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Abstract

The second full remeasurement of the annual inventory of the forests of Vermont was completed in 2017 and covers nearly 4.5 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 1,125 plots located across Vermont. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 71 percent of total forest land area. Of the forest land, 70 percent consists of large diameter trees, 23 percent contains medium diameter trees, and 7 percent contains small diameter trees. The volume of growing stock on timberland has continued to increase since the 1980s and currently totals nearly 9 billion cubic feet. The average annual net growth of growing stock on timberland from 2012 to 2017 was nearly 160 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, timber products, species composition, regeneration, and forest health. Sets of supplemental tables are available online at https://doi.org/10.2737/NRS-RB-120 and contain summaries of quality assurance data and a core set of estimates for a variety of forest resources.

Acknowledgments

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Cover: Fall color at Lake Dunmore in Addison County, Vermont. Photo by Erica Houskeeper, Vermont Sustainable Jobs Fund, used with permission.

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Randall S. Morin, Brett J. Butler, Susan J. Crocker, Joshua Halman, Cassandra M. Kurtz, Tonya W. Lister, William H. McWilliams, Mark D. Nelson, Rachel I. Riemann, Brian F. Walters, and Christopher W. Woodall

Questions about information found in this report should be directed to randall.s.morin@usda.gov.

About the Authors

Randall S. Morin is a research forester with the Forest Inventory and Analysis (FIA) program, Northern Research Station, Wyndmoor, PA.

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

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

Joshua Halman is a forest health specialist with the Vermont Department of Forests Parks, and Recreation, Essex Junction, VT.

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

Tonya W. Lister is a research forester with the FIA program, Northern Research Station, York, PA.

William H. McWilliams is a retired research forester with the FIA program, Northern Research Station, in Pennsylvania.

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

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

Foreword

The landscape of Vermont has experienced 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, 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 Vermont, so decisions and actions we make today need to be informed by accurate and timely data.

The Vermont Department of Forests, Parks and Recreation is pleased to be a partner of the USDA Forest Service in the Forest Inventory and Analysis of Vermont. The more we know about and understand 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.

Michael Snyder
Vermont State Forester

Contents

Highlights

On the Plus Side

- Vermont is proportionally the fourth most forested state in the United States.
- Participation in Vermont's use value appraisal program has increased, which may help reduce the amount of forest land converted to other uses.
- Changes in stocking of forest land area toward more moderately and fully stocked stands suggest that forest management practices over the past three decades have improved the general stocking condition across Vermont.
- Most forest carbon in the region is found in moderately 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 Vermont are at near record levels since the first inventory in 1948.
- The 0.9 percent tree mortality rate for the 2017 inventory is similar to what was reported for the 2012 inventory and slightly lower than what was reported for the 2007 inventory.
- Tree crowns are generally healthy and stable across Vermont.
- The ratio of growth to removals of 2.1:1.0 in Vermont indicates that growth is adding twice as much volume as is getting removed by harvesting each year.

Areas of Concern

- Commercial and residential development of forest land, particularly in the Champlain Valley, has resulted in reductions in forest land use. Vermont has lost forest land at rate of about 0.5 percent per year over the last 5 years.
- The predicted transfer of 1.5 million acres of family forest land foreshadowed by the age (65+) of many owners is an important trend to monitor as the fate of forests may change when forest land is passed to the next generation of owners.
- The total volume of sawtimber in Vermont has decreased slightly since 2012, mostly due to the decrease in forest land.

Photo at left: Forester Diana Frederick, looks up at birch trees marked for a timber sale at Smuggler's Notch State Forest in Cambridge, VT. Photo by Erica Houskeeper, Vermont Sustainable Jobs Fund, used with permission.

- 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 Vermont
- The proportion of ash basal area with poor crowns has more than doubled since 2012, but the relative amount is still low at 6 percent.
- The presence of nonnative invasive plant species sampled on FIA Phase 2+ plots has remained stable since the 2012 inventory and appears to be correlated with reduced densities of tree seedlings.

Issues to Watch

- The continuing 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 Vermont needs continued monitoring.
- Although wood volume continues to accumulate as the forests mature, less than one-third is low-grade material that is suitable and available for use as whole tree chips for large wood fuel users for which there is increasing demand.
- The volume of timber resources in Vermont has started to decrease for the first time since USDA Forest Service's Forest Inventory and Analysis (FIA) program began forest inventories in Vermont in 1948. The slight decrease in timberland acres, along with 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 likely 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 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 Vermont in the future include hemlock woolly adelgid and emerald ash borer.
- The risk of catastrophic economic and ecological loss of forest resources could increase because of 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 Vermont.
- The lack of natural or manmade disturbance continues to limit pioneer and other shade intolerant species that thrive in sunnier forested conditions.
- Tree damage was observed on 32 percent of trees and internal decay on 12 percent of trees in Vermont. This may indicate reduced tree health and timber quality.
- Urbanization is affecting an increasing amount of forest area in Vermont. A total of 0.9 million acres (21 percent forest land) was in wildland-urban interface (WUI) conditions by 1990, and between 1990 and 2010 forest land was being converted to WUI conditions in most counties at rates greater than 5 percent per decade.

Fall color in the Green Mountains near Stratton, VT. Photo by Erica Houskeeper, Vermont Sustainable Jobs Fund, used with permission.

Background

Heath Bunnell, master logger and avid mountain biker, rides with Caledonia County forester Matt Langlais. Photo by Erica Houskeeper, Vermont Sustainable Jobs Fund, used with permission.

Data Sources and Techniques

The forests of Vermont 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 Vermont 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 visits to 1,125 plots located across Vermont. Previous forest inventories in Vermont were completed in 1948 (McGuire and Wray 1952), 1965 (Kingsley and Barnard 1968), 1973 (Frieswyk and Malley 1985, Kingsley 1977), 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 Vermont in 2003 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 across the Nation that allows for comparisons to be made among states and regions. The most recent inventory period was conducted in from 2011 to 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. P2 plots consist of four 24-foot fixed-radius subplots on which standing trees are inventoried. This sampling design results in 1,125 long-term inventory plots in Vermont. 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 less 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 statistics and quality assurance report (Gormanson et al. 2018). A glossary of terms used in this report can be found at https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary; tables summarizing results for Vermont are available at https://doi.org/10.2737/NRS-RB-120.

