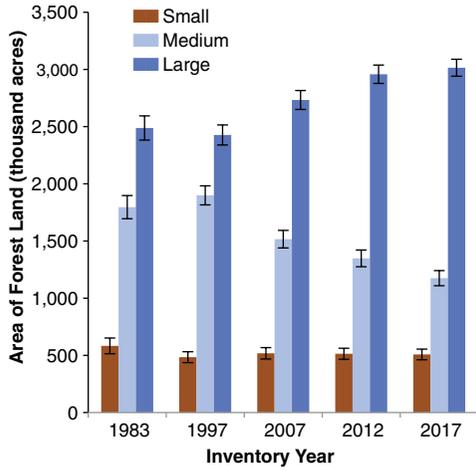
Stocking is a measure of the relationship between the growth potential of a site and the occupancy of the land by trees. The relative density (or stocking) of a forest is important for understanding growth, mortality, and yield. Five classes of stocking are reported by FIA: nonstocked (0–9 percent), poor (10–34 percent), moderate (35–59 percent), full (60–100 percent), and overstocked (>100 percent). Stocking levels are examined using all live trees and using growing-stock trees only in order to identify the amount of growing space that is being used to grow trees of commercial value versus the amount that is occupied by trees of little to no commercial value. For a tree to qualify as growing

stock, it must be a commercial species and cannot contain large amounts of cull (rough and rotten wood). The growth potential of a stand is considered to be reached when it is fully stocked. As stands become overstocked, trees become crowded, growth rates decline, and mortality rates increase. Poorly stocked stands can result from harvesting practices or forest growth on abandoned agricultural land; in contrast to moderately stocked stands, poorly stocked stands are not expected to grow into a fully stocked condition within a practical amount of time for timber production.

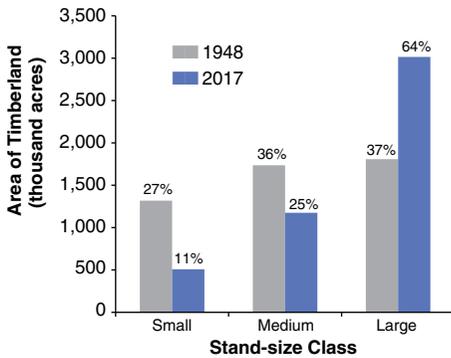
## What we found

In New Hampshire, the distribution of forest land by stand-size class continues the trend toward larger diameter stands. A substantial decrease in the area of medium diameter stands and a large increase in the area of large diameter stands have occurred since 1997 (Fig. 16). The trend toward increased area of large diameter trees is even more pronounced when current timberland estimates are compared with those from the 1948 inventory (USDA Forest Service 1954). Large diameter stands increased from 37 percent to 64 percent of the timberland area in New Hampshire between 1948 and 2017 (Fig. 17).

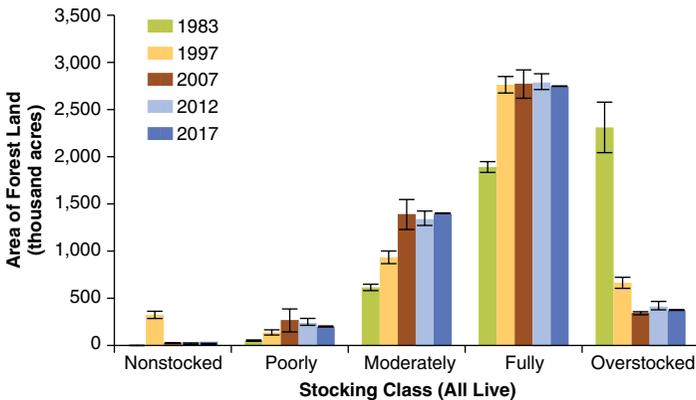
Since 1983, forest land area in the moderately and fully stocked classes for all live trees and growing-stock trees has increased, and at the same time, overstocked area has decreased in New Hampshire (Morin et al. 2011). However, since 2007, the distribution of forest land area among stocking classes has remained stable (Fig. 18). Only 34 percent of stands are less than fully stocked in New Hampshire as of 2017. A comparison of nonstocked or poorly stocked stands for all live trees (Fig. 18) and growing-stock trees (Fig. 19) in 2017 reveals that the area of such stands is nearly 2.8 times as great for growing-stock trees in New Hampshire (600,000 to 218,000 acres). This indicates that New Hampshire has more than 500,000 acres that are poorly stocked or nonstocked with growing-stock trees, but nearly half of those acres are moderately stocked, fully stocked, or overstocked when noncommercial species and cull trees are included. In New Hampshire 81 percent of forest stands, or about 3.8 million acres, are less than 80 years old (Fig. 20). The distribution of age classes is explored further in the Forest Habitats section starting on p. 77.



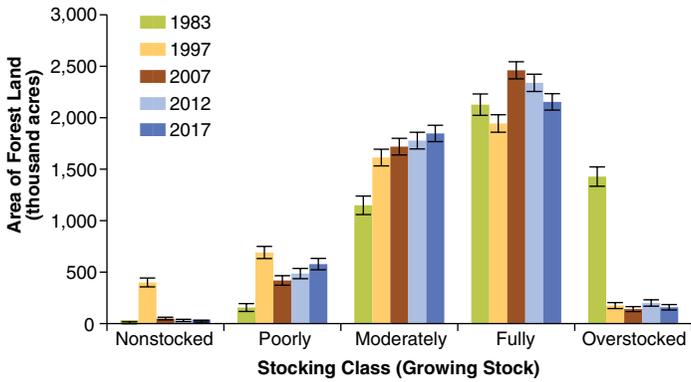
**Figure 16.**—Area of forest land by inventory year and stand-size class, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



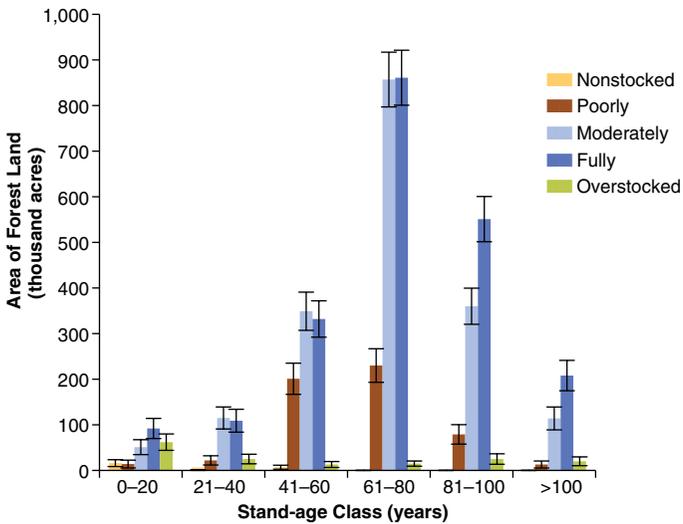
**Figure 17.**—Area of timberland and percentage of total timberland area by stand-size class and inventory year, New Hampshire.



**Figure 18.**—Area of forest land by stocking class of all live trees and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



**Figure 19.**—Area of forest land by stocking class of growing-stock trees and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



**Figure 20.**—Area of forest land by stand-age class and stocking class of growing-stock trees, New Hampshire, 2017. Error bars represent a 68 percent confidence interval around the mean.

## What this means

The trend of increasing forest land area in large diameter stands demonstrates the continuing maturation of New Hampshire forests to stands of larger, older trees. An important component of forest biodiversity is complex structural features. The decline in area of smaller diameter stands is a concern because many wildlife species depend on the habitat provided by young forests. On the other hand, mature stands do contain diverse structures due to gap dynamics and the presence of shade-tolerant species in the understory. The diversity of tree ages and sizes present in mature forests provides a broad range of habitats for wildlife and other organisms and makes forests better able to recover from disturbance.

The shifts in forest area out of nonstocked, poorly stocked, and overstocked stands into moderately and fully stocked stands are consistent with the regional trend of reforestation and maturation following the widespread land clearing that peaked in the late 1800s (Foster et al. 2004). They also suggest that forest management practices over the past three decades may have improved the general stocking condition across New Hampshire. Most of the forest land is well stocked with tree species of commercial importance. From a commercial perspective, continued management of these stands is anticipated to keep them growing optimally by preventing them from becoming overstocked. From an ecological perspective, New Hampshire has a low percentage of “old growth” forests, so consideration may be given to allowing some areas to continue growing beyond commercial benchmarks in order to allow the development of some ecologically mature forests that support certain wildlife species and ecological processes. Although the more than 0.5 million acres of forest land that are poorly stocked or nonstocked with commercially important species represent a loss of potential growth, these forests contribute to biodiversity. However, the higher light levels and open growing conditions in these poorly stocked or nonstocked stands may make them more susceptible to invasion by nonnative plant species (e.g., common barberry [*Berberis vulgaris*]), multiflora rose [*Rosa multiflora*]).

# Number of Trees

## Background

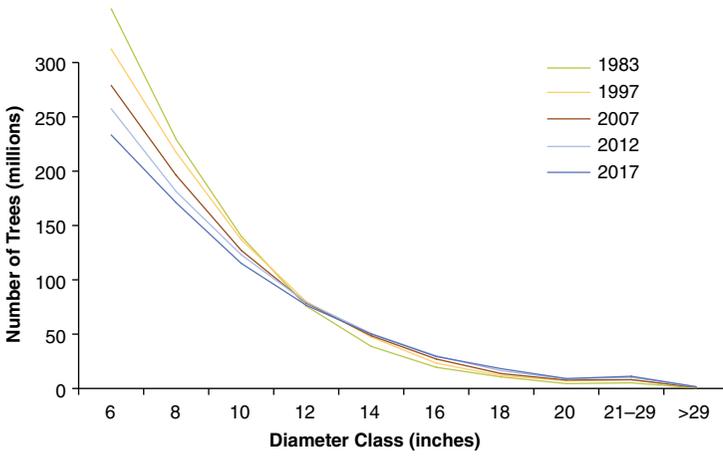
A basic component of forest inventory is the number of trees, an estimate that is easily understood, reliable, and easy to compare with past inventories. When combined with species and size, estimates of number of trees are valuable for showing the structure of forests and changes that are occurring over time. Young forests generally have many more trees per acre than older forests, but older forests usually have much more wood volume (or biomass) than younger forests.

## What we found

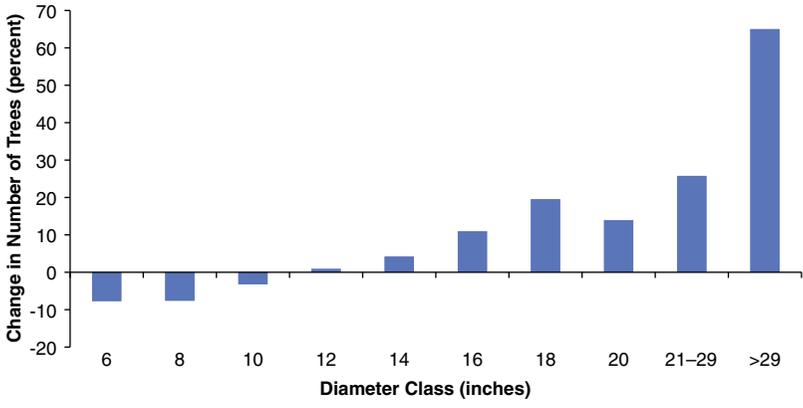
Since 1997, the number of trees in the 12-inch and smaller d.b.h. classes has decreased while the number of trees in the larger classes has increased (Fig. 21). In general, larger diameter classes had higher percentage increases in number of trees than did smaller diameter classes (Fig. 22).

For growing-stock trees with a d.b.h. of 5 inches or larger, the most numerous tree species in New Hampshire continues to be red maple (scientific names for all tree species mentioned in this report are in the appendix). Most of the abundant species in New Hampshire (eastern hemlock, balsam fir, sugar maple, northern red oak, paper birch, yellow birch, and American beech) decreased slightly in overall numbers between 2012 and 2017 while red spruce increased slightly. Red maple, eastern white pine, and paper birch had the largest decreases in number of growing-stock trees by percentage; all three species decreased by more than 10 percent (Fig. 23).

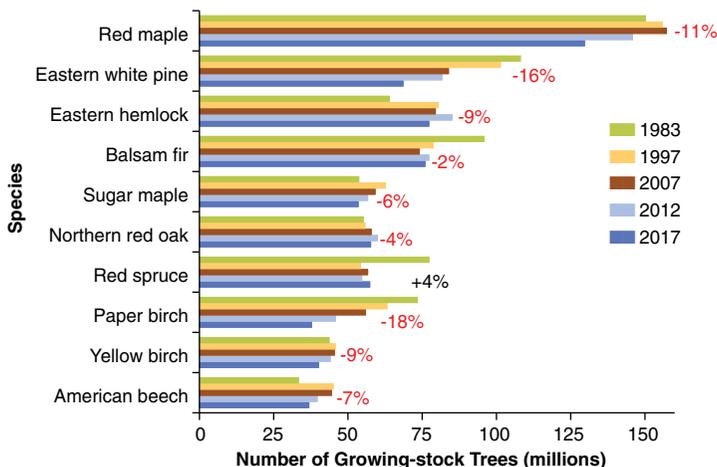
Numbers of sapling-size trees (1 to 4.9 inches d.b.h.) also decreased for some of the abundant tree species in New Hampshire, but paper birch, balsam fir, red spruce, eastern white pine, and American beech saplings increased. All noncommercial species grouped together continue to be the most abundant saplings other than balsam fir and American beech, although their numbers decreased by 7 percent between 2012 and 2017. Balsam fir is the most abundant individual sapling species in New Hampshire, continuing many years of increases. The largest proportional increase in number of saplings was in paper birch (9 percent). Tree species that decreased in number of saplings were red maple, yellow birch, eastern hemlock, sugar maple, and northern red oak (Fig. 24).



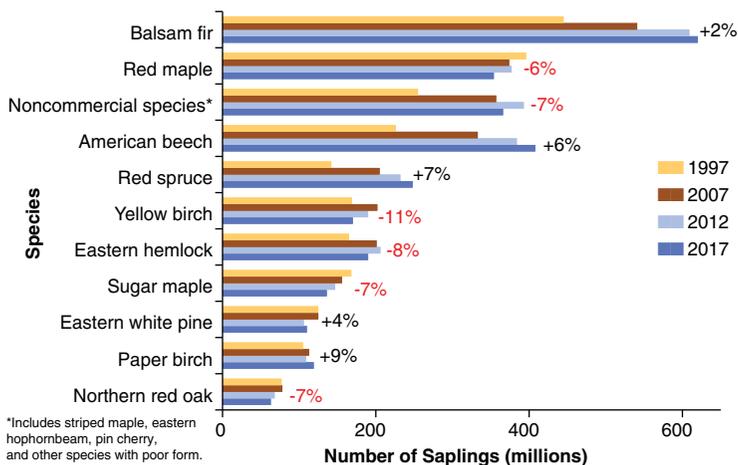
**Figure 21.**—Number of growing-stock trees on timberland by diameter class and inventory year, New Hampshire.



**Figure 22.**—Percent change in the number of growing-stock trees by diameter class, New Hampshire, 2012 to 2017.



**Figure 23.**—Number of growing-stock trees on timberland by species and inventory year, New Hampshire. Percentages indicate change from 2012 to 2017.



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

**Figure 24.**—Number of saplings (1 to 4.9 inches in diameter) on timberland by species and inventory year, New Hampshire. Percentages indicate change from 2012 to 2017.

## What this means

Saplings in today's forest are a prime indicator of the composition of the future forest. Saplings eventually replace large trees that are harvested or killed by insects, diseases, or weather events. The increasing dominance of American beech will have an impact on the future species composition of New Hampshire forests. Similarly, balsam fir is increasing in understory dominance. The high relative sapling abundance of noncommercial species may be a concern for timber management. Projections of future compositional changes are complicated by the potential impacts of climate change on the distributions of different tree species.

# Carbon Stocks

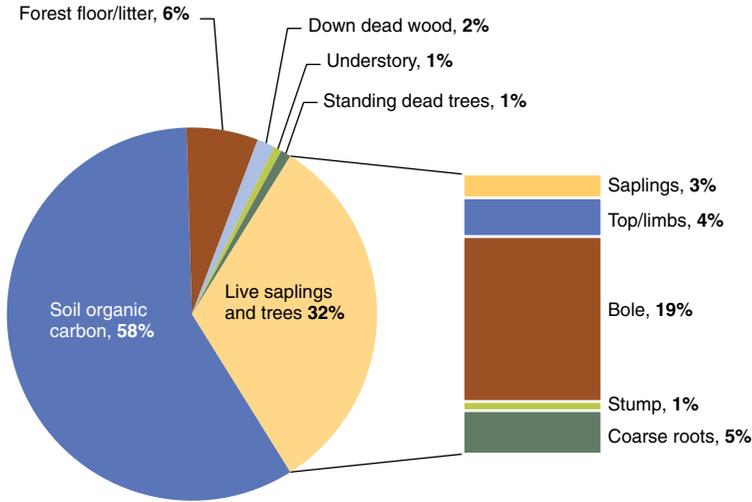
## Background

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 energy-containing organic (carbon) compounds that primarily accumulate in trees as wood; roughly 50 percent of tree biomass is carbon (based on dry weight). Over time, this stored carbon also accumulates in standing dead trees, down woody materials, litter, and forest soils. For most forests, the understory grasses, forbs, and nonvascular plants, as well as animals, represent minor pools of carbon stocks. FIA uses a combination of field measurements and models to estimate forest carbon stocks. Procedures for the estimation of carbon are detailed by the U.S. Environmental Protection Agency (2018).