An Overview of Forest Inventory

What is a tree?

Trees are perennial woody plants with central stems and distinct crowns. The FIA program 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 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 Vermont, about 95 percent of all forest land is classified as unreserved and productive timberland and 5 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 of growth.
- 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 20 cubic feet per acre per year.

- In earlier inventories, FIA measured trees only on timberland plots and did not report wood 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 an 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 Vermont?

Forest land in Vermont contains approximately 825 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 1125 (927 forested) plots. For information on sampling errors, see 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 consistent estimates across time and space–a primary objective for FIA. Regression models were developed for tree height and percent cull to reduce random variability across datasets.

Before the Component Ratio Method (CRM) was implemented, volume and biomass were estimated using separate sets of equations (Heath et al. 2009). With 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 deadwood, and down woody debris.

Another new method, 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 the 5.0-inch threshold. 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 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

Picturesque lake in Green Mountains near Stratton, VT. Photo by Erica Houskeeper, Vermont Sustainable Jobs Fund, used with permission.

Dynamics of the Forest Land Base

Background

Vermont's diverse, forested landscape includes the transition from the maple/beech/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 area 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 of the 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 forest-type groups.

What we found

Forests dominate the land cover across most of Vermont. The percentage of forest cover generally increases from west to east (Fig. 1), mostly due to the belt of agricultural land in the Champlain Valley in the northwestern part of the State. In 1948 when FIA completed its first inventory in Vermont, only 63 percent of the State's area was forested. Subsequent inventories showed a steady increase in forest cover as lands were reforested due to the abandonment of farmland. Vermont's forested land base increased rapidly between the 1940s and 1970s and continued to increase, although at continually slower rates, until reaching its peak in the 1990s (Fig. 2). Much of the nearly 1 million acre increase in forest land over that period was due to farmland reverting back into forest through natural regeneration, although a substantial portion of lost farmland was also developed to meet the needs of a growing population. These reverted forests increased the total forest land area in Vermont and nearly offset losses of forest land to development. Since 1997, the area of forest cover has declined by about 130,000 acres, but nearly 100,000 acres of that loss has occurred since 2007 (Fig. 2). Currently, Vermont is about 76 percent forested.

The forest land base in Vermont is composed of predominately hardwood forest types. The maple/beech/birch forest-type group comprises 71 percent of the forest land in the State, and nearly 70 percent of Vermont's forest land is in large-diameter stands (Figs. 1, 3).