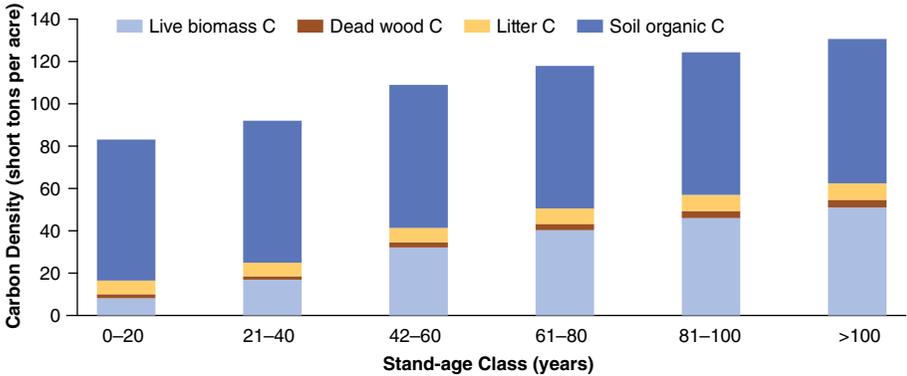
## What we found

Total forest ecosystem carbon stocks in New Hampshire are an estimated 546.8 million short tons. This represents a small decrease of 0.5 percent in total forest carbon stocks since 2012. Soil organic carbon and live trees are the largest pools and combined account for 90 percent of forest carbon (Fig. 25). Most of New Hampshire's forest carbon stocks are in stands between 61 and 100 years old (65 percent of total forest carbon). Considerably less carbon is found in stands younger than 61 years old (26 percent) and older than 100 years (9 percent). As a per acre estimate, average carbon density (short tons per acre) in the live biomass pools (live trees and understory) increases with stand age and net accumulation is greater within live biomass than in the dead wood, litter, and soil pools (Fig. 26). The maple/beech/birch

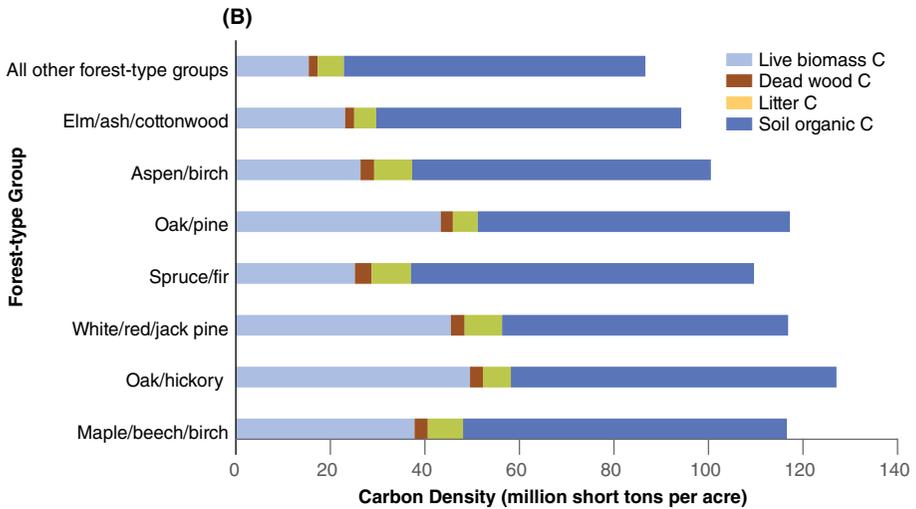
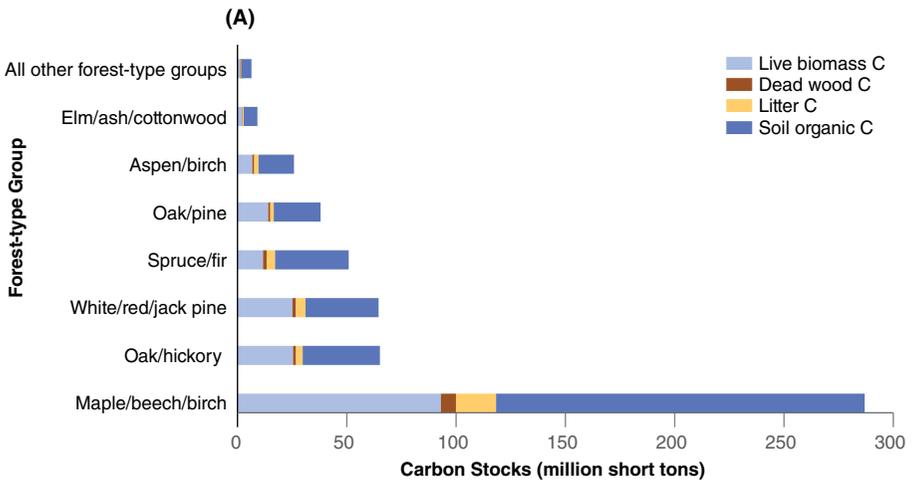
forest-type group contained the majority of total forest carbon (52 percent, or more than 286 million short tons), as it covers a large amount of the forest land (Fig. 27a). On a per acre basis, however, carbon density was highest in the oak/hickory forest-type group (127 short tons per acre), with the oak/pine forest-type group next at 117 short tons per acre (Fig. 27b).



**Figure 25.**—Percentage of carbon stocks on forest land by forest ecosystem component, New Hampshire, 2017.



**Figure 26.**—Aboveground carbon stocks per acre for live biomass, dead wood, and soil components on forest land by stand-age class, New Hampshire, 2017.



**Figure 27.**—(A) Carbon stocks by forest-type group, and (B) carbon stocks per acre by forest-type group, New Hampshire, 2017.

## What this means

Forest carbon stocks in New Hampshire have decreased slightly since 2012, with the main driver being the loss of forest land. Soil organic carbon accounts for the largest loss of carbon when forest is lost to other land uses. Despite the overall decline of forest carbon stocks, carbon in live trees has increased. The live tree carbon pool represents the best opportunity to increase carbon stocks in the future, as this pool can be most affected by forest management. Most forest carbon in New Hampshire is found in moderate-aged stands dominated by relatively long-lived species, suggesting that forest carbon stocks will continue to increase as stands mature and accumulate carbon in aboveground and belowground components. As mitigating U.S. greenhouse gas emissions becomes increasingly important, an understanding of trends in carbon sequestration and storage will be an essential tool for forest managers.

## Biomass

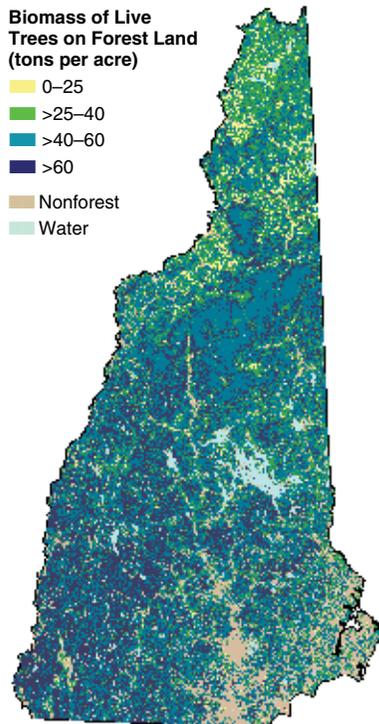
### Background

The increasing interest in carbon dynamics for questions related to carbon sequestration, emissions reduction targets, production of biofuels, and forest fire fuel loadings makes estimates of biomass a critical component of the FIA program. FIA defines aboveground biomass as the weight of live trees composed of the boles, aboveground portion of stumps, tops, and limbs (but excluding foliage). Due to increases in tree volume, New Hampshire forests contribute significantly to carbon sequestration (uptake and storage).

### What we found

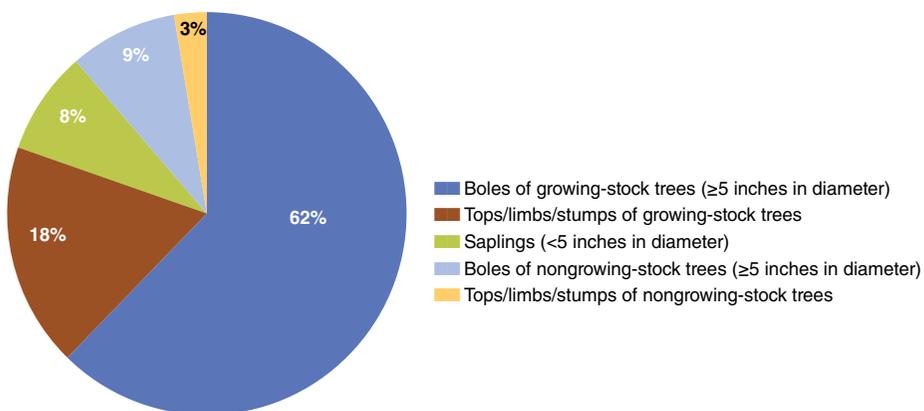
The forest land of New Hampshire has an estimated 291.6 million dry tons of aboveground tree biomass, with biomass per acre averaging 61.5 tons per acre of forest land. The distribution of biomass per acre on forest land is generally highest in southern New Hampshire (Fig. 28). The largest portion of the aboveground biomass is in the boles of growing-stock trees (62 percent), but this is also the part of the tree resource that can be converted into valuable wood products. The other 38 percent of the biomass is in tops, limbs, stumps, cull trees, or trees of noncommercial species (Fig. 29).

Total live dry biomass on timberland in New Hampshire has increased by 32 percent since 1983 (from 148 million to 196 million dry tons), primarily due to the increasing size of sawtimber trees. In contrast, biomass decreased in poletimber-size trees during this time period (Fig. 30).



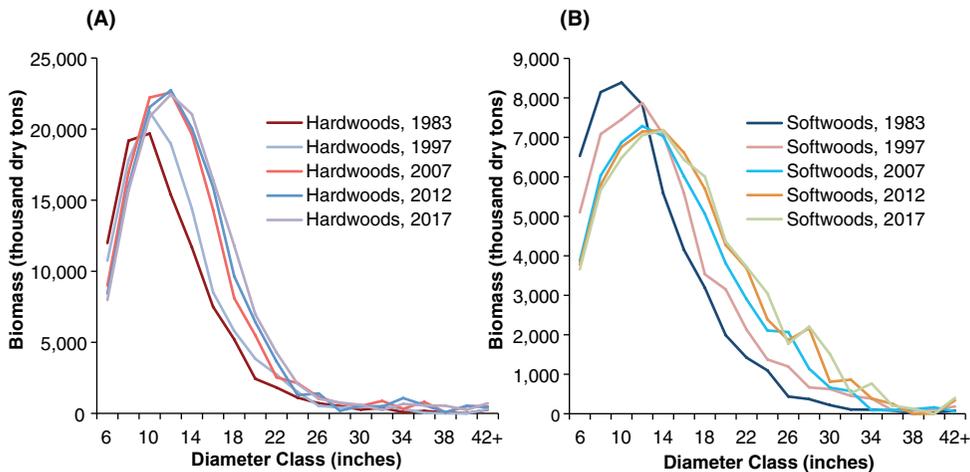
Projection: New Hampshire State Plane, NAD83.  
 Sources: USDA Forest Service, Forest Inventory and Analysis program, 2009; NLCD 2006 (Fry et al. 2011).  
 Geographic base data are provided by the National Atlas of the USA®. FIA data and Tools are available online at <https://www.fia.fs.fed.us/tools-data/>.  
 Cartography: R.S. Morin, USDA Forest Service, February 2019.

**Figure 28.**—Live-tree biomass (dry tons) per acre of trees 1 inch in diameter and larger on forest land, New Hampshire, 2009.



**Total biomass = 291,567,000 dry tons**

**Figure 29.**—Percentage of live-tree biomass (trees 1 inch in diameter and larger) on forest land by aboveground component, New Hampshire, 2017.



**Figure 30.**—Distribution of live-tree biomass (trees 1 inch in diameter and larger) in (A) hardwoods and (B) softwoods on timberland by diameter class and inventory year, New Hampshire.

## What this means

The forests of New Hampshire are continuing to accumulate biomass as they mature. Because most of the biomass is contained in the boles of growing-stock trees and most of the gains in biomass stocks are found in these higher value sawtimber-size trees, only a fraction of the accumulated material is available for use as whole tree chips for large wood fuel users. If the demand for biomass increases with increased demand in heating, power production, and (potentially) the production of liquid fuels, the wood-using market would become more competitive. This creates an opportunity for enhancing forest management practices to benefit both traditional forest products supplies and those for bioenergy. The Biomass Energy Resource Center produced a detailed report on supply and sustainability of available low-grade wood for New England (Biomass Energy Research Center 2019).

Private forest landowners are the holders of the majority of the forest biomass in New Hampshire (71 percent). Thus they play an important role in sustaining this resource. Currently, forest landowners are not financially compensated for the carbon sequestration service provided by the trees on their land. However, the markets for forest carbon sequestration are growing, so this scenario could change in the future. If carbon trading and biomass production become more common, reliable estimates of biomass and carbon in forests, both in the aboveground biomass and in soils, will become more important. The future of this scenario depends on political decisions and prices for energy-producing fuels including crude oil and natural gas.

# Volume of Growing-stock Trees

## Background

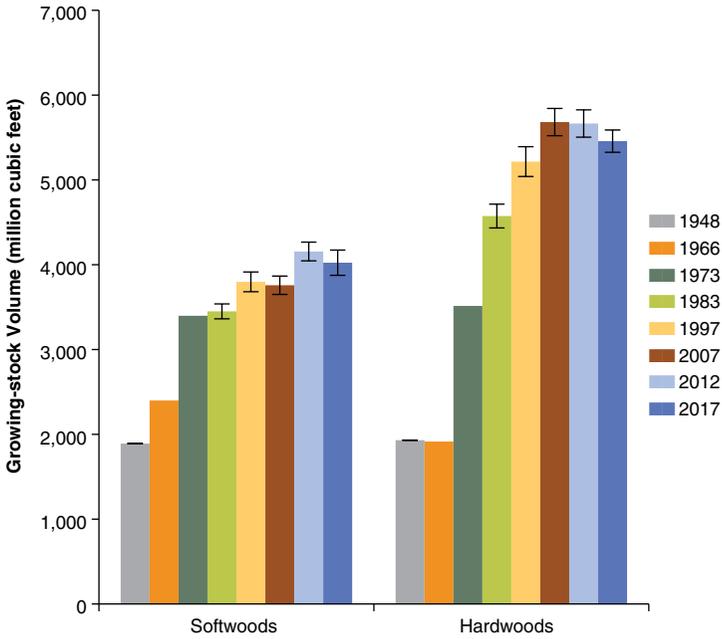
To assess the amount of wood potentially available for commercial products, FIA computes growing-stock volumes for trees growing on timberland that meet requirements for size, straightness, soundness, and species. Growing-stock volume includes only commercial tree species with a d.b.h. of 5 inches or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

## What we found

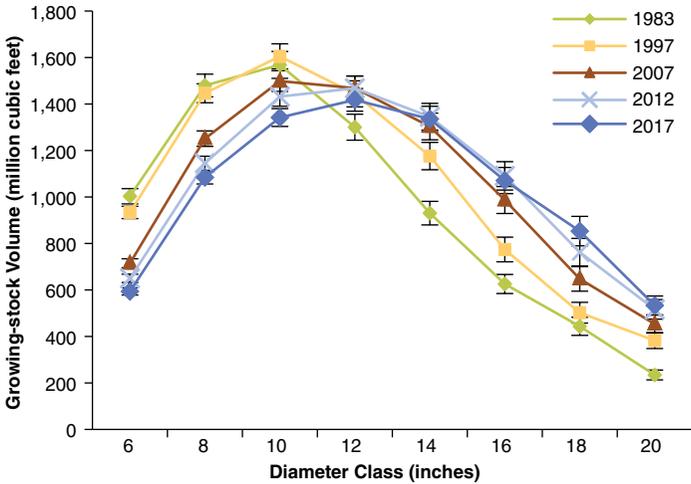
The total growing-stock volume in New Hampshire increased steadily from the 1940s to 2012, but in recent years total growing-stock has begun to decrease. The 2017 estimate of 9.5 billion cubic feet is a substantial increase from the 1983 estimate of 8.0 billion cubic feet but indicates a return almost to 2007 levels (9.4 billion cubic feet) (Fig. 31). The decrease in growing-stock volume between 2012 and 2017 is in contrast to the 1 to 4.5 percent annual increases in previous decades. Distribution of growing-stock volumes by diameter class from the current and four previous inventories reveals a steady shift toward larger diameter trees (Fig. 32). During the most recent inventory (2017), volume increased in the two largest d.b.h. classes but decreased in the diameter classes below 18 inches (Fig. 33).

In general, total volumes are higher in southern New Hampshire than in northern New Hampshire. Volume per acre varies spatially by species (Fig. 34). Sugar maple density is highest in northern New Hampshire. Red maple is distributed throughout the State, with the highest volumes in the southern regions. Eastern white pine, northern red oak, and eastern hemlock are most concentrated in southern New Hampshire.

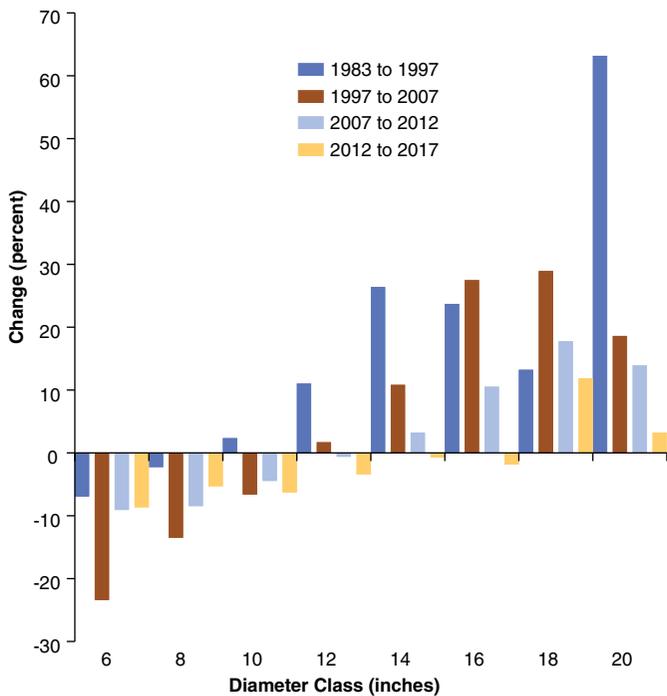
The level of growing-stock volume on timberland in New Hampshire averages over 2,100 cubic feet per acre. Of this volume, 58 percent is in hardwood species and 42 percent is in softwood species. Red maple (25 percent), northern red oak (22 percent), sugar maple (14 percent), and yellow birch (9 percent) make up 70 percent of the hardwood growing-stock volume. Eastern white pine (51 percent), eastern hemlock (24 percent), red spruce (13 percent), and balsam fir (10 percent) account for 98 percent of softwood growing-stock volume (Fig. 35).



**Figure 31.** — Growing-stock volume on timberland by species group and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.

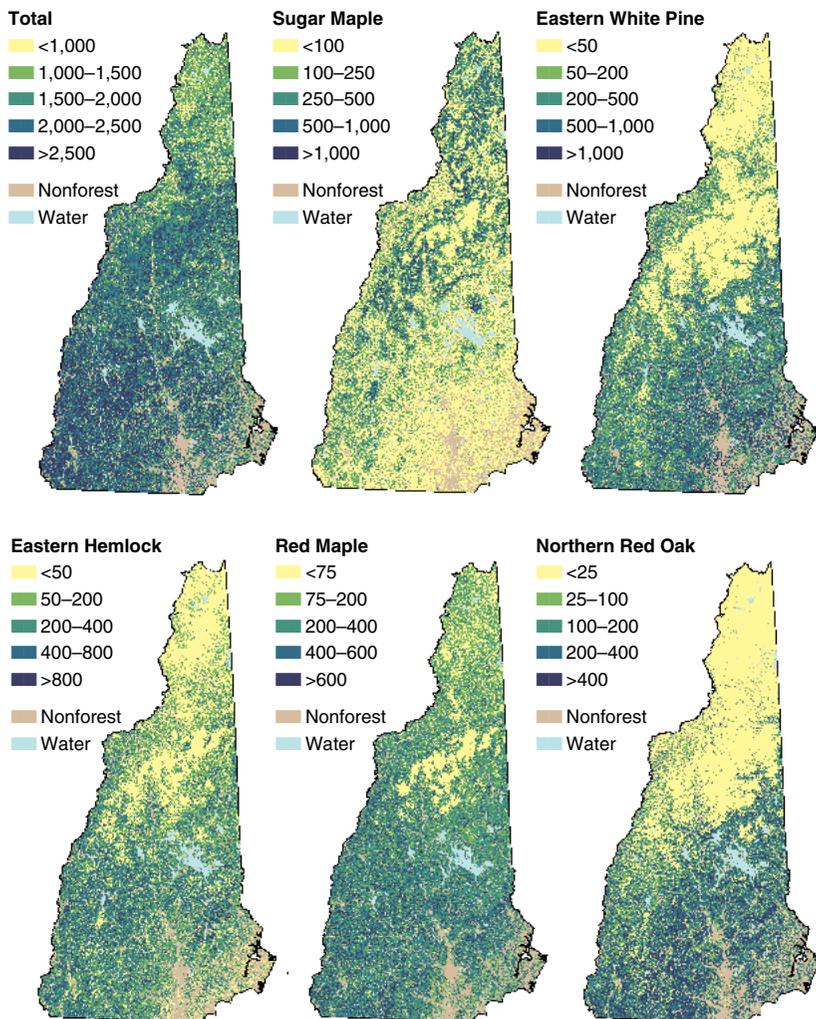


**Figure 32.** — Growing-stock volume on timberland by diameter class (2-inch intervals) and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



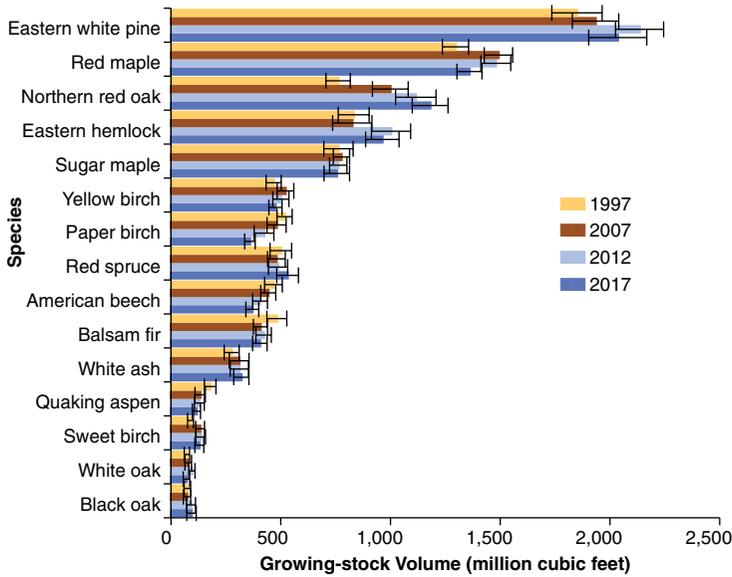
**Figure 33.**—Percent change in growing-stock volume on timberland by diameter class (2-inch intervals) and inventory year, New Hampshire.

## Volume on Forest Land (cubic feet per acre)



Projection: New Hampshire State Plane, NAD83.  
 Sources: USDA Forest Service, Forest Inventory and Analysis program, 2009; NLCD 2006 (Fry et al. 2011).  
 Geographic base data are provided by the National Atlas of the USA®.  
 FIA data and Tools are available online at <https://www.fia.fs.fed.us/tools-data/>.  
 Cartography: R.S. Morin, USDA Forest Service, February 2014.

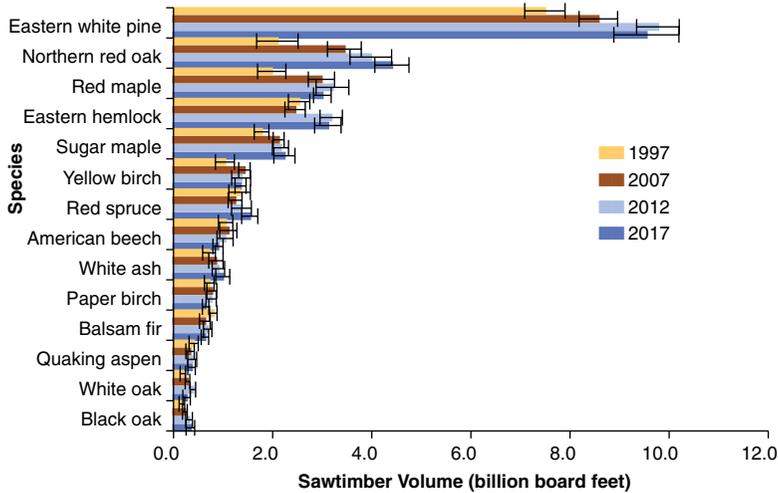
**Figure 34.**—Cubic-foot volume per acre on forest land for major tree species (for trees 5 inches in diameter or larger), New Hampshire, 2009.



**Figure 35.**—Growing-stock volume on timberland by species and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.

Overall, eastern white pine has 50 percent more growing-stock volume than the next most abundant species, red maple, followed by northern red oak, eastern hemlock, and sugar maple. These five species make up 67 percent of the total growing-stock volume in New Hampshire. Species that showed modest increases in growing-stock volume between 2012 and 2017 were northern red oak and red spruce, each of which increased by more than 5 percent. In contrast, paper birch and white oak both decreased by more than 5 percent (Fig. 35).

When board-foot volume is estimated, the order of the four species with the highest volumes is slightly different from the order for growing-stock volume. Eastern white pine remains the leading species by a large margin, but northern red oak replaces red maple as the second highest (Fig. 36). Eastern white pine makes up over 30 percent of the total sawtimber volume in New Hampshire. Red spruce had the largest gain in sawtimber volume between the 2012 and 2017 inventories (12 percent), and white oak showed the largest decrease (33 percent). Total board-foot volume has remained stable since 2012.



**Figure 36.**— Board-foot volume of sawtimber on timberland by species and inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.

## What this means

The total volume of timber resources in New Hampshire has started to decrease for the first time since FIA began doing inventories in the State in 1948. The slight decrease in timberland area along with a slowing rate of increase in total growing-stock volumes has resulted in this reduction in total timber volume, and growth rates may decrease further as the forest ages. Even though the per acre rate of volume increase is leveling off, the forests of New Hampshire are adding value at an increasing rate due to growth that is occurring on the higher valued trees. Landowners and the forest products industry can benefit from the increase in value, but care in management and harvesting practices will be important to ensure a steady supply of desirable species into the future as the population of pole-timber-size trees replaces the sawtimber-size trees.

# Sawtimber Quality

## Background

The value of a tree in the forest products market is determined by its species, size, and quality. High quality timber is generally characterized by a large diameter and the absence of defects such as knots, wounds, and poor form. Timber used in the manufacture of cabinets, furniture, flooring, or other millwork is the most valuable. Lower quality trees are utilized as pallets, pulpwood, or fuelwood. The quality of an individual tree can be influenced by species as well as diameter, growth rate, and management practices. According to FIA standards, hardwood trees must have a d.b.h. of at least 11 inches to qualify as sawtimber. FIA assigns tree grades to sawtimber-size trees as a measure of quality. Tree grade is based on tree diameter and the presence or absence of defects such as knots, decay, and curvature of the bole (sweep and crook). These grades have parallels to log grades used by sawmills, but they are not identical. Quality decreases from grade 1 (high grade lumber) to grade 3. Grade 4 is assigned to material for ties and local use.

## What we found

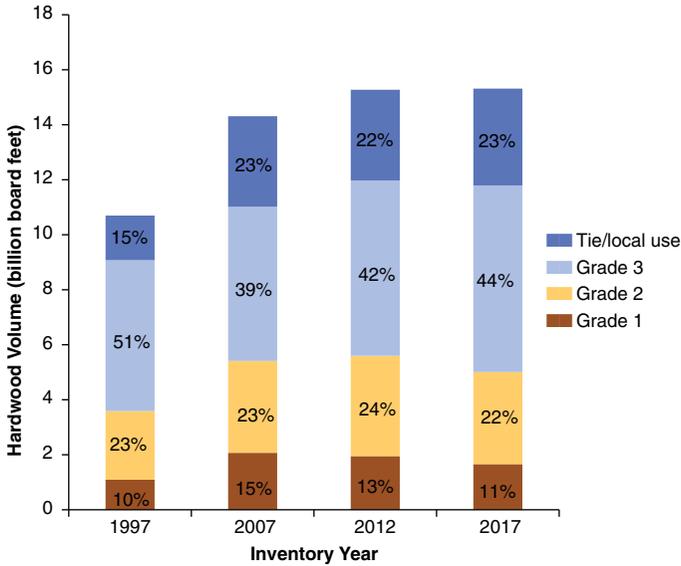
The proportion of hardwood sawtimber volume in the highest quality categories (tree grades 1 and 2) decreased in New Hampshire between 2012 and 2017. There are currently 5 billion board feet in tree grades 1 and 2 in New Hampshire. The proportion of volume in tree grades 3 and tie/local use increased by 3 percent between the two latest inventories (Fig. 37).

Eastern hemlock and red spruce are the only species among those leading by sawtimber volume with more than 50 percent of their volume in tree grades 1 and 2. Northern red oak, sugar maple, and white ash have at least 30 percent of their sawtimber volume in grades 1 and 2. In contrast, red maple has less than 20 percent and American beech has less than 1 percent of their sawtimber volume in grades 1 and 2 (Fig. 38).

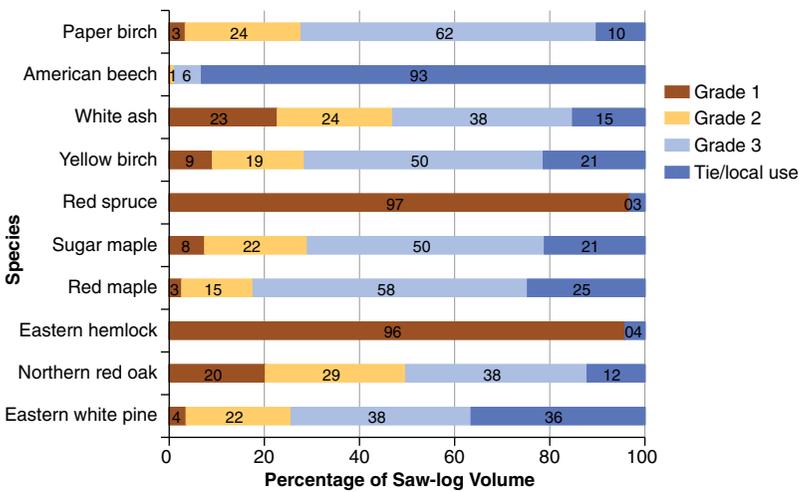
## What this means

The quality and total volume of saw logs in New Hampshire have declined slightly since the last inventory, and board-foot volume has started to decrease for many species. Changes in species composition point toward continued reductions in tree quality into the future. Many beech trees contain cankers and large amounts of rotten wood due to the impacts of beech bark disease, an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga*) and the exotic canker fungus *Neonectria*

*coccinea* var. *faginata* or the native *Neonectria galligena*. Red maple typically has more defects than other species. The species with the highest proportion of low-grade volume, American beech, is also the most abundant hardwood sapling species in the State. Red maple has the second highest proportion of low-grade volume and is also a relatively low value species.



**Figure 37.**—Hardwood volume by inventory year and tree grade, New Hampshire. Percentages of total volume for each grade are also indicated by inventory year. Percentages may not add to 100 because of rounding.



**Figure 38.**—Percentage of saw-log volume on timberland by species and tree grade, New Hampshire, 2017.

# Average Annual Net Growth and Removals

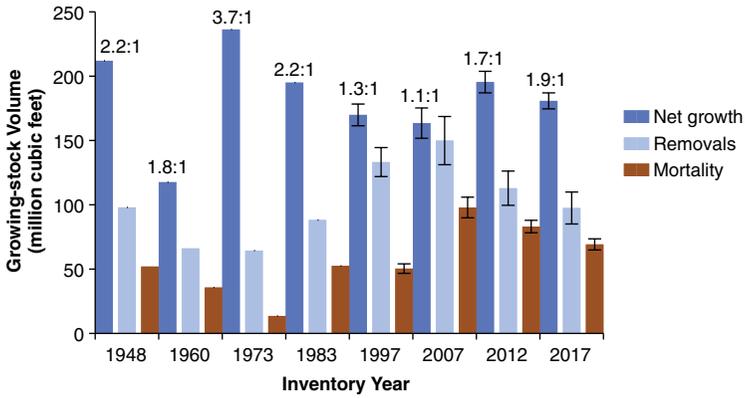
## Background

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. Net growth is negative when mortality exceeds gross growth. A useful measure to assess growth is the ratio of annual net growth to current 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.

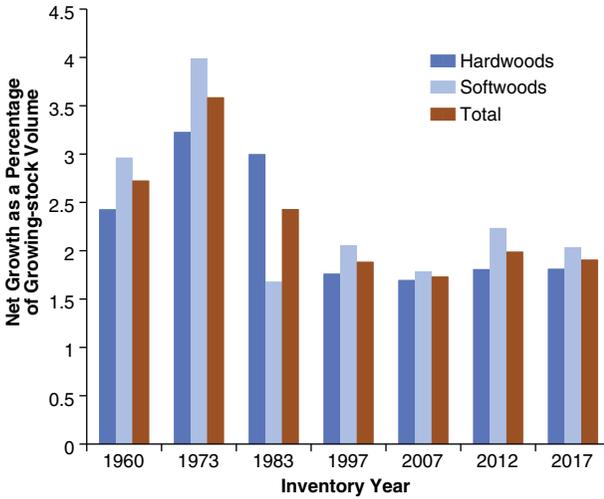
## What we found

Since 2012, average annual net growth has decreased in New Hampshire (Fig. 39). Net growth of growing-stock trees averaged 181 million cubic feet annually as of 2017, about 2 percent of growing-stock volume on timberland. In comparison to previous inventories, annual net growth as a percentage of growing-stock volume has been generally decreasing from 1973 to 2017 (Fig. 40). In 2017, about 55 percent of annual net growth was in hardwoods and 81 percent was on privately owned land.

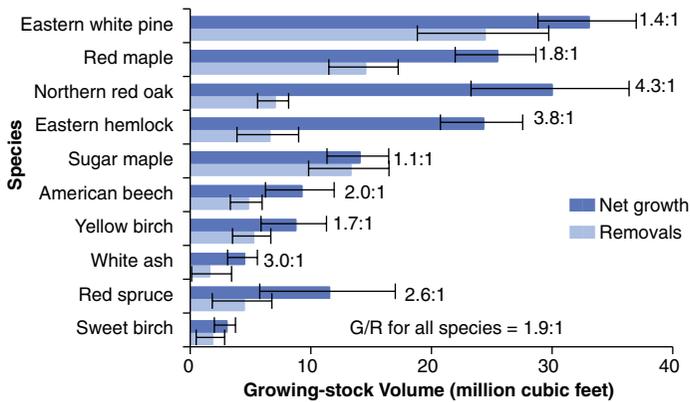
The nine species with the greatest growing-stock volume accounted for 85 percent of the average annual net growth of growing stock on timberland as of 2017. The ratio of net growth to removals averaged 1.9:1.0, which is a small increase from what was reported for 2012 (1.7:1.0). Variation between species was considerable. Net growth exceeded removals for all major species (Fig. 41). Northern red oak, eastern hemlock, and white ash had the highest growth-to-removals ratios at 4.3:1.0, 3.8:1.0, and 3.0:1.0, respectively. The largest positive changes in growth-to-removals ratios between 2012 and 2017 were in white ash (from 1.3 to 3.0) and red spruce (from 1.0 to 2.6). In contrast, changes in the growth-to-removals ratio for American beech (from 2.7 to 2.0) and eastern white pine (from 1.8 to 1.4) were negative (Morin et al. 2015a).



**Figure 39.**—Growing-stock volume and growth-to-removals ratio of growing stock on timberland by inventory year and growth category, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



**Figure 40.**—Average annual net growth of growing stock on timberland as a percentage of growing-stock volume, by inventory year and forest type, New Hampshire.



**Figure 41.**—Average annual net growth, average annual removals, and growth-to-removals ratio (G/R) of growing-stock trees for major species on timberland, New Hampshire, 2017. Error bars represent a 68 percent confidence interval around the mean.

## What this means

The well-stocked stands in the current forests of New Hampshire developed as a result of the growth-to-removals ratios being well above 1.0:1.0 for most of the second half of the 20th century. More recently, the forests of New Hampshire have matured and the rate of growth has slowed (Fig. 39). At the current rates of growth, mortality, and removals, the forests of New Hampshire are increasing in volume at a rate of roughly 2 percent per year. This rate is higher on private lands, most likely due to a larger proportion of public lands being located on high elevation, low productivity sites. Fortunately, more than 95 percent of the removals volume is 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 low growth-to-removals ratio of sugar maple (1.1:1.0) suggests that this species could be decreasing in abundance. In contrast, red spruce is among the species with the highest number of saplings and appears to be increasing in numbers.

## Average Annual Mortality

### Background

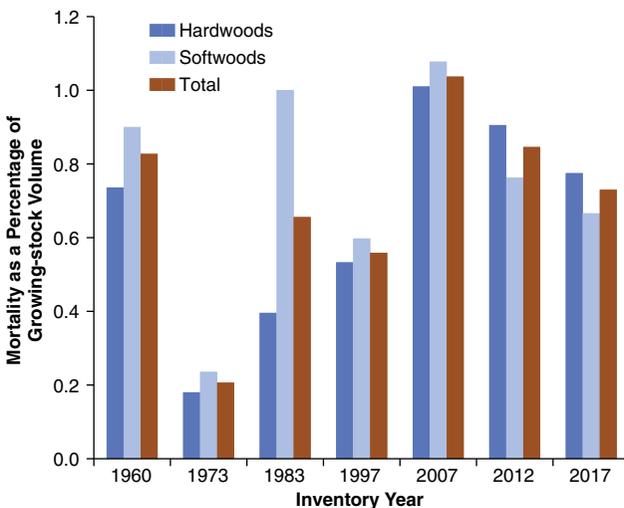
Mortality is a natural part of stand development in healthy forest ecosystems. Many factors contribute to mortality, including competition, succession, insects, disease, fire, human activity, and drought. Mortality is often initiated by one causal agent (inciting factor) that is followed by other contributing 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. Biotic and abiotic disturbances can stress forests either as inciting factors or as contributors to mortality.

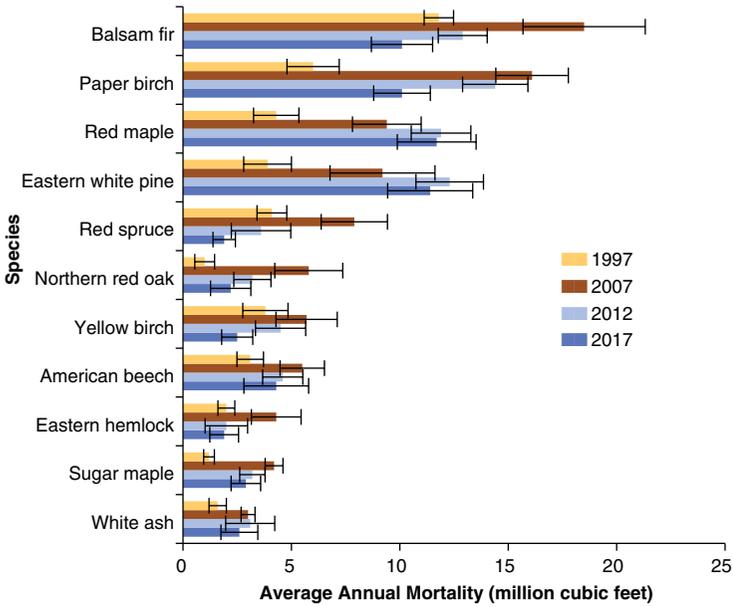
## What we found

The estimated average annual mortality for growing-stock trees in New Hampshire for 2017 was 69 million cubic feet, which is approximately 0.7 percent of growing-stock volume. This is a small decrease compared to the rates reported for 2007 and 2012. In most inventory periods, softwoods have a higher mortality rate than hardwoods, but since 2012, the hardwood mortality rate has been higher (Fig. 42). The mortality rates are similar to other states in the region, such as Maine (1.0 percent) (McCaskill et al. 2011) and New York (1.1 percent) (Widmann et al. 2015).