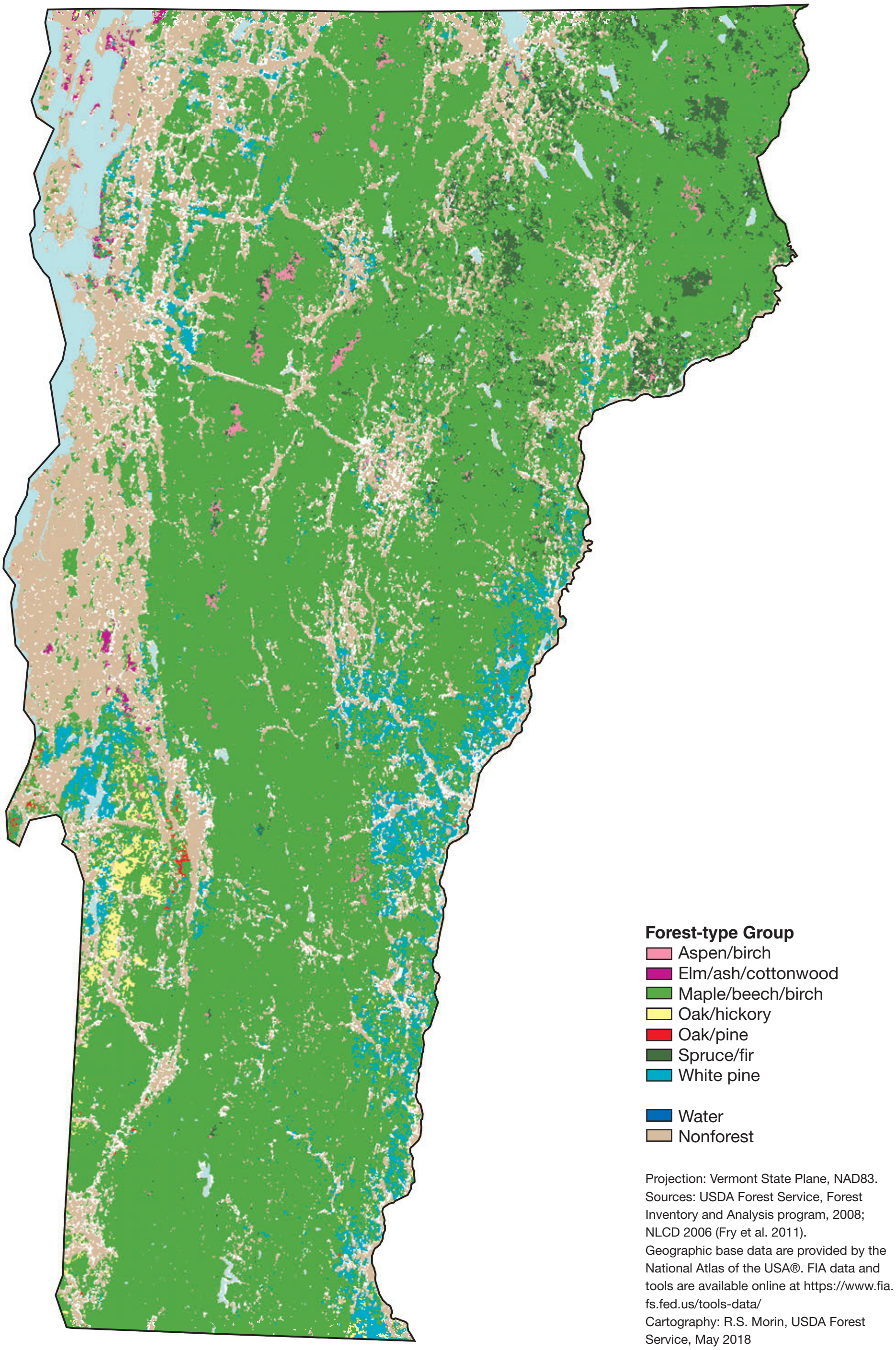

Figure 1.—Distribution of forest type-groups, Vermont, 2008. Data are available at http://data.fs.usda.gov/geodata/rastergateway/forest_type/index.php.

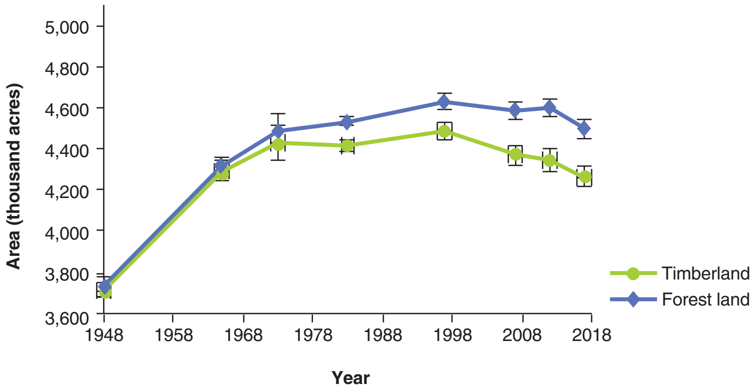

Figure 2.—Area of forest land and timberland by inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

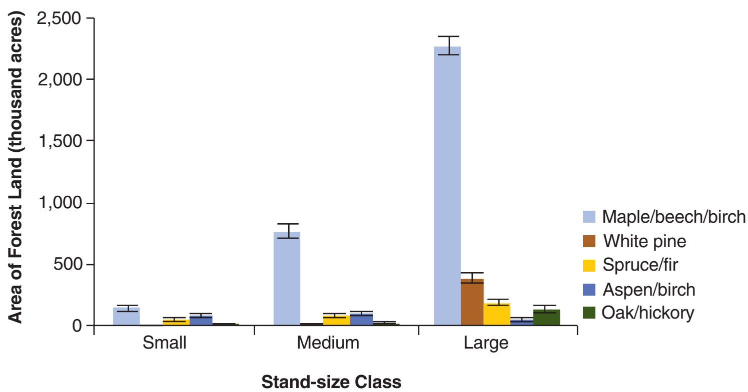

Figure 3.—Area of forest land for the five most common forest-type groups by stand-size class, Vermont, 2017. Error bars represent a 68 percent confidence interval around the mean.

What this means

With forests covering 76 percent of the land, Vermont is, by proportion, the fourth most forested state. Statewide estimates of forest land have decreased by about 3 percent over the last two decades, but most of this decrease has occurred over the last 5 years. The largest proportional losses in forest land over this period occurred in Bennington, Caledonia, Franklin, and Rutland Counties. Future changes in Vermont's forest land base will depend on the pace of land development, particularly in the northwestern and southern parts 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 year and that is not legally restricted from being harvested is classified as timberland. If harvesting is restricted on forest land by statute or administrative decision, then it is designated as reserved regardless of its productivity class. The harvesting intentions of private forest landowners are not used to determine the reserved status. The category, other forest land, is made up of forest land that is unreserved and low in productivity.

What we found

Ninety-five percent of the forest land of Vermont meets the definition of timberland (Fig. 2), and 83 percent of that timberland is in private ownership. Estimates of the amount of timberland have decreased by nearly 5 percent since 1997. Most of the land in the reserved class is in designated natural areas and is located on the Green Mountain National Forest (Fig. 4). Other forest land (i.e., unreserved and unproductive) is rare and accounts for less than 1 percent of total land (Fig. 5).

What this means

Because the vast majority of the forest land in Vermont 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.