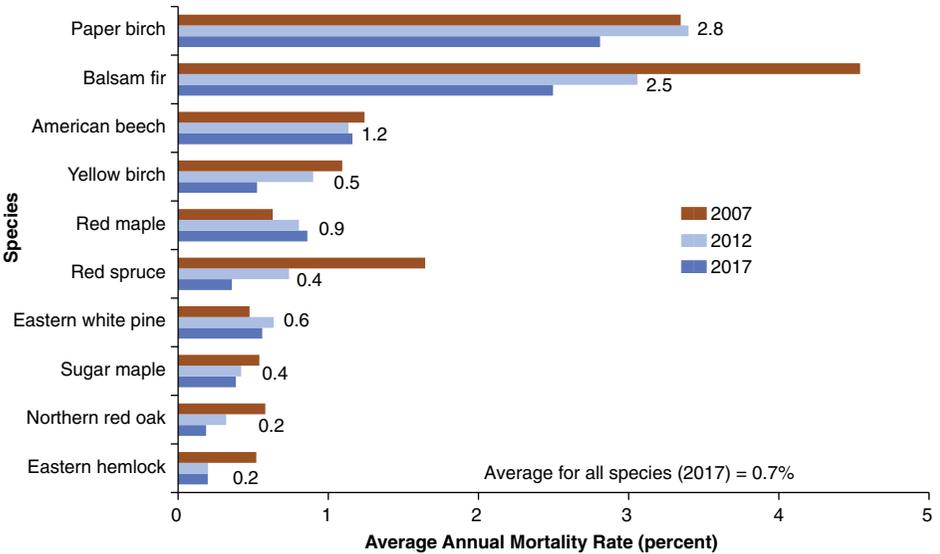
Mortality decreased across nearly all species between 2012 and 2017 in New Hampshire, but the decreases were generally not statistically significant (Fig. 43). Most of the abundant species in New Hampshire have relatively low mortality rates that are below the 0.7 percent annual average for all tree species combined. In contrast, balsam fir and paper birch have mortality rates that are more than triple the statewide average (Fig. 44).



**Figure 42.**—Average annual mortality of growing stock on timberland as a percentage of growing-stock volume, by inventory year and forest type, New Hampshire.



**Figure 43.**—Average annual mortality of growing stock on timberland for major species by inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean.



**Figure 44.**—Average annual mortality rate for major species by inventory year, New Hampshire. Labeled values are for 2017.

## What this means

Tree mortality rates in New Hampshire are comparable to those in surrounding states. Some of the mortality can be explained by stand dynamics (e.g., competition and succession) and the impacts of insects and diseases that affect specific species (e.g., beech bark disease on American beech). In the normal maturation process, some trees lose vigor and eventually die from being outcompeted or succumb to insects and disease during their weakened state; this is especially apparent in trees with a d.b.h. of 12 inches or less.

Most species in New Hampshire have low mortality rates, but some have elevated rates. Species such as balsam fir and paper birch have increased in overall mortality rates. American beech has been heavily impacted by beech bark disease for many decades and is now showing reductions in mortality (see “Beech Bark Disease” starting on p. 66). Weather-related events that affected tree health during this time include the after-effects of the 1998 ice storm and droughts during 1999 and 2001. Recovery from the ice storm was particularly poor for beech and paper birch trees. Drought effects were especially severe for species with shallow root systems such as birch and beech, or for species that typically grow on sites with shallow soils such as balsam fir and red spruce. Additional health problems were observed from forest tent caterpillar (*Malacosoma disstris*) defoliation, spruce winter injury, and balsam woolly adelgid (*Adelges piceae*). Recovery after stress events often depends on soil fertility; trees growing on calcium-rich sites are more likely to recover (Schaberg et al. 2006, Shortle and Smith 1988).

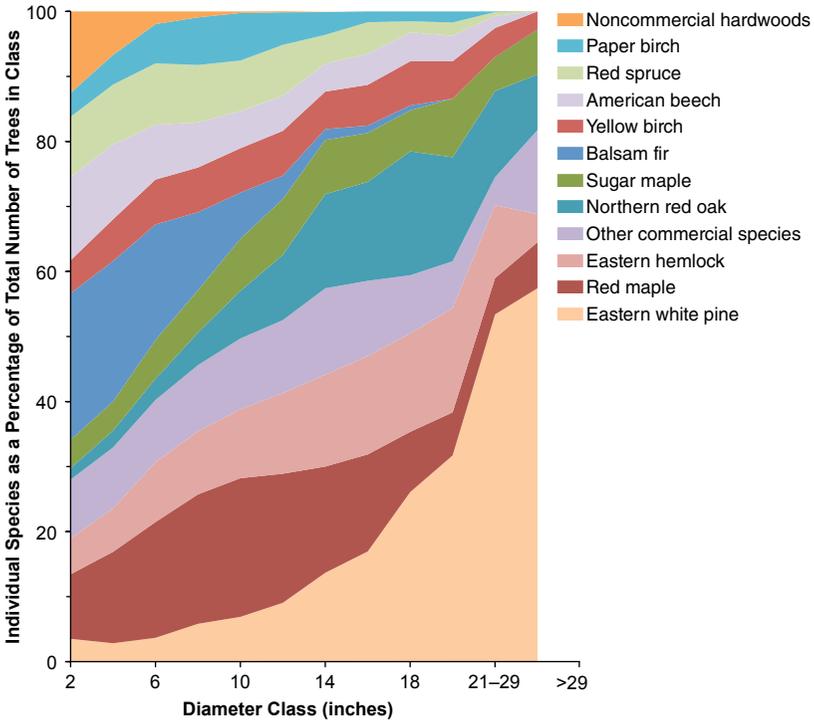
## Species Composition

### Background

The species composition of a forest is the result of the interaction over time of multiple factors, such as climate, soils, disturbance, and competition among tree species. Causes of forest disturbance in New Hampshire include ice storms, logging, droughts, insects and diseases, and land clearing followed by abandonment. The species composition of the growing-stock volume and large diameter trees represents today’s forest, while the species composition of the smaller diameter classes represents the potential future forest. Comparisons of species composition by diameter class can provide insights into potential changes in future overstory species composition.

## What we found

In New Hampshire, balsam fir is the most numerous sapling species on forest land, accounting for 22 percent of all saplings (trees 1 to 4.9 inches d.b.h.), followed by American beech (13 percent) and red maple (11 percent) (Fig. 45). Noncommercial tree species combined also represent a large portion of saplings at 9 percent, which is an increase of 2 percentage points since the 2012 inventory (Morin et al. 2015a). Striped maple is the most numerous of the noncommercial species, followed by pin cherry and eastern hophornbeam. Eastern white pine is the dominant species in all diameter classes 16 inches d.b.h. and larger, but it is poorly represented in the sapling classes (less than 5 percent). Other species that have a lower representation in the sapling classes compared to the larger diameter classes include eastern hemlock and sugar maple. In contrast, American beech, balsam fir, and red spruce make up a higher proportion of total saplings relative to their share of larger trees (Fig. 45).

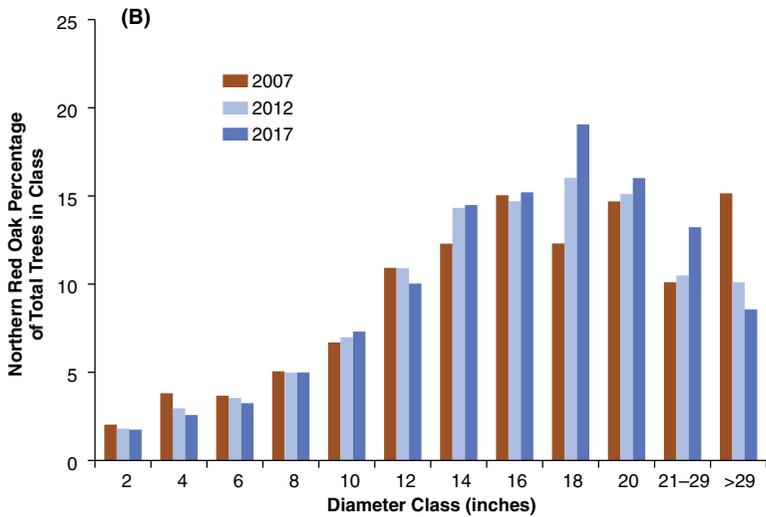
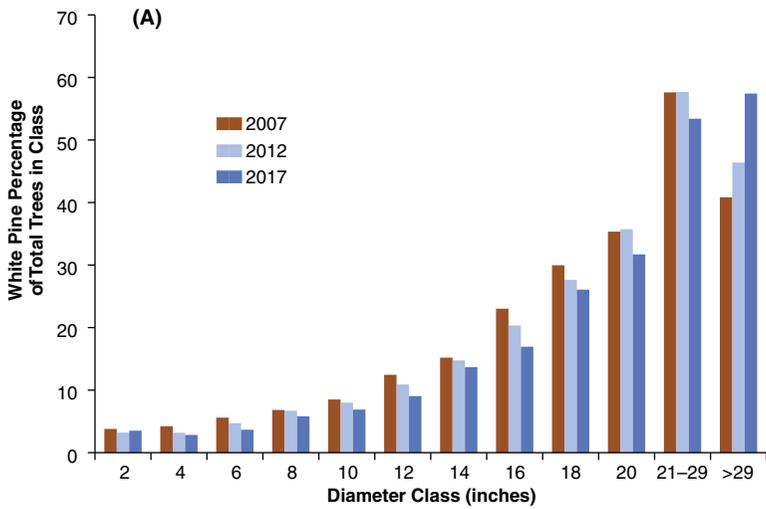


**Figure 45.**—Species composition by diameter class on forest land, New Hampshire, 2017.

## What this means

Conditions in the understory of older forests favor the reproduction of shade-tolerant species, as shown by the higher proportion of American beech, balsam fir, and red spruce in the sapling diameter classes compared to the larger diameter classes. However, sugar maple is a shade-tolerant species that is noticeably absent from this list. Besides being shade-tolerant, American beech saplings may be present in large numbers as the result of root sprouts following harvesting and beech bark disease. Many of these young beech trees will eventually succumb to the disease before they have the opportunity to grow into the overstory, while occupying valuable growing space and inhibiting the regeneration and growth of more valuable species. In contrast, eastern hemlock, another shade-tolerant species, makes up a lower percentage of tree numbers in the sapling diameter classes when compared to the larger diameter trees. This indicates that hemlock is not regenerating as well as expected in the maturing forests of New Hampshire. Noncommercial species provide habitat diversity in the understory, but they can interfere with the reproduction of commercial species if they become too numerous. Striped maple now makes up 7 percent of trees in the 2-inch diameter class. Similarly, the dominance of beech in regenerating stands may be interfering with desirable species such as sugar maple (Hane 2003). Land managers should be aware of the potential for these species to cause problems in forest regeneration.

Eastern white pine and northern red oak are well represented in the large diameter classes, ranking first and second statewide in sawtimber volume in New Hampshire (Fig. 36). However, both generally continue to decrease as a percentage of total number of trees in all but the largest diameter classes (Fig. 46), so they are likely to be replaced by other species as the larger eastern white pine and northern red oak trees die or are harvested. Red maple and balsam fir represent large proportions of trees in medium-size diameter classes (4 to 14 inches for red maple and 2 to 8 inches for balsam fir). Those two species are positioned to increase in dominance in New Hampshire forests in future decades. Trends in volume show that since the 1960s, eastern hemlock and northern red oak have increased in the proportion of total volume they represent in New Hampshire, but increases in those species are likely to slow and reverse because they are not as well represented in the sapling-size class as they are in larger trees. If the current species composition remains constant as saplings mature, these data foretell a future forest overstory with more red maple, red spruce, and balsam fir trees and less eastern white pine, eastern hemlock, sugar maple, and northern red oak than today. Silvicultural efforts will need to be made to regenerate some species, particularly eastern white pine, eastern hemlock, and northern red oak. Long-term changes in forest composition will alter wildlife habitats and affect the value of the forest for timber products. Close examination of species composition changes in the future will be necessary to evaluate the potential impacts of climate change on individual species.



**Figure 46.**—Percentage of the total number of trees on forest land that are (A) eastern white pine and (B) northern red oak by diameter class and inventory year, New Hampshire, 2017.

# Ecosystem Indicators and Services



View of the White Mountains from the summit of Mount Washington. Photo by Randall Morin, USDA Forest Service.

# Tree Crown Health and Damage

## Background

The crown condition of trees is influenced by various biotic and abiotic stressors. Biotic stressors include native or introduced insects, diseases, invasive plant species, and animals. Abiotic stressors include drought, flooding, cold temperatures or freeze injury, nutrient deficiencies, the physical properties of soils that affect moisture and aeration, and toxic pollutants. New Hampshire forests have suffered from the impacts of well-known exotic and invasive agents such as European gypsy moth (*Lymantria dispar*), hemlock woolly adelgid (*Adelges tsugae*), and the beech bark disease complex for many decades. A more recent invasion includes emerald ash borer (*Agrilus planipennis*).

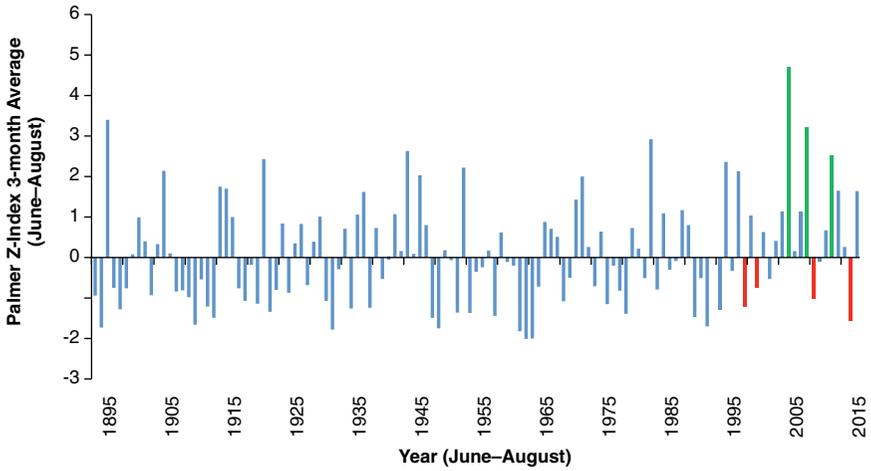
Seasonal or prolonged drought periods have long been a significant and historical stressor in New Hampshire. Over the past 20 years, droughts have occurred in some regions during 1999, 2001, 2010, and 2016; conversely, some of the wettest years on record were 2006, 2009, and 2013 (Fig. 47) (National Centers for Environmental Information 2019). These extreme precipitation events can produce conditions that facilitate outbreaks of insects or disease (or both) and can be even more devastating to trees that are already stressed by pest damage or other agents. The risk of catastrophic economic and ecological loss of forest resources could increase due to forest maturity and more extreme weather-related events, including hurricanes, droughts, and floods caused by a changing climatic regime.

Tree-level crown dieback data are collected on P2+ plots. Crown dieback, defined as recent mortality of branches with fine twigs, reflects the severity of recent stresses on a tree. A crown is labeled as “poor” if crown dieback is more than 20 percent. This threshold is based on findings by Steinman (2000) that associate crown ratings with tree mortality. Additionally, crown dieback has been shown to be highly correlated with tree survival (Morin et al. 2015b).

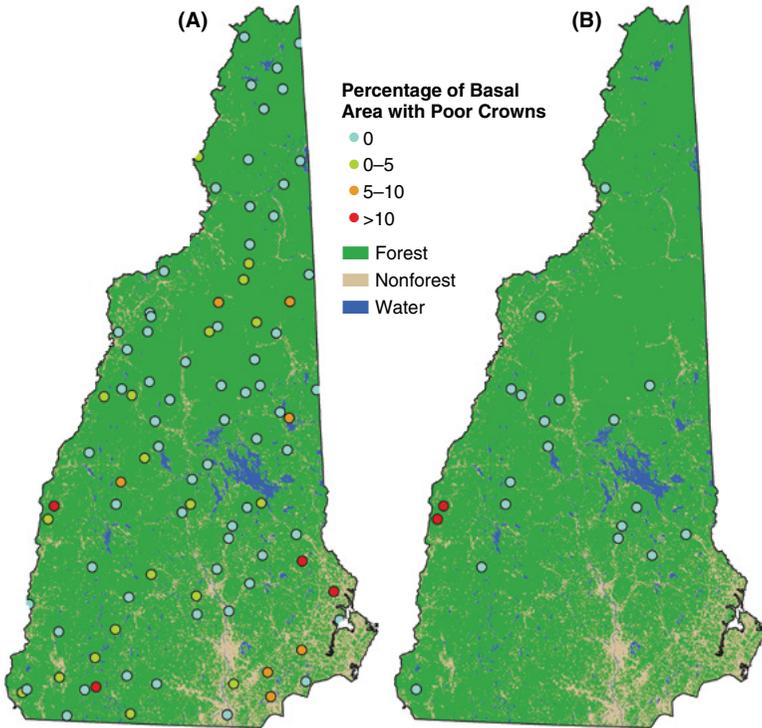
Tree damage is assessed for all trees with a d.b.h. of 5.0 inches or greater. Up to three of the following types of damage can be recorded: insect damage, cankers, decay, fire, animal damage, weather, and logging damage. If more than three types of damage are observed, decisions about which three are recorded are based on the relative impact on the tree (USDA Forest Service 2016).

## What we found

The incidence of poor crown condition is concentrated in southern New Hampshire (Fig. 48) and is particularly prevalent among ash species. The species with the highest proportion of live basal area containing poor crowns is white ash at 6 percent.



**Figure 47.**—Palmer Z-Index 3-month average (June–August), New Hampshire, by year. Recent dry years are shown in red, and recent wet years are shown in green.



Projection: New Hampshire State Plane, NAD83.  
 Sources: USDA Forest Service, Forest Inventory and Analysis program, 2017; NLCD 2006 (Fry et al. 2011).  
 Geographic base data are provided by the National Atlas of the USA®.  
 FIA data and Tools are available online at <https://www.fia.fs.fed.us/tools-data/>.  
 Cartography: R.S. Morin, USDA Forest Service, May 2019.

**Figure 48.**—Percentage of live basal area with poor crowns for (A) all species and (B) ash species on inventory plots, New Hampshire, 2017. Depicted plot locations are approximate.

Conversely, other species have very low occurrence of poor crowns (Table 1). Additionally, the proportion of basal area with poor crowns has changed by less than 2 percent for all species except white ash since 2012, and the proportion of basal area with poor crowns has dropped substantially for American beech since 2007 (Table 1).