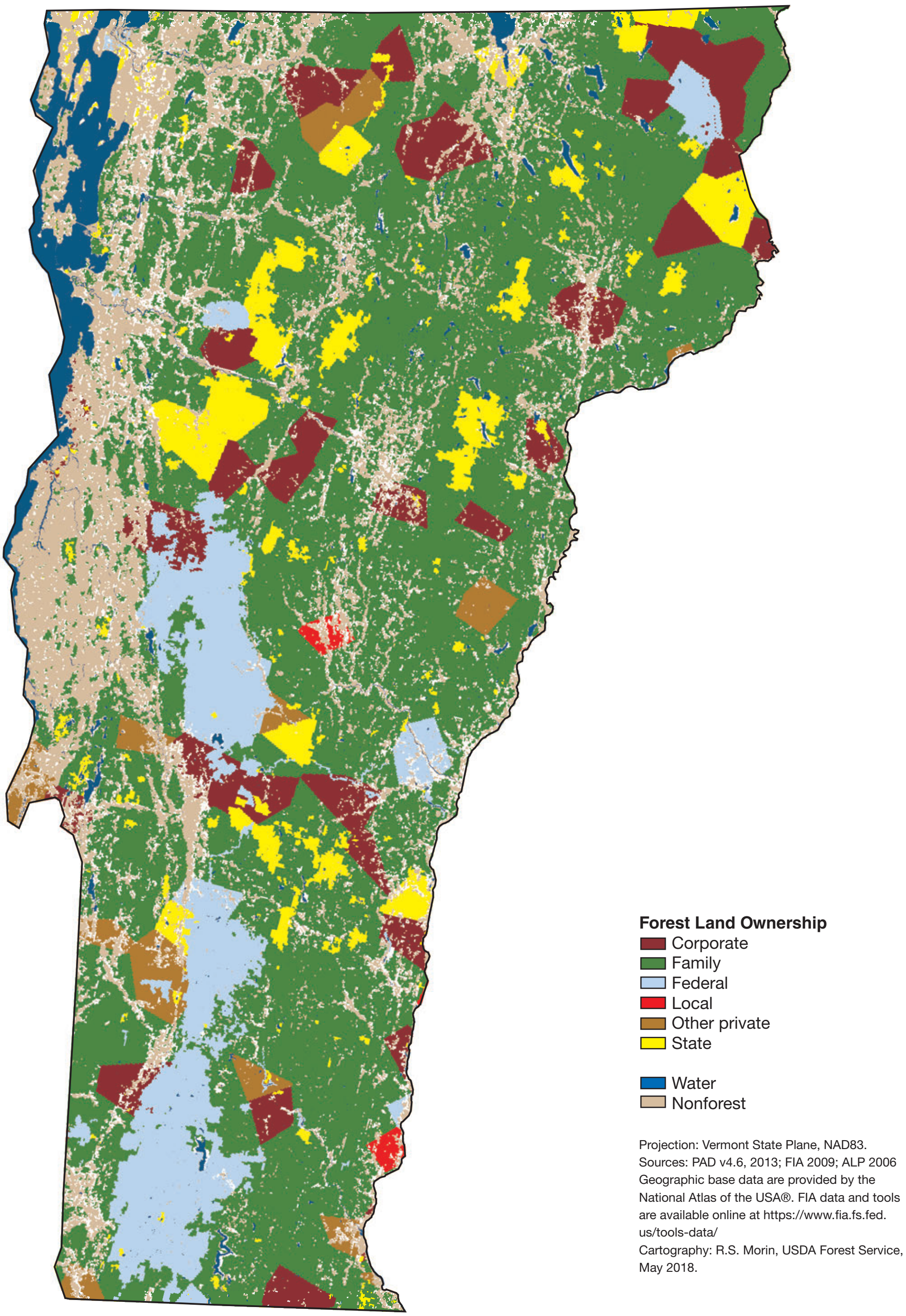

Figure 4.—Distribution of forest land by owner group, Vermont, 2013.

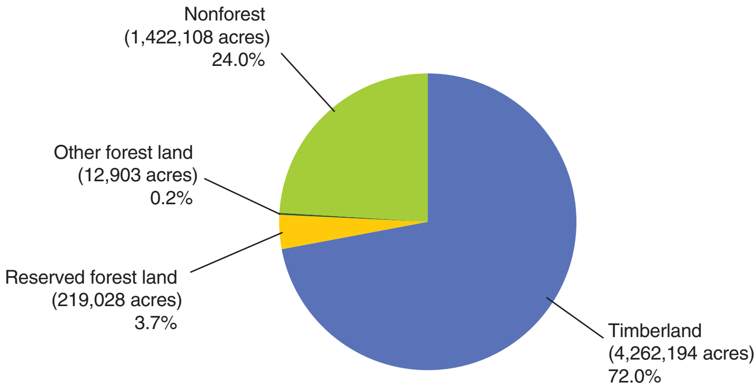

Figure 5.—Distribution of forest land by category, Vermont, 2017.

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 land owners, the forest conservation community can better help owners meet their needs, and in so doing, help conserve the State's forests for future generations. The National Woodland Owner Survey (NWOS; 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 440 family forest ownerships from Vermont that participated between 2011 and 2013 (Butler et al. 2016).[1] 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, 2011-2017, FIA inventory.

[1] Data for the 2017-2018 NWOS are currently being collected with results anticipated for release in the near future.

What we found

General Ownership Patterns

An estimated 79 percent (3.5 million acres) of the forest land of Vermont is privately owned. About 69 percent these private acres, an estimated 2.7 million acres, are owned by family forest owners. Details about this group are discussed below. Corporations own an estimated 710,000 acres and other private owners, including conservation organizations and unincorporated clubs and partnerships, own an estimated 110,000 acres.

Public owners control 21 percent of Vermont forest land. The Federal government manages an estimated 500,000 acres of forest land, much of this in the Green Mountain National Forest. State forest, park, and wildlife agencies are stewards of another 360,000 acres of forest land. Local governments control an estimated 70,000 acres of forest land in the State.

Between 2006 and 2017 the estimated acreage owned by family and other private forest owners decreased by 9 and 42 percent, respectively. Other ownership categories realized increases in land area by 8 to 45 percent (Fig. 6).

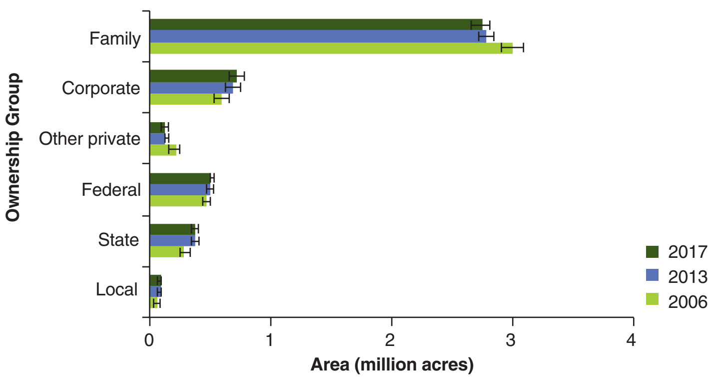

Figure 6.—Area of forest land by ownership group, Vermont, 2006, 2013, and 2017.