Average crown dieback ranged from less than 1 percent for the important softwood species to 5 percent for paper birch (Table 2) and did not vary substantially over time for any species. The proportion of the trees that die increases with increasing crown dieback, except for the highest category of crown dieback. Fifteen percent of trees with crown dieback between 11 and 20 percent during the 2012 inventory were dead when visited again during the 2017 inventory (Fig. 49).

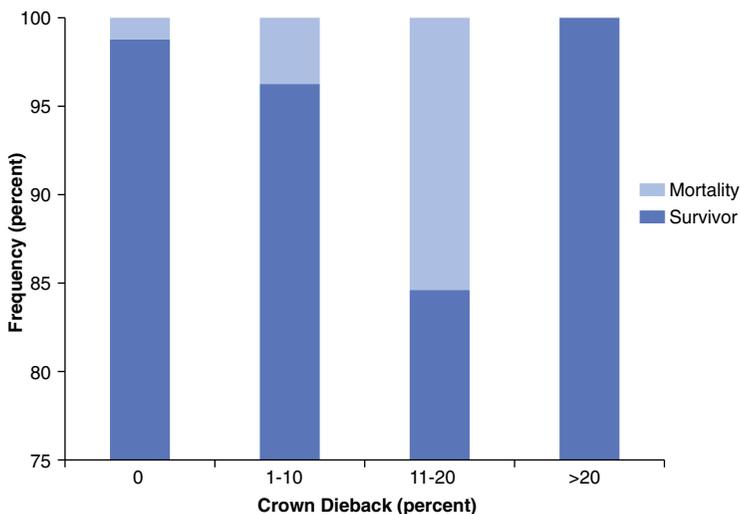
Damage was recorded on approximately 25 percent of the trees in New Hampshire, but there was considerable variation between species (Fig. 50). The most frequent damage recorded for all species was decay (present in 11 percent of trees), ranging from less than 4 percent on softwood species to 23 percent on American beech and red maple. Notably, cankers were present on 86 percent of American beech trees, 35 percent of white pine trees suffered branch or shoot damage from insects, and 17 percent of sugar maple trees showed signs of damage from bole borers. The high incidence of white pine damage is due to the accumulation of deformed stems caused by the native white pine weevil, *Pissodes strobe*, which typically causes stem deformities. The occurrence of all other injury types was below 10 percent.

**Table 1.**—Percentage of live basal area with poor crowns by inventory year, New Hampshire

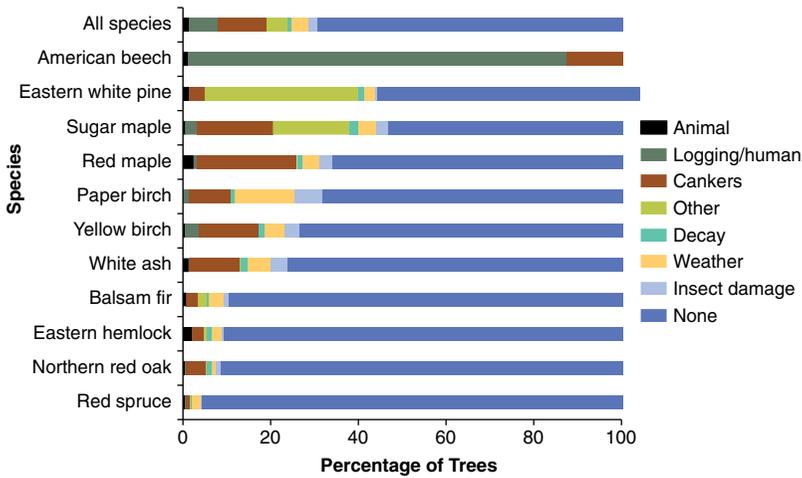
Species	Percentage of basal area with poor crowns		
	2007	2012	2017
Balsam fir	5.2	0.0	1.0
Red spruce	9.7	0.0	0.3
Eastern white pine	0.3	1.0	0.4
Eastern hemlock	0.3	0.0	0.0
Red maple	7.8	2.9	3.2
Sugar maple	3.1	0.1	0.2
Yellow birch	2.2	0.0	0.8
Paper birch	5.4	3.1	3.4
American beech	6.2	4.1	2.6
White ash	1.2	2.7	6.2
Northern red oak	0.0	0.0	1.5

**Table 2.**—Mean crown dieback and other statistics for live trees ( $\geq 5$  inches in diameter) on forest land by species, New Hampshire, 2017

Species	Trees sampled	Mean	SE	Minimum	Median	Maximum
	number	-----percent-----				
Paper birch	176	5.0	1.0	0	0	99
White ash	89	4.7	1.7	0	0	99
Red maple	468	3.4	0.4	0	0	99
Northern red oak	243	3.3	0.3	0	0	30
American beech	231	2.9	0.4	0	0	65
Sugar maple	225	1.6	0.2	0	0	20
Yellow birch	220	1.4	0.2	0	0	20
Eastern white pine	195	1.1	0.3	0	0	40
Balsam fir	274	0.5	0.2	0	0	45
Red spruce	238	0.4	0.3	0	0	65
Eastern white pine	318	0.4	0.1	0	0	15



**Figure 49.**—Crown dieback distribution by tree survivorship for remeasured trees, New Hampshire, 2012 to 2017.



**Figure 50.**—Percentage of trees with damage, by species, New Hampshire, 2017.

## What this means

Ash is a minor component in most forests across New Hampshire, but it is important for biodiversity due to its value as a food source for many insect, bird, and small mammal species. The mortality rate of white ash has increased in New Hampshire since 1997, but the rate is still low (Fig. 43). The relatively unhealthy crowns of ash sampled may reflect the impact of ash yellows (Morin and Lombard 2013). An additional concern for the health of ash trees is the emerald ash borer (EAB; *Agrilus planipennis*), which was discovered in southern New Hampshire in 2016 (see “Emerald Ash Borer” starting on p. 68).

American beech contains a substantial volume of wood in New Hampshire and makes up a large component of seedlings and saplings in the understory. It is an important species due to its value to wildlife and as a pulpwood and firewood species. American beech mortality decreased slightly between the 2007 and 2017 inventories. The decrease in mortality and occurrence of poor crowns is likely to be related to the reduction in impacts from beech bark disease (BBD) as more stands move into the aftermath phase of the disease (see “Beech Bark Disease” starting on p. 66).

Decay is the most commonly observed damage, which is not unusual given that mature trees dominate most New Hampshire forests. Frequent tree damage (25 percent of trees) and internal decay on 11 percent of trees in New Hampshire may be an indication of reduced tree health and timber quality. The high frequency of cankers on American beech is due to the long history of BBD in the region. Although

weevil damage on white pine is common, it does not typically kill trees, but the form and quality of saw logs are impacted. Finally, the native sugar maple borer, *Glycobius speciosus*, is a common pest of sugar maple that is the likely cause of bole borer damage. Infestations can lead to lumber defect caused by discoloration, decay, and larval galleries and may make trees more susceptible to breakage during storms.

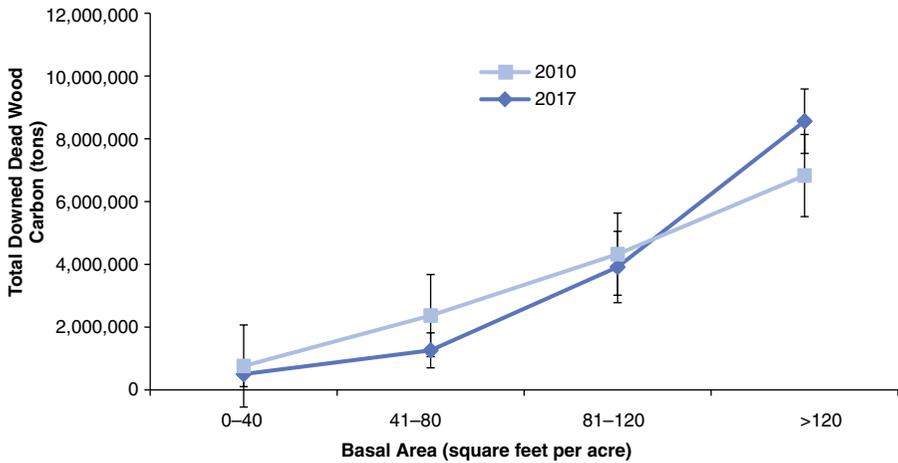
## Down Woody Materials

### Background

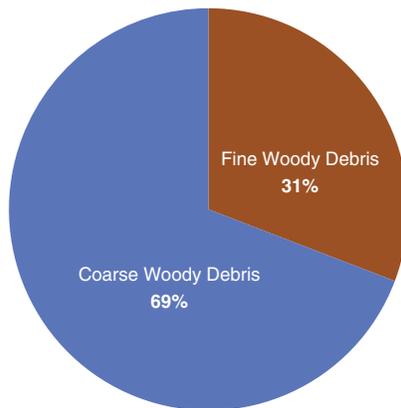
Down woody materials, in the various forms of fallen trees and shed branches, play a critical role in the forests of New Hampshire. Down woody materials provide valuable wildlife habitat, seedling browse protection, stand structural diversity, and a store of carbon and biomass. These materials also contribute to forest fire hazards via surface woody fuels.

### What we found

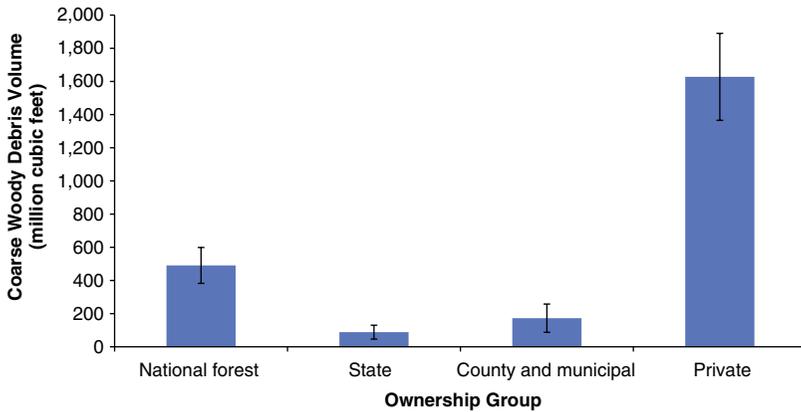
The total carbon stored in down woody materials (fine and coarse woody debris and residue piles) on New Hampshire forest land exceeded 13 million tons in 2017, which is roughly equivalent to the 2010 estimate. Downed woody debris carbon was positively related to the amount of live tree basal area; forests with more than 120 square feet per acre of basal area had the highest amounts of downed dead wood carbon (about 8.6 million tons) (Fig. 51). The downed dead wood biomass within New Hampshire forests is dominated by coarse woody debris (Fig. 52) at approximately 19 million tons with fine woody debris representing 31 percent of statewide totals. No piles of coarse woody debris (i.e., harvest residue piles) were sampled during this current inventory. The total volume of coarse woody debris in 2017 was highest in the private ownership category, at approximately 1.6 billion cubic feet in New Hampshire forests (Fig. 53). The White Mountain National Forest had the second largest total volume of coarse woody debris (490 million cubic feet).



**Figure 51.**—Total carbon (short tons) and associated sampling errors in down woody materials (fine and coarse woody debris and piles) by live-tree basal area class on forest land, New Hampshire, 2006 to 2010 and 2012 to 2017. Error bars represent a 68 percent confidence interval around the mean.



**Figure 52.**—Proportion of down woody material biomass by dead wood component (fine and coarse woody debris) on forest land, New Hampshire, 2017. No residue piles were sampled, 2012 to 2017.



**Figure 53.**—Total volume and associated sampling error of coarse woody debris and dead wood piles on forest land by ownership group, New Hampshire, 2017. Error bars represent a 68 percent confidence interval around the mean.

## What this means

Given the relatively moist temperate forests across New Hampshire, only in times of drought would the biomass of down woody materials be considered a fire hazard, especially as no residue piles were sampled during the current inventory. This stands in contrast to forests in southeastern states (Woodall et al. 2013), where industrial forest management is more widespread and rates of residue pile detection are higher. Although the carbon stocks associated with New Hampshire’s down woody materials are relatively small compared to those of soils and standing live biomass, these materials are still a critical component of the carbon cycle as a transitory stage between live biomass and other detrital pools such as the litter (Russell et al. 2015). Given that the vast majority of coarse woody debris volume was estimated to be in private ownership, it is the management of New Hampshire’s private forests that may affect the future of down woody material contributions to statewide forest carbon stocks and wildlife habitat (i.e., stand structure). Fuel loadings are estimated to be not excessively high across the state, so the numerous ecosystem services provided by down woody materials may outweigh possible fire dangers.

## Tree Pests and Diseases of Special Concern

### FOREST PESTS

Invasions by exotic diseases and insects are one of the most important threats to the productivity and stability of forest ecosystems around the world (Liebhold et al. 1995, Pimentel et al. 2000, Vitousek et al. 1996). Over the last century, forests of

New Hampshire have suffered the effects of native insect pests such as forest tent caterpillar (*Malacosoma disstria*) and well-known exotic and invasive agents such as Dutch elm disease (*Ophiostoma ulmi*), chestnut blight (*Cryphonectria parasitica*), European gypsy moth (*Lymantria dispar*), and the beech bark disease complex. More recent invaders include hemlock woolly adelgid (*Adelges tsugae*) and emerald ash borer (*Agrilus planipennis*). Additionally, Asian longhorned beetle (*Anoplophora glabripennis*) is an impending threat that caused an extensive infestation in Worcester, MA in 2008.

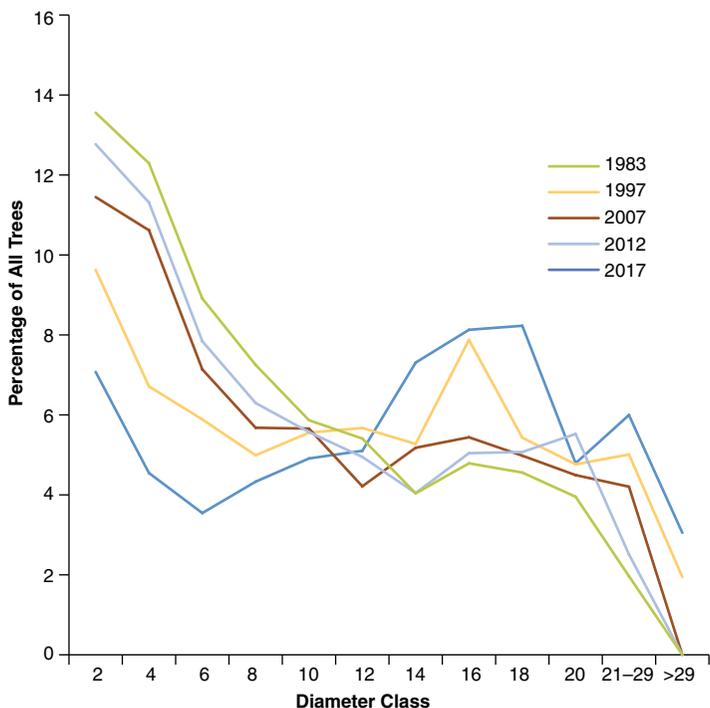
## BEECH BARK DISEASE

### Background

American beech is a major component of the maple/beech/birch forest-type group, which makes up 52 percent of the forest resource in New Hampshire (Fig. 4). American beech is an important pulpwood and firewood species and is also important for wildlife due to the hard mast that it produces. Beech bark disease (BBD) is an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga*) and the exotic canker fungus *Neonectria coccinea* var. *faginata* or the native *Neonectria galligena* that kills or injures American beech. Three phases of BBD are generally recognized: 1) the advancing front, which corresponds to areas recently invaded by scale populations; 2) the killing front, which represents areas where fungal invasion has occurred (typically 3 to 5 years after the scale insects appear, but sometimes as long as 20 years) and tree mortality begins; and 3) the aftermath forests, which are areas where the disease is endemic (Houston 1994, Morin and Liebhold 2015, Shigo 1972). The disease was inadvertently introduced via ornamental beech trees into North America at Halifax, Nova Scotia, in 1890 and then began spreading across New England. By 1975, all New Hampshire counties were infested.

### What we found

Currently, the annual mortality rate for American beech is nearly double that of all trees in New Hampshire (1.2 percent), which is similar to the rate reported in previous inventories (Morin et al. 2011, 2015a). The impacts of BBD on mortality of large diameter beech have steadily skewed the diameter distribution of beech toward smaller trees since 1983 (Fig. 54). The number of beech seedlings per acre increased slightly between 2007 and 2012 and has since remained stable.



**Figure 54.**—Proportion of all trees on timberland that are American beech, by diameter class and inventory year, New Hampshire.

## What this means

New Hampshire has been infested by BBD for over 40 years, so forests are largely in the aftermath phase of BBD. Aftermath forests are often characterized by a dearth of large beech trees due to past BBD-induced mortality, which is associated with large numbers of beech seedlings and saplings. This condition, often referred to as “beech brush,” can interfere with regeneration of other hardwood species such as sugar maple (Hane 2003). Beech brush includes trees with low vigor and slow growth that often succumb to the disease before making it into the overstory. These trees are also unlikely to reach sawtimber size or produce mast, which is important for wildlife.

## HEMLOCK WOOLLY ADELGID

### Background

Eastern hemlock is a major component of the forest resources in New Hampshire. Due to its high value as a timber species, the wildlife habitat it provides, and the unique niche it fills in riparian areas, it is an ecologically important species. Hemlock woolly adelgid (HWA) is native to East Asia and was first noticed in the eastern

United States in the 1950s (Ward et al. 2004). Since then, it has slowly expanded its range. In areas where HWA has established, populations often reach high densities, causing widespread defoliation and sometimes mortality of eastern hemlock (McClure et al. 2001, Morin and Liebhold 2015, Orwig et al. 2002).

## What we found

Hemlock woolly adelgid was first observed in Rockingham County, New Hampshire in 2001. By 2012, the insect had been discovered in seven counties in southern New Hampshire. Forests with the highest proportion of hemlock volume are located in southern New Hampshire (Fig. 34). Unlike many other states that have been impacted by HWA, there has been no significant change in hemlock annual mortality rate (Fig. 44), crown health (Tables 1, 2), or incidence of insect damage (Fig. 50) in New Hampshire. Additional analyses revealed no differences in the mortality rate and crown health of hemlock between infested and uninfested counties.

## What this means

Hemlock woolly adelgid has already spread into some of the counties of New Hampshire where hemlock is the most abundant. Morin et al. (2009) estimate that HWA is spreading to the north at a rate of between 9 and 10.6 miles per year. However, cold winter temperatures can cause considerable adelgid mortality and trigger dramatic population declines (Skinner et al. 2003). Therefore, the rate of spread of HWA into the rest of New Hampshire may be influenced by temperature. Although the health of eastern hemlock in the forests of New Hampshire does not appear to have been impacted by HWA yet, it is important to continue monitoring crown health and mortality over the coming decade. A previous study reported that hemlock mortality increases were not substantial until HWA had infested counties for more than 20 years (Morin and Liebhold 2015), suggesting impacts in New Hampshire will not be apparent for another 5 to 10 years.