Family Forest Ownerships

As of 2013, the date of the latest available data[1], there are an estimated 40,200 family forest ownerships (standard error [SE]=2,600) across Vermont that each own at least 10 acres of forest land. This group controls a collective 2.5 million acres (note that approximately 200,000 acres are owned by family forest owners that own less than 10 acres of forest land). The family forest acreage decreased by 10 percent since 2006, but the number of ownerships remained relatively stable (i.e., changed by less than 1 percent). The average forest holding size of this group decreased from 70.3 acres per ownership (SE = 8.5 acres) to 63.1 acres per ownership (SE=4.4). As of 2013, 65 percent of these family forest ownerships own less than 50 acres of forest land, but 77 percent of the family forest land is in holdings of at least 50 acres (Fig. 7).

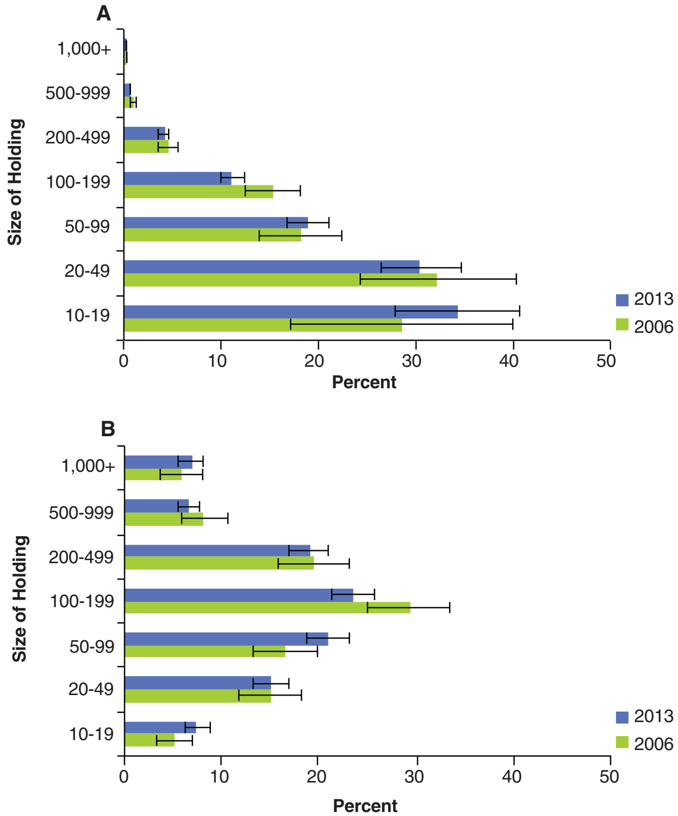

Figure 7.—Percentage of family forest ownerships (A) and acres of forest land (B) by size of forest land holdings, Vermont, 2006 and 2013. Error bars represent a 68 percent confidence interval around the mean.

The primary reasons for owning forest land are related to amenity values, such as aesthetics, nature, privacy, and wildlife (Fig. 8). Much less frequently cited are objectives related to financial values, including timber production and land investment. 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. 9). Due to changes in

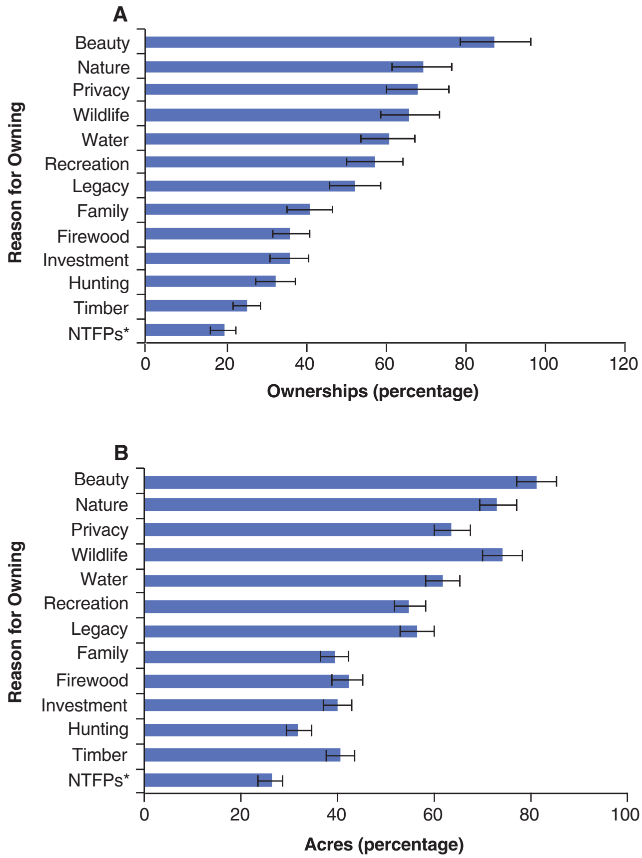

Figure 8.—Percentage of family forest ownerships (A) and acres of forest land (B) by reasons for owning forest land ranked as very important or important, Vermont, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the mean. *Nontimber forest products (NTFPs).

wording of the question, it is not possible to directly compare responses to the 2013 NWOS questions on ownership objectives to those in the 2006 NWOS.[2]

Although the percentages are higher in Vermont than for most other states, most family forest ownerships have not participated in traditional forestry management and assistance programs in the past 5 years (Fig. 10). Forty-two percent of the ownerships in Vermont, owning 62 percent of the family forest land, reported receiving forest management advice in the past 5 years. Thirty-six percent of the ownerships, owning 66 percent of the family forest land, reported participating in the State's tax program. This is likely part of the reason for the higher percentage

[2] More concerted efforts were made to keep the questions as consistent as possible between the 2013 and the forthcoming 2018 iterations of the NWOS to allow for more direct analyses of changes over time.