## EMERALD ASH BORER

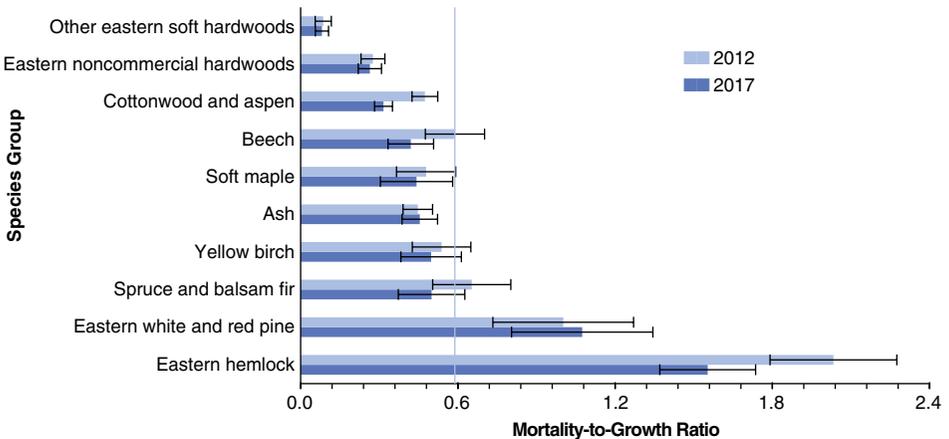
### Background

Emerald ash borer (EAB), a wood-boring beetle native to Asia, was first detected in North America in 2002, where it was found near Detroit, MI (Herms and McCullough 2014). As EAB is difficult to detect at low levels, natural spread was exacerbated by human-mediated transportation of infested materials; spread of EAB has outpaced detection, with population establishment averaging 3 to 8 years prior

to identification (Herms and McCullough 2014). This beetle has been present in New Hampshire since 2013, when it was detected in Merrimack County. All North American ash are hosts of EAB. Although EAB shows some preference for stressed trees, all trees 1 inch in diameter or greater are susceptible regardless of vigor (Herms and McCullough 2014). Mortality due to EAB varies by infestation level, but a mortality-to-gross-growth ratio above 0.6 is indicative of an acute forest health issue (Conkling et al. 2005).

## What we found

There are an estimated 89.4 million ash trees (d.b.h. of 1 inch or greater), or 2 percent of total species abundance on forest land. White ash is the most prevalent ash species (93 percent of total ash abundance), followed by black ash (6 percent) and green ash (less than 1 percent). Ash is present on 1.4 million acres, or 30 percent of forest land, but it generally makes up less than 25 percent of total live-tree basal area. Average annual mortality of ash on forest land slightly decreased from 4.0 million cubic feet in 2012 to 3.4 million cubic feet in 2017; ash mortality represented 3 percent of total mortality in 2017. Between 2012 and 2017, the mortality-to-gross-growth ratio for ash decreased from 0.48 to 0.44 (Fig. 55).



**Figure 55.**—Ratio of average annual mortality volume to gross growth volume for selected species groups on forest land by inventory year, New Hampshire. Error bars represent a 68 percent confidence interval around the mean. Vertical line shows the threshold indicating an acute health issue (Conkling et al. 2005).

## What this means

Ash is an important component of New Hampshire's woodland, riparian, and urban forest resource. Currently, the ash resource is stable. However, EAB has caused extensive ash mortality throughout the eastern United States and therefore represents a significant threat to the ash resource in New Hampshire. Mortality of ash is expected to increase as EAB persists and populations grow. 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 in forested settings.

## Regeneration Status

### Background

Trajectories for long-term sustainability of forest values are set in the forest understory during the stand-initiation phase of development, which makes regeneration management a key factor for sustaining healthy and productive forests (Smith et al. 1997). The Wildlife Society recently issued a policy statement for managing forest biodiversity in the northeastern United States that addresses two tenets of sustainable restoration management (Ronis 2018):

- “Sustainable forest management strategies can promote a mosaic of forest structure and age-classes across a landscape and create various habitat types, which contribute to the maintenance of biological diversity.”
- “In the northeastern United States, land use changes, such as natural succession and development, have created an underrepresentation of both early- and late-successional habitat, and a predominance of secondary growth (40-100 year-old forests) across the region.”

Forest restoration management and policy aimed at “young forest” (seedlings up to trees 20 years old) are critically important, but are complicated by multiple stressors and their interactions, such as a changing climate, invasive plants, herbivory, and wildfire exclusion.

In 2012, the Forest Service's Northern Research Station (NRS) FIA implemented a set of regeneration indicator (RI) measurement protocols on a subset of NRS-FIA core sample plots (Phase 2, or P2) measured during the growing season (Phase 2+) to identify contemporary challenges for managers and policymakers (McWilliams et al. 2015). The results in this report are based on measurements of 94 sample plots measured from 2013 through 2017. The procedures measure all established tree seedlings at least 2 inches tall by height class and include a browse impact assessment

for the surrounding area. The measurements of small seedlings supplement FIA’s P2 seedling estimates, which are limited to hardwood stems at least 1 foot long and softwood stems at least 6 inches long.

## What we found

The 0- to 20-year stand-age class is FIA’s primary indicator for young forest extent, condition, and health. Currently, only 4.9 percent of New Hampshire forest land is 20 years or younger. The four most extensive forest-type groups, which make up 85 percent of the total forest land in New Hampshire, all have low amounts of young forest (Table 3), with percentages ranging from 0 for oak/hickory (no samples found) to 7.7 for spruce/fir. Young forest has become so rare that the P2 sample results in high sampling errors.

**Table 3.**—Summary of young forest<sup>a</sup> resource for the most prevalent forest-type groups, New Hampshire, 2017

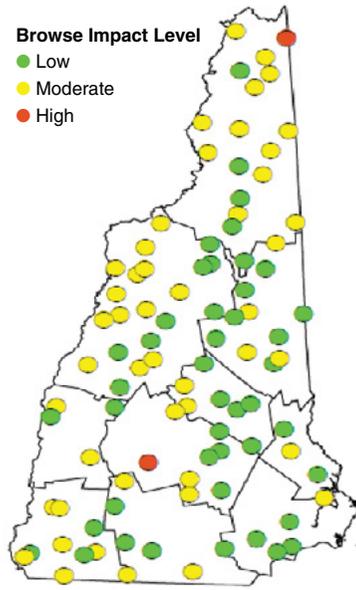
	<i>percent</i>	<i>percent</i>	<i>acres</i>	<i>acres</i>
Maple/beech/birch	51.9	4	97,189	22,956
White/red/jack pine	11.6	1	7,949	5,943
Oak/hickory	10.8	0	N/A	N/A
Spruce/fir	9.8	8	35,951	14,158

<sup>a</sup> Young forest is defined here as the area of forest land in the 0- to 20-year age class.

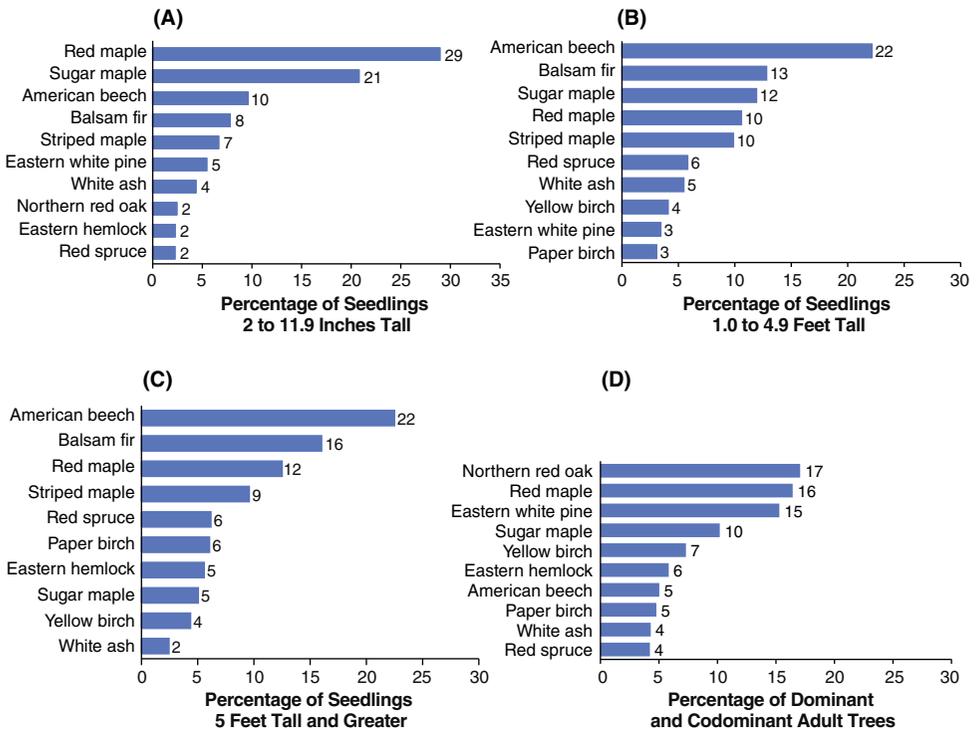
<sup>b</sup> Confidence intervals based on 68 percent sampling errors.

The impacts of large ungulate browsing of young tree seedlings are a large impediment to establishing viable forest regeneration (Russell et al. 2001). Where forest land has at least moderate browse impacts, managers should consider whether to include ameliorative treatments in their regeneration management prescriptions (Brose et al. 2008). Just over half the samples had at least moderate impacts and are spread evenly across the New Hampshire forest landscape (Fig. 56).

The RI estimate of the number of established seedlings at least 2 inches tall is 28.6 billion, or 5,579 per acre. Comparing tree-seedling composition (taxa) and abundance (numbers of stems) by size class with total aboveground biomass (AGB) for dominant and codominant adults sheds light on trends in recruitment (Fig. 57). Although high sampling errors make it difficult to make precise inferences, some broad directions are apparent. Prospective “gainers” are taxa with comparatively high percentages of stems in the reproduction pool. Balsam fir and American beech are posting high percentages across all seedling size-classes. Red maple, sugar maple, and red spruce



**Figure 56.**—Browse impact level based on Forest Inventory and Analysis forested Phase 2+ sample plots, New Hampshire, 2013 to 2017. Depicted plot locations are approximate.



**Figure 57.**—(A–C) Numbers of seedlings based on Forest Inventory and Analysis forested Phase 2+ sample plots by height class for the 10 most abundant species in each class, and (D) number of dominant and codominant adult trees for the 10 species using Phase 2 sample plots, New Hampshire, 2017.

are poised to continue as canopy dominants. At this time, eastern white pine emerges as a “loser” among regenerating species because it shows relative seedling abundance far below its AGB coverage of 15 percent. Findings for northern red oak also indicate underrepresentation in the seedling component.

## What this means

As forests continue to mature, the rich array of goods, services, and wildlife habitat available from young forest is missing in some areas of New Hampshire. Stand age was not recorded in the earliest FIA report (USDA Forest Service 1954); however, the small diameter stand-size class for timberland is a rough surrogate for the 0- to 20-year age class because it represents conditions dominated by seedlings and saplings. In 1948, 24 percent of the timberland area was classified as small diameter stands, compared with 11 percent in 2017. Over the same period, large diameter stands increased from 39 percent to 64 percent of timberland. The current distribution of forest land by stand-size and stand-age class exhibits a deficit in young forest that has ramifications for sustainability, particularly for wildlife species that depend on early-successional forest for part or all of their life cycle.

The RI seedling inventory results suggest potential shifts in composition of canopy adults. Northern red oak is currently among the most abundant species in New Hampshire, but its reproduction pool is too low to maintain this role in the future. It is likely to be replaced by red maple as the most dominant species in coming decades. Positive results for balsam fir and red spruce seedlings indicate that young stands preferred symbiotically by snowshoe hare (*Lepus americanus*) and Canada lynx (*Lynx canadensis*) are being established (Litvaitis 1985). American beech may be expected to become a future dominant, but beech bark disease and the viability of root sprouts leave this issue unresolved and something to watch in future inventories. The signal that eastern white pine has a low reproduction pool tells us that species-specific stand management is needed across the different associations within which it occurs, from mixed to pure.

The ecological implications of browsing are expected to have severe long-term impacts on forest composition, structure, and function (Côté et al. 2004, Russell et al. 2001). The results of the browse evaluation confirm that forest regeneration management will need to consider local browse conditions during the stand-initiation phase across much of New Hampshire.

New Hampshire forests face a variety of forest health risks, and establishing desired tree seedlings is an integral step in addressing most of them during the early phases of forest development. The interactions of factors such as browsing and invasive species

make it more difficult to establish forests, particularly oaks. These conditions do not preclude regeneration of the oak/hickory forests because management techniques to develop young oak/hickory forests have proven successful (Dey 2014). The future of young forest and related resources will depend on the number of stand-initiation disturbances and the frequency of planned regeneration harvests and restoration versus unplanned major disturbances, such as catastrophic mortality or wind throw.

## **Invasive Plant Species**

### **Background**

Invasive plant species (IPS) are a concern throughout the world. Some invasive plants are alternate hosts for insects and diseases and can cause severe agricultural impacts. The presence of IPS also affects forest structure, health, and diversity. These invaders often form very dense colonies that limit availability of light, nutrients, and water. While some invasive plants have beneficial characteristics, such as for medicinal purposes (e.g., common barberry) (Kurtz 2013) or culinary use (e.g., garlic mustard), the negative impacts to ecosystems are problematic. Annually, nonnative IPS cost billions of dollars through monitoring and removal. Because of the vast implications of IPS, it is important to increase awareness through informing and educating private landowners and the rest of the public.

### **What we found**

During the 2017 inventory, 111 P2 invasive plots in New Hampshire were monitored for the presence of 39 IPS and one undifferentiated genus (nonnative bush honeysuckle) (Table 4) as a part of the invasive plant monitoring protocol. Invasive plant species were present on 13 plots (11.7 percent). This result is similar to what was found in 2012, when 11.2 percent of plots had one or more IPS present.

Eight of the monitored IPS were observed. The most commonly observed invasive plant was Oriental bittersweet (7 plots; 6.3 percent), closely followed by glossy buckthorn (Fig. 58, Table 5). Oriental bittersweet was found on a higher percentage of plots than in 2012, when 2.6 percent of plots contained this species (Morin et al. 2015a).

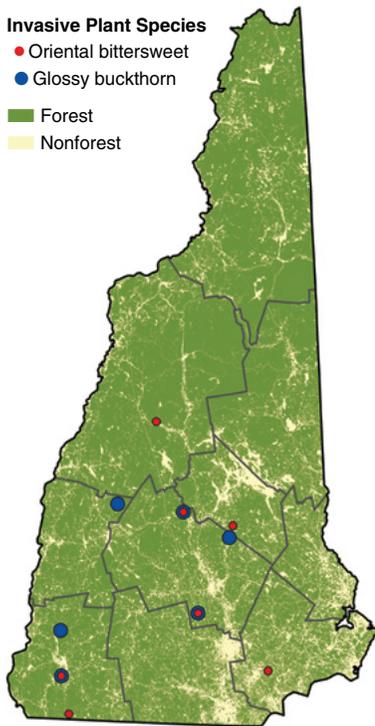
In New Hampshire, most plots did not have invasive plants, but one plot had six invasive plants (Fig. 59). The majority of plots with IPS are in the southern part of the State; few northern plots contained monitored invasive plants. New Hampshire has about half as many plots with IPS as neighboring Vermont.

**Table 4.**—The 39 invasive plant species and 1 undifferentiated genus monitored by the Northern Research Station on Forest Inventory and Analysis Phase 2 invasive plots, 2007 to present

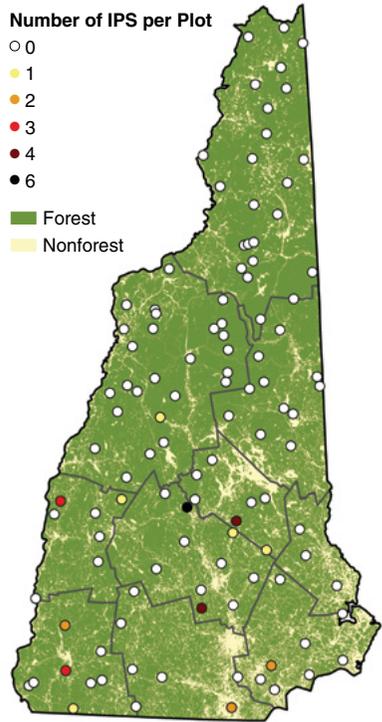
Tree Species	Vine Species
black locust ( <i>Robinia pseudoacacia</i> )	English ivy ( <i>Hedera helix</i> )
chinaberry ( <i>Melia azedarach</i> )	Japanese honeysuckle ( <i>Lonicera japonica</i> )
Norway maple ( <i>Acer platanoides</i> )	Oriental bittersweet ( <i>Celastrus orbiculatus</i> )
princesstree ( <i>Paulownia tomentosa</i> )	
punktree ( <i>Melaleuca quinquenervia</i> )	Herbaceous Species
Russian olive ( <i>Elaeagnus angustifolia</i> )	black swallow-wort ( <i>Cynanchum louiseae</i> )
saltcedar ( <i>Tamarix ramosissima</i> )	bull thistle ( <i>Cirsium vulgare</i> )
Siberian elm ( <i>Ulmus pumila</i> )	Canada thistle ( <i>Cirsium arvense</i> )
silktree ( <i>Albizia julibrissin</i> )	creeping jenny ( <i>Lysimachia nummularia</i> )
tallow tree ( <i>Triadica sebifera</i> )	dames rocket ( <i>Hesperis matronalis</i> )
tree of heaven ( <i>Ailanthus altissima</i> )	European swallow-wort ( <i>Cynanchum rossicum</i> )
Woody Species	garlic mustard ( <i>Alliaria petiolata</i> )
autumn olive ( <i>Elaeagnus umbellata</i> )	giant knotweed ( <i>Polygonum sachalinense</i> )
common barberry ( <i>Berberis vulgaris</i> )	Japanese knotweed ( <i>Polygonum cuspidatum</i> )
common buckthorn ( <i>Rhamnus cathartica</i> )	leafy spurge ( <i>Euphorbia esula</i> )
European cranberrybush ( <i>Viburnum opulus</i> )	Bohemian knotweed ( <i>Polygonum xbohemicum</i> )
European privet ( <i>Ligustrum vulgare</i> )	purple loosestrife ( <i>Lythrum salicaria</i> )
glossy buckthorn ( <i>Frangula alnus</i> )	spotted knapweed ( <i>Centaurea stoebe</i> ssp. <i>micranthos</i> )
Japanese barberry ( <i>Berberis thunbergii</i> )	Grass Species
Japanese meadowsweet ( <i>Spiraea japonica</i> )	common reed ( <i>Phragmites australis</i> )
multiflora rose ( <i>Rosa multiflora</i> )	Nepalese browntop ( <i>Microstegium vimineum</i> )
nonnative bush honeysuckle ( <i>Lonicera</i> spp.)	reed canarygrass ( <i>Phalaris arundinacea</i> )

**Table 5.**—Invasive plant species observed on Forest Inventory and Analysis Phase 2 invasive plots, and frequency of observation, New Hampshire, 2017

	Percentage of plots
Oriental bittersweet	6.3
Glossy buckthorn	5.4
Japanese barberry	4.5
Nonnative bush honeysuckle	3.6
Multiflora rose	2.7
Autumn olive	1.8
Norway maple	1.8
Common buckthorn	1.8



Projection: New Hampshire State Plane, NAD83.  
 Source: ESRI data and maps, 2008.  
 FIA data and Tools are available online at  
<https://www.fia.fs.fed.us/tools-data>.  
 Cartography: C.M. Kurtz, USDA Forest Service, November 2019.



Projection: New Hampshire State Plane, NAD83.  
 Source: ESRI data and maps, 2008.  
 FIA data and Tools are available online at  
<https://www.fia.fs.fed.us/tools-data>.  
 Cartography: C.M. Kurtz, USDA Forest Service, November 2019.

**Figure 58.**—Distribution of the two most common invasive plant species observed on Forest Inventory and Analysis Phase 2 invasive plots, New Hampshire, 2017. Depicted plot locations are approximate.

**Figure 59.**—Number of invasive plant species (IPS) observed on Forest Inventory and Analysis Phase 2 invasive plots, New Hampshire, 2017. Depicted plot locations are approximate.

## What this means

Since the last survey in 2012, there has been little change in the percentage of plots invaded or the number of plots containing each IPS. It will be important to continue to watch how these species spread and whether new IPS are observed. Invasive plants are a concern because they can cause detrimental forest changes. These plants can alter hydrology, displace native species, and reduce the aesthetic appeal of an area. Heavily infested areas may result in a change in wildlife habitat. Once established, IPS can rapidly increase in cover and impact co-occurring native plant species. Through continual monitoring of invasive species, managers will be aware of the presence of these aggressive species and be able to make better informed management decisions.

# Forest Habitats

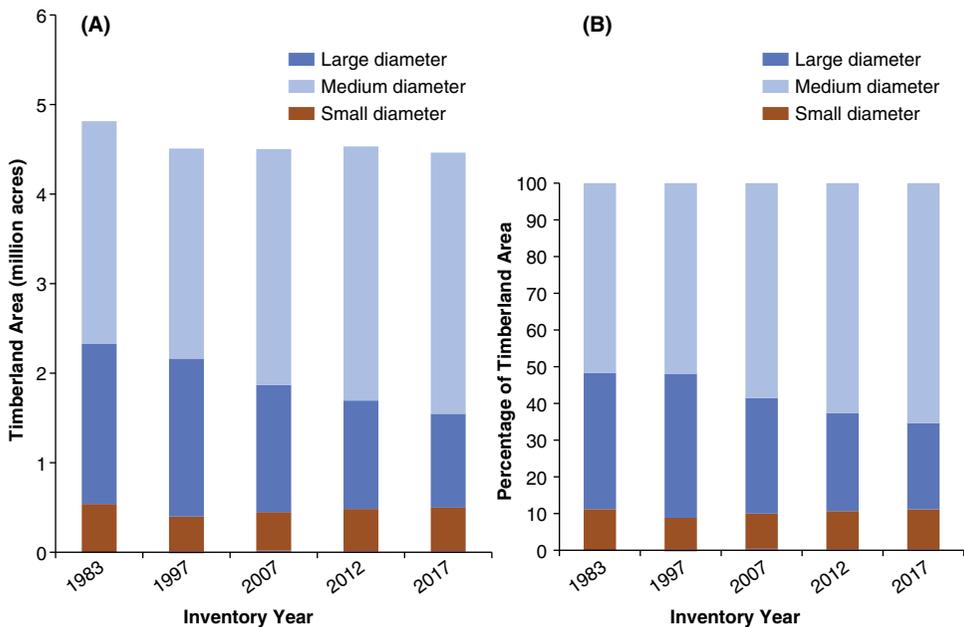
## Background

New Hampshire forests provide habitat for numerous species of mammals, birds, reptiles, and amphibians, as well as for fish, invertebrates, and plants. Several indicators of wildlife habitat abundance can be derived from FIA data. Forest composition and structure affect the suitability of habitat for each species. According to the 2015 New Hampshire Wildlife Action Plan (New Hampshire Fish and Game Department [NH FGD] 2015), forest habitat types at highest risk from the effects of natural system modifications include floodplain forest, lowland spruce-fir forest, and shrublands, while hemlock-hardwood-pine forest and pine barrens were ranked with a medium threat score. Lowland spruce-fir forests, for example, provide habitat for over 100 species of vertebrates, including black bear (*Ursus americanus*), hoary bat (*Lasiurus cinereus*), Canada lynx, American three-toed woodpecker (*Picoides dorsalis*), and American marten (*Martes americana*), and provide deer (*Odocoileus* spp.) yards during heavy snow years (NH FGD 2015). Shrublands and other woody early-successional habitats are declining in New Hampshire and throughout the Northeast, posing threats to associated wildlife species such as golden-winged warbler (*Vermivora chrysoptera*), New England cottontail (*Sylvilagus transitionalis*), American woodcock (*Scolopax minor*), ruffed grouse (*Bonasa umbellus*), smooth green snake (*Opheodrys vernalis*), wood turtle (*Glyptemys insculpta*), and the black racer (*Coluber constrictor priapus*) (NH FGD 2015). Abundance and trends in forest structure and successional stages serve as indicators of population carrying capacity for wildlife species (Hunter et al. 2001).

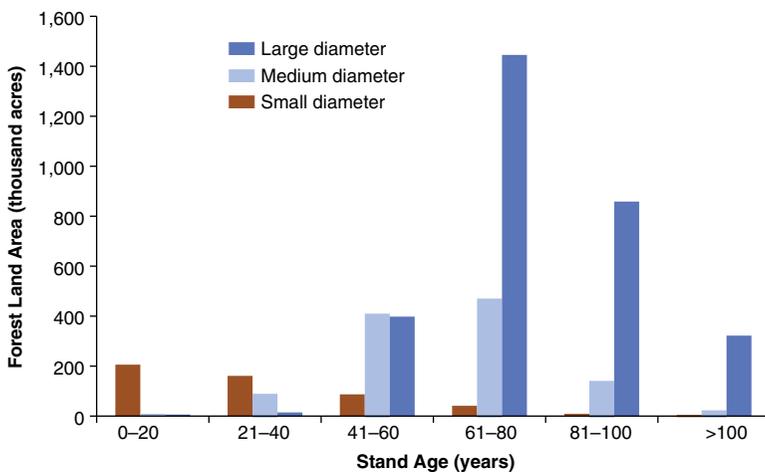
## What we found

Area of timberland in New Hampshire decreased slightly between 1983 and 2017, from 4.8 million acres to 4.5 million acres. During that time, the proportion of timberland in the small diameter stand-size class decreased from 11 percent to 9 percent, then returned to 11 percent, while distribution of medium diameter forest decreased from 37 percent to 24 percent, and large diameter forest increased steadily from 52 percent to 65 percent of total timberland area (Fig. 60).

A large majority of New Hampshire forest land (82 percent) is in stand-age classes between 40 and 100 years. About 8 percent is over 100 years of age. Small diameter stand-size classes predominate in forests of 0 to 40 years, and large diameter predominates in forests over 60 years of age; forests of 41 to 60 years contain almost equally large acreages of medium and large diameter stand-size classes (Fig. 61).



**Figure 60.**—(A) Area and (B) percentage of timberland by inventory year and stand-size class, New Hampshire.



**Figure 61.**—Area of forest land by stand-age class and stand-size class, New Hampshire, 2017.

## What this means

Decreasing abundance of medium diameter stand-size classes is offset by increasing abundance in the large diameter size classes. However, the great majority of stands in the large diameter class (89 percent) are less than 100 years of age. Although both stand-size class and stand-age class provide indicators of forest successional and structural stage, the two attributes are not exactly interchangeable and are best viewed in combination.

The New Hampshire Wildlife Action Plan states: “Many shrublands will naturally succeed into forests and therefore, natural disturbances or specific management practices should be allowed to occur to sustain this habitat” (NH FGD 2015). In contrast, “some conservation strategies for lowland spruce-fir forests are to protect unfragmented blocks of land and to maintain late successional habitat” (NH FGD 2015). These approaches reflect the need to monitor and maintain forest conditions in multiple forest type, size, and age classes, including both early (young) and late (old) successional stages to provide habitats for all forest-associated species.

## Standing Dead Trees

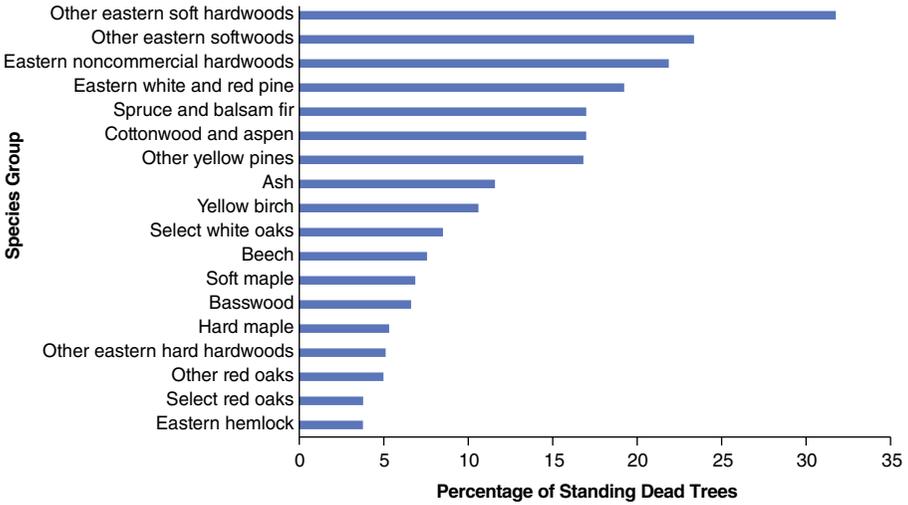
### Background

Snags provide areas for foraging, nesting, roosting, hunting perches, and cavity excavation for wildlife, from primary colonizers such as insects, bacteria, and fungi to birds, mammals, and reptiles. Stands with numerous snags provide more food and potential nests for species like American three-toed woodpecker, and the majority of northern long-eared bats (*Myotis septentrionalis*) roost in snags (NH FGD 2015). The number and density of standing dead trees (5 inches or greater d.b.h.), together with decay classes, species, and sizes, define the snag resource across New Hampshire forests.

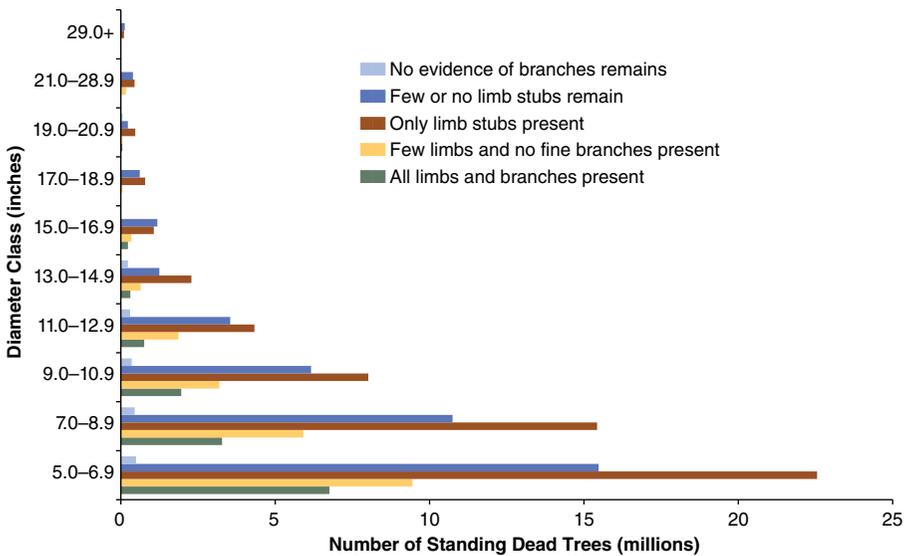
### What we found

There are over 132 million standing dead trees on the 4.7 million acres of forest in New Hampshire. This represents an overall density of 28 standing dead trees per acre of forest land, ranging from 21 per acre on private lands to 56 per acre on national forest lands. Species groups with the largest percentages of standing dead trees include other eastern soft hardwoods (32 percent), other eastern softwoods (23 percent), eastern noncommercial hardwoods (22 percent), and eastern white and red pine (19 percent). Other red oaks, select red oaks, and eastern hemlock had the lowest percentages (less than 5 percent) (Fig. 62).

Across New Hampshire, more than 83 percent of standing dead trees were smaller than 11 inches d.b.h. The greatest number of standing dead trees (89 percent) was estimated for the three intermediate decay classes, with the fewest (1 percent) in the class of most decay (Fig. 63).



**Figure 62.**—Percentage of standing dead trees by species or species group, New Hampshire, 2017.



**Figure 63.**—Distribution of standing dead trees by decay and diameter classes for all dead trees, New Hampshire, 2017.

## What this means

Snags result from a variety of potential causes, including diseases and insects, weather damage, fire, flooding, drought, and competition. The spruce and balsam fir species group contained the greatest total number of standing dead trees (over 36 million), but rankings varied when the percentage of standing dead trees was assessed within each species group. Snags provide habitat for many vertebrate and invertebrate life forms. Most cavity nesting birds are insectivores, which help to control insect populations. Providing a variety of forest structural stages and retaining specific features like snags on both private and public lands are ways that forest managers maintain the abundance and quality of habitat for forest-associated wildlife species in New Hampshire.

# Urbanization and Fragmentation of Forest Land

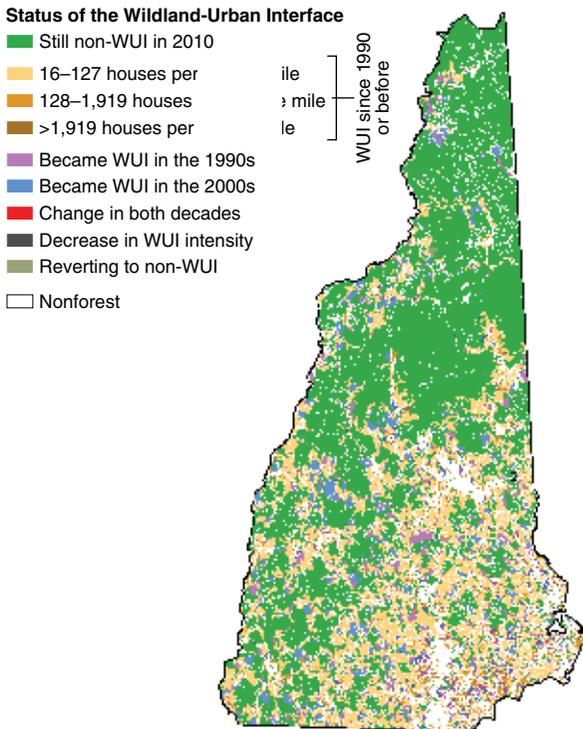
## Background

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. 2017). Although originally defined to identify the area where wildfires pose the greatest risk to people, the WUI is associated with a variety of consequential human-environment conflicts. These include impacts such as the loss and fragmentation of native species, the introduction and spread of nonnative species (e.g., Gavier-Pizarro et al. 2010, Riitters et al. 2018), the loss of habitat area or critical connectivity (e.g., Bregman et al. 2014, Rogers et al. 2016), increased mortality of wildlife (e.g., Klem 2009, Loss et al. 2013), reductions in regional complexity of plant and animal communities (e.g., Ferguson et al. 2017, Mack et al. 2000), increases in nonnative insect and disease invasions (e.g., Guo et al. 2018), and impacts on water quality and quantity from impervious surfaces and increased pollution (e.g., Bar-Massada et al. 2014, Gonzalez-Abraham et al. 2007). The 2018 report from the New England Climate Change Response Framework on New England and New York forest ecosystem vulnerability (Janowiak et al. 2018) identified fragmentation and land use change as among the six current greatest stressors and threats to forest ecosystems. In turn, forest fragmentation and urbanization heavily influence two of the other major threats: invasion by nonnative species, and forest diseases and insect pests.

In previous reports in several areas we summarized forest spatial integrity using a spatial integrity index that combined forest patch size, local forest density, and connectedness to core 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 (e.g., Widmann et al. 2015).

With the recent completion of a temporally consistent census block-level dataset capable of accurately comparing block-level change in housing densities between 1990 and 2010 (Mockrin et al. 2019, Radeloff et al. 2017), we are now able to analyze changes in house density and forest land at a finer spatial resolution and with more accuracy than previously possible. We have used these data here to identify FIA forest land and changes in WUI levels of house density via the following categories: forest land in census blocks that have had house densities above established WUI thresholds for 30 years or more (from 1990 or before), forest that first reached WUI house density levels in the 1990s, forest that first reached WUI house density levels in the 2000s, forest that underwent change in WUI house density in both decades, and forest land that remained in non-WUI census blocks in 2010 (Fig. 64). In Figure 64 forest land is depicted in the map using the 2011 National Land Cover Dataset (Jin et al. 2013) to mask out nonforest areas; however, all forest land statistics reported are summarized from the FIA plot data.

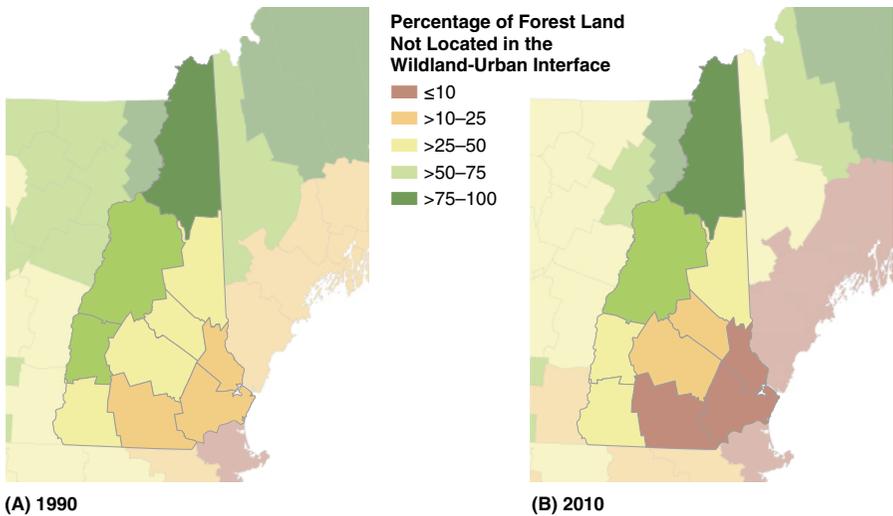


**Figure 64.**—Map of forest cover by census block-level change in wildland-urban interface (WUI) status between 1990 and 2010, New Hampshire.