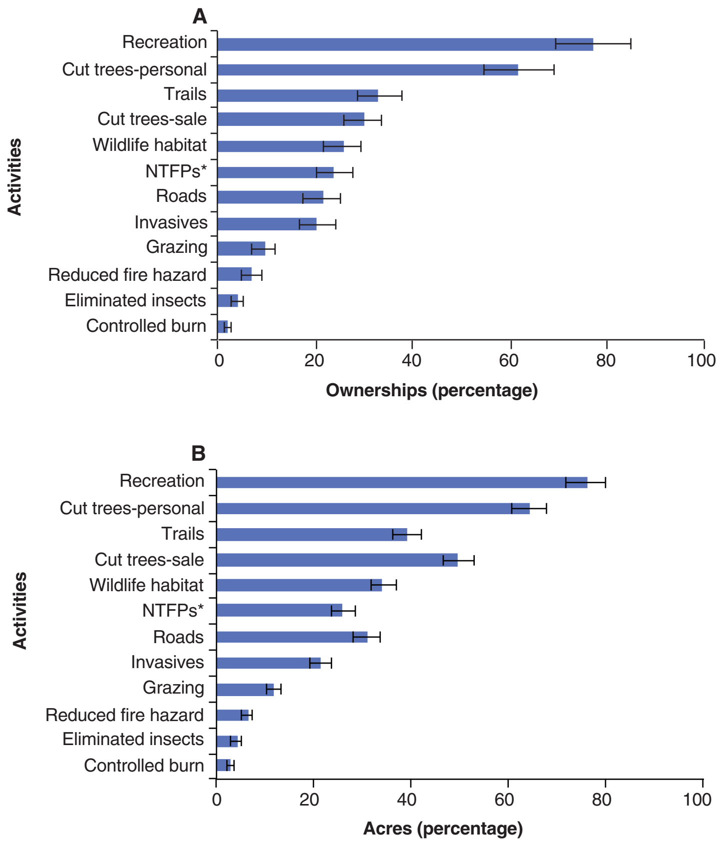

Figure 9.—Percentage of family forest ownerships (A) and acres of forest land (B) by activities in the past 5 years, Vermont, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the mean. *Nontimber forest products (NTFPs).

of ownerships with a management plan, 37 percent of the ownerships who own 65 percent of the family forest land, as compared to most other states. Again, comparisons between the 2006 and 2013 iterations of the NWOS are unfortunately not feasible due to changes in question wording.[2]

The average age of family forest owners in Vermont is 58.8 years (SE=6.5 years). Thirty-nine percent of the forest land is owned by people 65 or older (Fig. 11). Between 2006 and 2013, there was a decrease in the percentage of owners 75 or older and a marked increase in owners 55 to 64 years old.

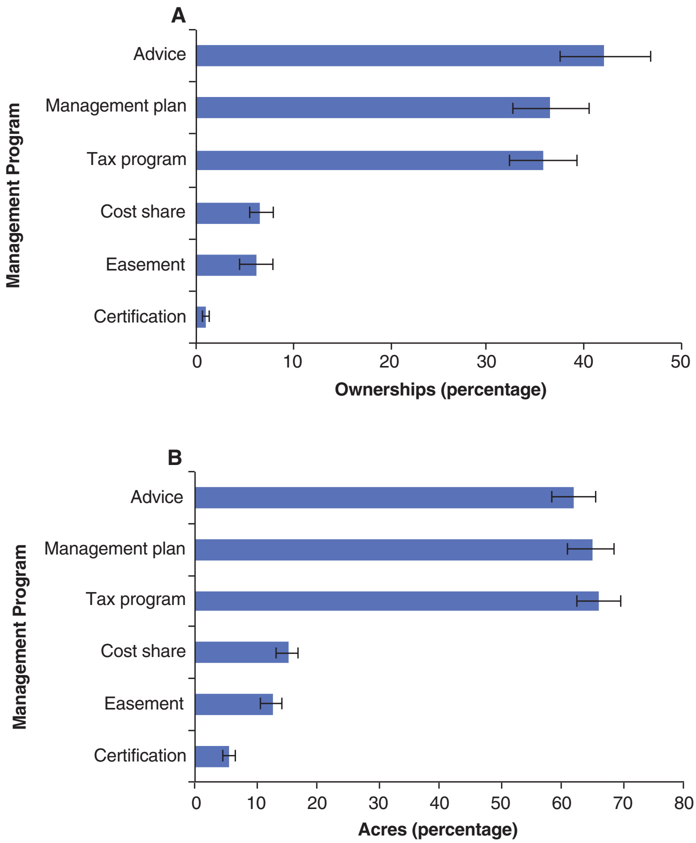

Figure 10.—Percentage of family forest ownerships (A) and acres of forest land (B) by participation in forest management programs, Vermont, 2013. Categories are not exclusive. Error bars represent a 68 percent confidence interval around the mean.

What this means

The fate of the forests lies primarily in the hands of those who own and control the land. Therefore, it is 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 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 have written forest managements plans is higher compared to most other states, there are still significant opportunities to help these owners increase their engagement and stewardship of their lands. Programs such as Tools for Engaging Landowners Effectively (http://www.engaginglandowners.org) can

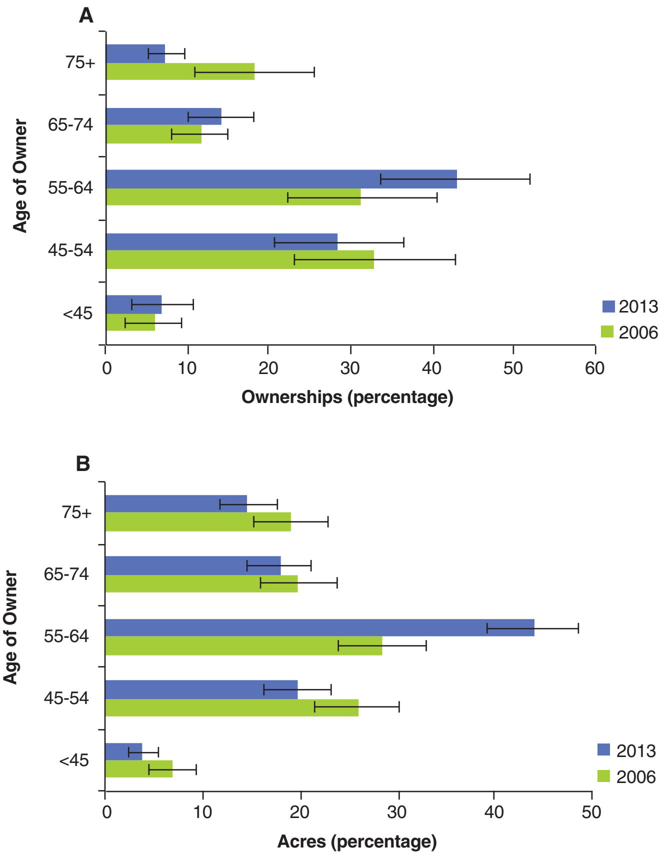

Figure 11.—Percentage of family forest ownerships (A) and acres of forest land (B) by age of primary owner, Vermont, 2006 and 2013. Error bars represent a 68 percent confidence interval around the mean.