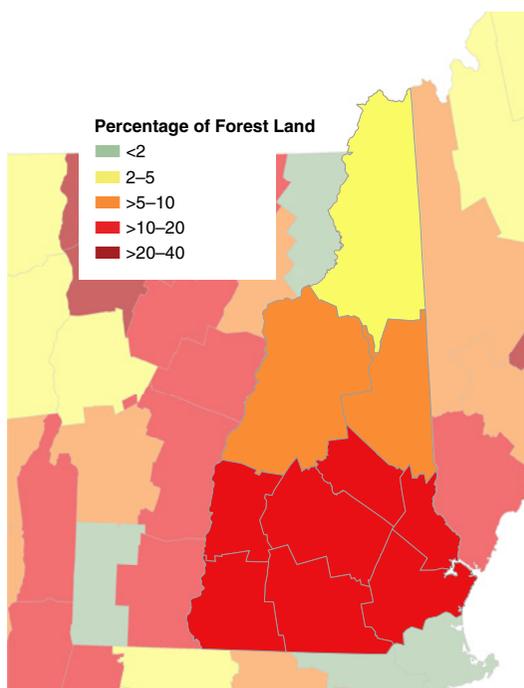
We examined 1) how much forest land is changing or is at risk of change because of its proximity to WUI levels of housing development, 2) the rate of change between 1990 and 2010, 3) the extent to which WUI house densities occur in forest land that might otherwise be considered high integrity or core forest land, and 4) whether differences in forest type, ownership, and stand size have been affected by urbanization levels above the low (16 to 127 houses per square mile), medium (128 to 1,919), and high (>1,919) WUI housing density thresholds (hereafter referred to collectively as WUI).

## What we found

Both the area and proportion of New Hampshire forest that is non-WUI continued to shrink, from 3.4 million acres to 3.0 million acres (72 percent to 62 percent of the total forest land) between 1990 and 2010 (Fig. 65). By 2020, 1.3 million acres of New Hampshire forest land will have been in WUI conditions for at least 30 years. Urbanization of forest land occurred in some areas at higher rates during the 1990s, and in others, during the 2000s. For still other areas, the rate of forest urbanization was somewhat constant throughout both decades. Most counties experienced additional urbanization at rates greater than 5 percentage points per decade (Fig. 66).



**Figure 65.**—Proportion of forest not located in the wildland-urban interface in (A) 1990 and (B) 2010.



Projection: New Hampshire State Plane, NAD83. Sources: USDA Forest Service, Forest Inventory and Analysis program, 2008; Wildland-urban interface 2010 (Radeloff et al. 2017). Geographic base data are provided by the National Atlas of the USA®. Cartography: R. Riemann, USDA Forest Service, June 2019.

**Figure 66.**—Proportion of forest land in each county that changed from non-wildland-urban interface (non-WUI) conditions to WUI conditions, New Hampshire, 1990 to 2010.

Urbanization affected forest types to differing degrees by 2010, from 5 percent of the forest area for paper birch and red spruce forest types to 73 percent of the forest area for white oak/red oak/hickory and eastern white pine/northern red oak/white ash forest-type groups) (Table 6). Three additional forest types or forest-type groups had 50 percent or more of their area in WUI as of 2010 (eastern white pine/eastern hemlock, eastern white pine, and hard maple/basswood). The eastern white pine/northern red oak/white ash, hard maple/basswood, and white oak/red oak/hickory forest-type groups had the greatest proportion of their area converted to WUI between 1990 and 2010, at 17 to 19 percent. Seven forest types had 10 percent or more of their forest area converted to WUI during that time (Table 6). Four forest types are being disproportionately affected by WUI development. For example, 14 percent of the total forest area in WUI in New Hampshire in 1990 was in the eastern white pine forest type, which itself represents only 8 percent of the total forest area in New Hampshire. Conversely, the sugar maple/beechn/yellow birch forest-type group was affected by WUI to a much lower degree (33 percent) than its proportion of the total forest area in New Hampshire (44 percent) (Table 7).

**Table 6.**—Summary of wildland-urban interface (WUI) change groups by forest type or forest-type group, New Hampshire (percentages may not add to 100 because of rounding)

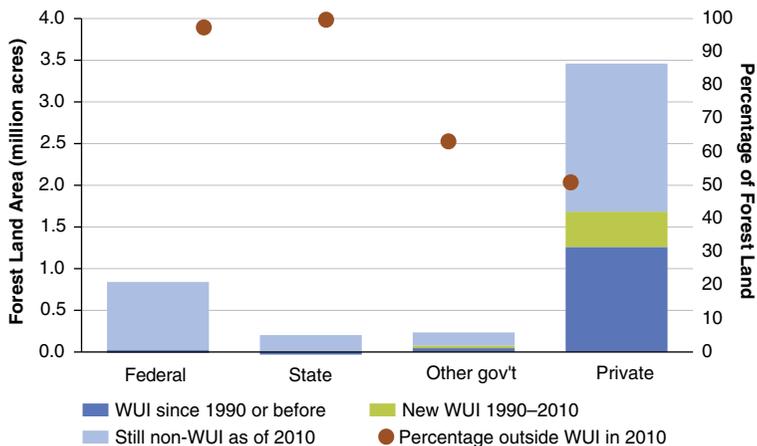
Forest type or forest-type group	Total acres	All classes	WUI change group				Proportion of area in WUI in 2010
			WUI since 1990 or earlier	New WUI 1990–2010	Still non-WUI as of 2010	Potential WUI decrease	
<b>Total area (acres) or percentage</b>	<b>4,783,480</b>	<b>100</b>	<b>28</b>	<b>9</b>	<b>62</b>	<b>1</b>	<b>73</b>
		<i>percent</i>	<i>-----percent-----</i>				
White oak/red oak/hickory	194,118	4	56	17	25	2	73
Eastern white pine/northern red oak/white ash	297,759	6	53	19	25	2	73
Eastern white pine/eastern hemlock	121,465	3	64	5	31	0	69
Eastern white pine	377,647	8	50	14	35	1	64
Hard maple/basswood	100,322	2	35	17	45	3	52
Red maple/lowland	73,793	2	44	0	35	21	44
Remaining forest types (<70,000 acres each)	266,761	6	44	0	35	21	44
Northern red oak	283,240	6	28	14	57	0	43
Red maple/upland	244,223	5	29	11	61	0	39
Eastern hemlock	85,320	2	25	10	65	0	35
Sugar maple/beech/yellow birch	2,094,740	44	21	7	71	0	29
Balsam fir	211,948	4	8	2	89	1	10
Red spruce/balsam fir	131,144	3	0	7	93	0	7
Paper birch	200,420	4	3	3	95	0	5
Red spruce	100,583	2	5	0	95	0	5

**Table 7.**—Summary of contribution by forest type or forest-type group to wildland-urban interface change group, New Hampshire (percentages may not add to 100 because of rounding)

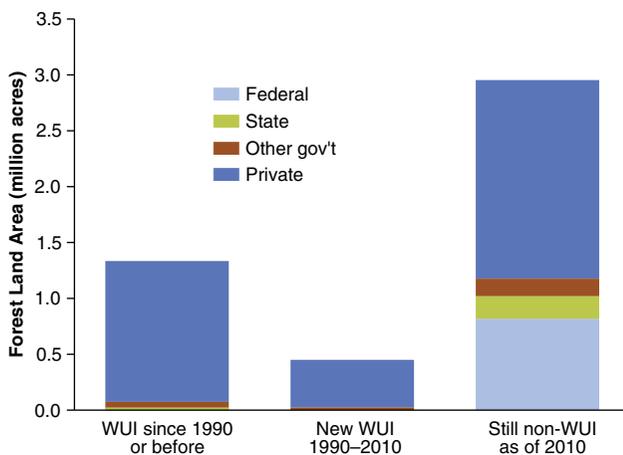
Forest type or forest-type group	Total acres	All classes	WUI change group			
			WUI since 1990 or earlier	New WUI 1990–2010	Still non-WUI as of 2010	Potential WUI decrease
<b>Total area (acres) or percentage</b>	<b>4,783,480</b>	<b>100</b>	<b>1,334,515</b>	<b>449,575</b>	<b>2,953,802</b>	<b>45,589</b>
		<i>percent</i>	<i>-----percent-----</i>			
Sugar maple/beech/yellow birch	2,094,740	44	33	35	50	11
Eastern white pine	377,647	8	14	12	4	10
Eastern white pine/northern red oak/white ash	297,759	6	12	13	3	14
Northern red oak	283,240	6	6	9	6	0
Red maple/upland	244,223	5	5	6	5	0
Balsam fir	211,948	4	1	1	6	6
Paper birch	200,420	4	0	1	6	0
White oak/red oak/hickory	194,118	4	8	7	2	8
Red spruce/balsam fir	131,144	3	0	2	4	0
Eastern white pine/eastern hemlock	121,465	3	6	1	1	0
Red spruce	100,583	2	0	0	3	0
Hard maple/basswood	100,322	2	3	4	2	8
Eastern hemlock	85,320	2	2	2	2	0
Red maple/lowland	73,793	2	2	0	1	35
Remaining forest types (<70,000 acres each)	266,761	6	7	7	5	8

Ownerships with the greatest proportion of their forest land area remaining as non-WUI forest were State (100 percent) and Federal (97 percent) ownerships. The private ownership group had the lowest proportion of its forest land remaining in non-WUI conditions in 2010 (51 percent), followed by the county and local government ownership group (63 percent). However, the large amount of forest land in private ownership in New Hampshire meant that it had 1.7 times the number of acres remaining in non-WUI conditions in 2010 as State and Federal land combined (Fig. 67). Almost all the forest land undergoing a change in WUI status between 1990 and 2010 was in private ownership (Fig. 68).

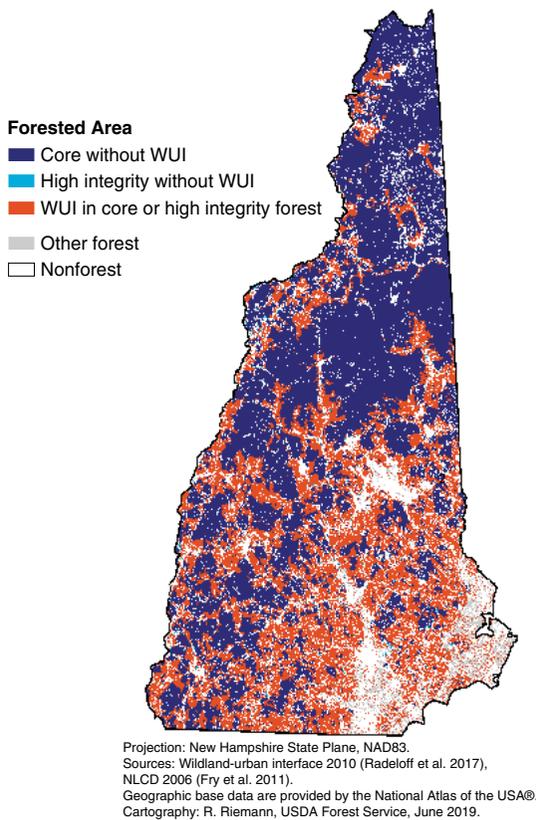
In New Hampshire, 84 percent of the forest land had a spatial integrity index value of “core” or “high integrity” at both the 30 m and 250 m scales (Fig. 69), as defined by its patch size, local forest density, and connectedness. However, of that core or high integrity forest land, 33 percent occurred in WUI conditions in 2010, the most recent census data available. Between 1990 and 2010 conversions of core and high spatial integrity forest to WUI conditions took place at an average rate of 4.5 percentage points per decade.



**Figure 67.**—Forest land by ownership group and wildland-urban interface (WUI) change group, New Hampshire.



**Figure 68.**—Forest land by wildland-urban interface (WUI) change group and ownership group, New Hampshire.



**Figure 69.**—Locations where wildland-urban interface (WUI) conditions occurred within forest land calculated to have core or high spatial integrity at two scales, New Hampshire, 2010.

If we look only at core forest, 73 percent of the forest land in New Hampshire had a spatial integrity index value of “core” at both scales, but 28 percent of that core forest occurred in WUI conditions in 2010. From 1990 to 2010 this core forest was converted to WUI conditions at an average rate of 4.0 percentage points per decade.

### What this means

Urbanization is affecting an increasing amount of forest area in New Hampshire, including unfragmented forest land in otherwise core or high spatial integrity situations. A total of 1.3 million acres (28 percent of New Hampshire forest land) was in WUI conditions by 1990, and between 1990 and 2010 forest land was still converted to WUI conditions at rates greater than 5 percentage points per decade in most counties. In addition, these changes were not limited to already fragmented forest land. In New Hampshire, forest land in otherwise core and high spatial integrity conditions was converted to WUI conditions at an average rate of 4.5 percentage points per decade between 1990 and 2010.

Increasing urbanization has the potential to change how New Hampshire forests function, exacerbating their vulnerability to threats such as insect pests and diseases, nonnative species proliferation, and loss of native species. Diminished function hinders their overall resilience in the face of both these threats and the additional changes and disturbances expected due to a changing climate. 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 (e.g., Vermont Department of Forests, Parks and Recreation 2015). Many of the reported changes in forest ecosystems happen over time and thus forest land which has only recently become WUI may not look different yet. Changes may be more apparent in forest land that has been in WUI conditions for over 30 years.

Given the well-documented negative effects of residential development on forest land and the amount of forest land occurring in WUI conditions, how we manage those residential areas is of great importance. Strategies are available to reduce the effects of those residential land uses on surrounding forest land. In addition, planning interventions are almost certainly required to maintain remaining forest connectivity.

## Urban Forests

### Background

Urban forests include all trees growing in urban areas. More than 80 percent of the U.S. population lives in urban areas. Trees in cities and towns offer a wide range of benefits to urban residents, including the improvement of air and water quality, aesthetic appeal and visual barriers, mitigation of rainfall runoff and flooding, and lower noise impacts. Given the ecological and economic importance of urban forests, there is a need to quantify and monitor this critical resource.

Historically, the focus of the FIA inventory had been to collect information on trees that were part of a forest at least 1 acre in size with a natural or unmaintained understory. Because many urban trees do not fall into this category, they were not captured in the traditional FIA inventory. To address this data gap and improve urban forest monitoring, FIA established a national urban forest inventory program in 2014 and began monitoring in urban areas, focusing on the 100 most populous cities. The urban FIA program uses established FIA monitoring methods, database and reporting tools, and statistical techniques, along with i-Tree software tools that quantify ecosystem services. The ultimate goal of this effort is to have a seamless reporting system that uses the existing FIA protocols to provide new and valuable information on trees in previously unmeasured areas.

## What we found

According to the 2010 U.S. Census, New Hampshire has 412,000 acres of urban land, which covers 7.2 percent of the State's land area (U.S. Census Bureau 2010). While this percentage of urban land is modest compared to that of southern New England (38 percent), it is above the national average (3.0 percent). The city of Manchester and surrounding towns and suburbs in the south account for a large proportion of New Hampshire's urban area (Fig. 70). Urban area grew slightly in New Hampshire between 2000 and 2010 and is projected to increase 10.5 percent by the year 2060 (Nowak and Greenfield 2018b).

With the goal of characterizing New Hampshire's urban tree resource and its associated benefits and values, FIA will be focusing data collection within the city of Manchester and will establish a less intensified plot sample in urban areas across the whole State. Annualized inventory monitoring will begin in Manchester in summer 2020, with tree and site field data being collected on approximately 200 sample plots within the city. Data collection on these plots will be spread out over a 7 year cycle; thus one-seventh of the plots will be visited each year and remeasurement will occur every seventh year.



**Figure 70.**—Distribution of census urban areas and proposed target city for intensified urban Forest Inventory and Analysis sampling in New Hampshire.

The urban FIA inventory in New Hampshire is still being established, so it will be several years before data are published based on this field-collected sample; however, other studies can be used to derive urban forest attributes. Nowak and Greenfield (2018a) conducted a study to quantify urban tree cover and cover change in the United States using aerial photointerpretation methods. According to their data, trees cover 56 percent of urban land in New Hampshire, which puts the State among the five states having the highest percent urban tree cover. Tree cover also remained relatively constant between 2009 and 2015.

Based on the forest cover data and various generalizations and assumptions using data specific to New Hampshire, the dollar value of a set of ecosystem services associated with the urban forest (carbon sequestration, air pollution removal, avoided energy use, and avoided emissions) was estimated and summed. The total value of these urban forest benefits in New Hampshire is estimated to be roughly \$63 million per year (Nowak and Greenfield 2018b).

## **What this means**

New Hampshire's urban areas are among the most forested in the Nation, with trees covering more than half of the state's urban land. Urban forests are important to the health and well-being of the people of New Hampshire, and the ecosystem services they provide have both ecological and economic value. For these reasons, along with constant forest changes due to such forces as development, storms, aging forests, insects and diseases, tree planting, and natural regeneration, it is especially important to monitor the urban forest resource and quantify changes in its structure, composition, and health. With implementation of the urban inventory program in New Hampshire, FIA will soon be able to provide sample-based estimates of urban forest structure and associated ecosystem services and value data for Manchester and will be poised to monitor changes through time.

Urban inventory data for cities with completed cycles are available on the Urban Data Mart (<https://apps.fs.usda.gov/fia/urban/datamart.html>) and posted for interactive data exploration on the My City's Trees App (<http://tfsfrd.tamu.edu/mycitystrees>). More information on the FIA program, including field guides, and a national implementation status map are available on the Urban FIA Web Site (<https://www.fs.fed.us/research/urban/fia.php>).



Spruce/fir forest and flower-filled meadow in the White Mountains. Photo by Randall Morin/ USDA Forest Service.

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# Appendix

## Common and Scientific Names of Tree Species Mentioned in this Report

Common name	Scientific name
balsam fir	<i>Abies balsamea</i>
striped maple	<i>Acer pensylvanicum</i>
red maple	<i>Acer rubrum</i>
sugar maple	<i>Acer saccharum</i>
yellow birch	<i>Betula allegheniensis</i>
sweet birch	<i>Betula lenta</i>
paper birch	<i>Betula papyrifera</i>
hickory	<i>Carya</i> spp.
American beech	<i>Fagus americana</i>
white ash	<i>Fraxinus americana</i>
black ash	<i>Fraxinus nigra</i>
green ash	<i>Fraxinus pennsylvanica</i>
eastern hophornbeam	<i>Ostrya virginiana</i>
red spruce	<i>Picea rubens</i>
jack pine	<i>Pinus banksiana</i>
red pine	<i>Pinus resinosa</i>
eastern white pine	<i>Pinus strobus</i>
quaking aspen	<i>Populus tremuloides</i>
pin cherry	<i>Prunus pensylvanica</i>
black cherry	<i>Prunus serotina</i>
white oak	<i>Quercus alba</i>
northern red oak	<i>Quercus rubra</i>
northern white-cedar	<i>Thuja occidentalis</i>
basswood	<i>Tilia</i> spp.
eastern hemlock	<i>Tsuga canadensis</i>

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The second full remeasurement of the annual inventory of the forests of New Hampshire was completed in 2017 and covers more than 4.7 million acres of forest land, with an average volume of over 2,300 cubic feet per acre. The data in this report are based on 1,162 plots located across New Hampshire. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 52 percent of total forest land area. Of the forest land, 64 percent consists of large diameter trees, 25 percent contains medium diameter trees, and 11 percent contains small diameter trees. The volume of growing stock on timberland has continued to increase since the 1980s and currently totals nearly 9.5 billion cubic feet. The average annual net growth of growing stock on timberland from 2012 to 2017 was over 180 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, species composition, regeneration, and forest health. Sets of supplemental tables are available online at <https://doi.org/10.2737/NRS-RB-119> and contain: 1) tables that summarize quality assurance and 2) a core set of estimates for a variety of forest resources.

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

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