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 owners being relatively advanced in age, this portends many acres of land passing on to the next generation in the not too distant future. There are programs such as Your Land Your Legacy (http://masswoods.net/monthly-update/your-land-your-legacy-deciding-future-your-land) and Ties to the Land (http://tiestotheland.org) that 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 76 percent of the land area in Vermont, 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 Vermont 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 Vermont 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 Vermont's forest resources and helps land managers make informed policy decisions.

What we found

Forest land area in Vermont comprises about 4.5 million acres. Agricultural land uses, along with urban, water, and other nonforest land uses, cover 1.7 million acres of the States' surface area. Between 2012 and 2017 most of the land use in Vermont either remained forested (82.5 percent) or stayed in a nonforest land use (16.3 percent). The total area of forest land in Vermont remained relatively stable between inventories, with a 0.44 percent average annual rate of decline. For mapping purposes, change plots are defined as remeasured plots having land-use gain or loss of at least 25 percent. Forest loss plots are distributed throughout the State, with forest gain plots being less numerous and constrained to the northern half of the State (Fig. 12).

On the 1.2 percent of surface area where land use changed between inventories (Fig. 13), 70,000 acres of forest were diverted to nonforest and 25,000 acres of nonforest land that reverted to new forest land. Overall, there was a net loss in forest land area (Fig. 14).

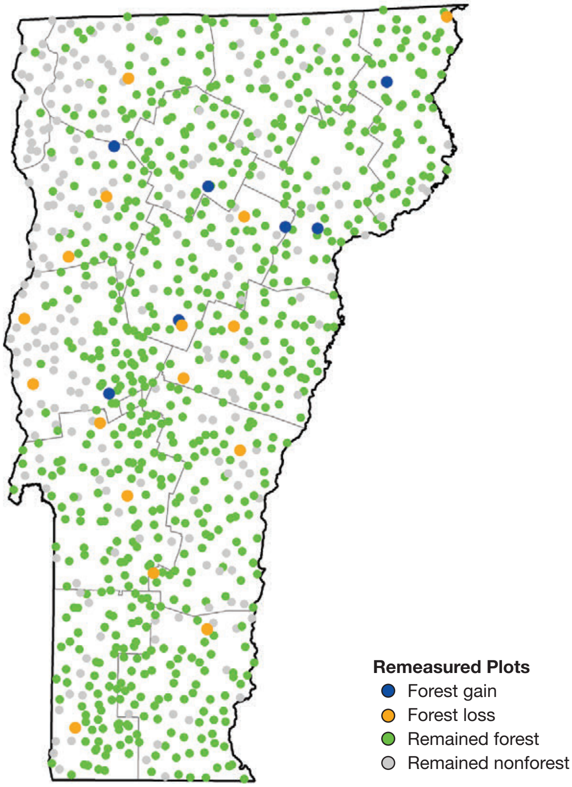

Figure 12.—Approximate locations of remeasured FIA plots showing forest gain, forest loss, remained forest, and remained nonforest, Vermont, 2008-2012 to 2011-2017.

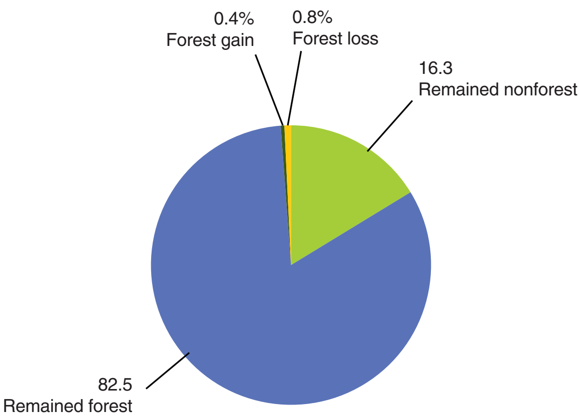

Figure 13.—Land use dynamics showing percentage of unchanged land, forest loss, and forest gain, Vermont, 2008-2012 to 2011-2017.

Forty-eight percent (34,000 acres) of the gross forest loss was due to diversion to agriculture (Fig. 14). Forest loss also resulted from forest land converted to developed land use (27,000 acres or 37 percent), other land uses (10,000 acres or 14 percent), and water (less than 1 percent). Fifty-one percent of forest gain in Vermont was from developed land converting to forest (12,000 acres). Other sources for new forest land included agricultural land (9,000 acres or 37 percent), and other sources (3,000 acres or 12 percent) (Fig. 14).

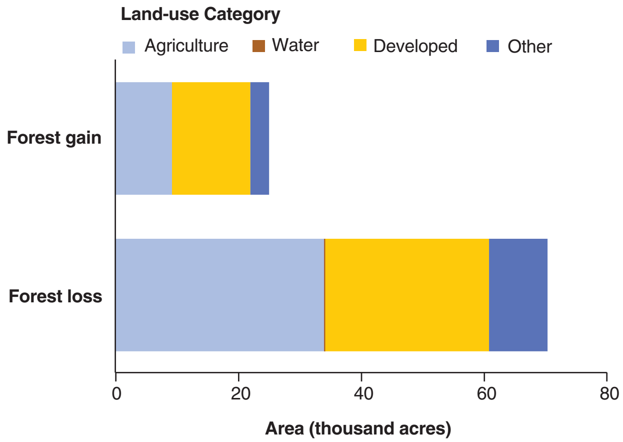

Figure 14.—Gross area forest loss and forest gain by land-use category, Vermont, 2008-2012 to 2011-2017.

What this means

The net loss of forest land reported in this inventory is small. Gains and losses from multiple causes are driving land-use change dynamics in Vermont. 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 provide 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 of 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 to 9 percent), poor (10 to 34 percent), moderate (35 to 59 percent), full (60 to 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 Vermont, the distribution of forest land by stand-size class continues a trend toward larger diameter stands. Since 1997, there has been a decrease in the area of medium and small diameter stands and an increase in the area of large diameter stands (Fig. 15). 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 (McGuire and Wray 1952). Large diameter stands increased from 51 percent to 67 percent of the timberland area in Vermont between 1948 and 2017 (Fig. 16).

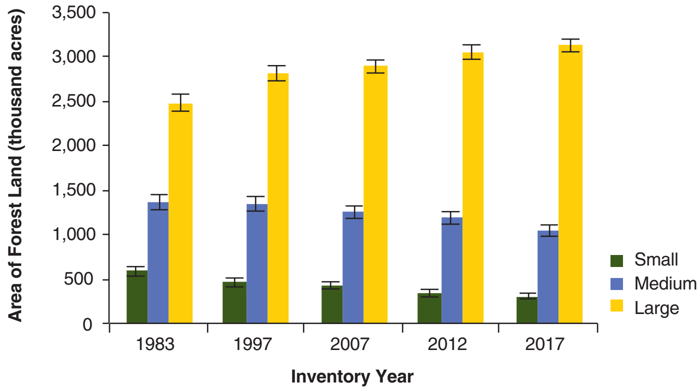

Figure 15.—Area of forest land by inventory year and stand-size class, Vermont. Error bars represent a 68 percent confidence interval around the mean.

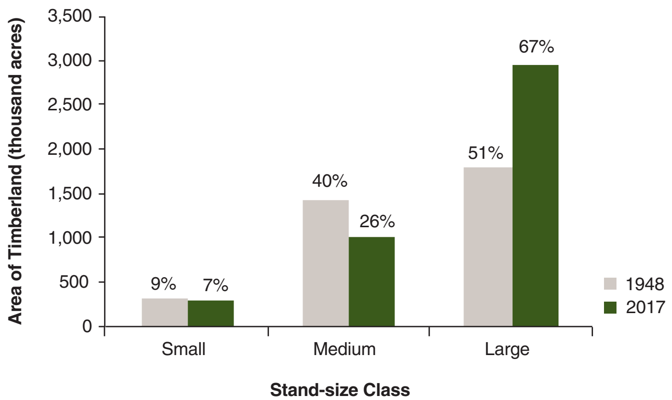

Figure 16.—Area of timberland and percentage of total by stand-size class and inventory year, Vermont.

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, area of stands considered overstocked has decreased in Vermont (Morin et al. 2011). However, since 2007, the distribution of forest land area among stocking classes has remained stable (Fig. 17). Only 32 percent of stands are less than fully stocked in Vermont as of 2017. A comparison of nonstocked or poorly stocked stands for all live trees (Fig. 17) and growing-stock trees (Fig. 18) in 2017 reveals that the area is 2.5 times greater for growing-stock trees in Vermont (622,000 to 247,000 acres). This indicates that

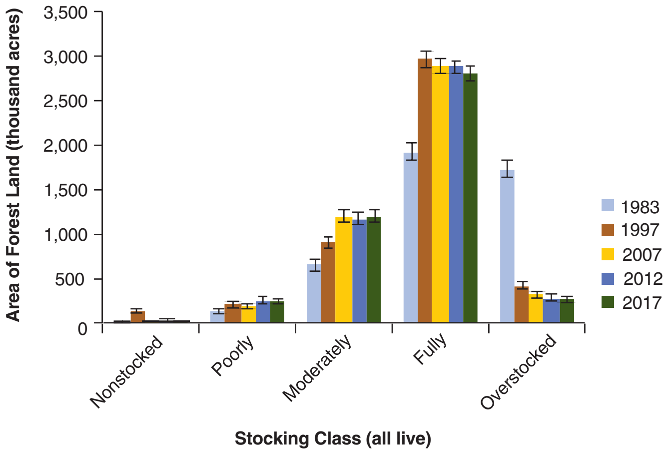

Figure 17.—Area of forest land by stocking class of all live trees and inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

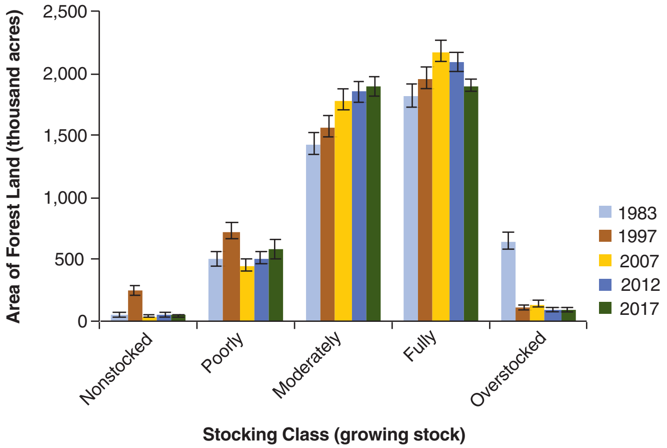

Figure 18.—Area of forest land by stocking class of growing-stock trees and inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

Vermont has over one-half million acres that are poorly stocked or nonstocked with growing-stock trees, but half of that area is moderately, fully, or overstocked when noncommercial species and cull trees are included. In Vermont nearly 50 percent of poorly or nonstocked forest land area is less than 40 years old and 85 percent is less than 80 years old (Fig. 19). The distribution of age classes is explored further in a subsequent section. See "Forest Habitats" on page 77.

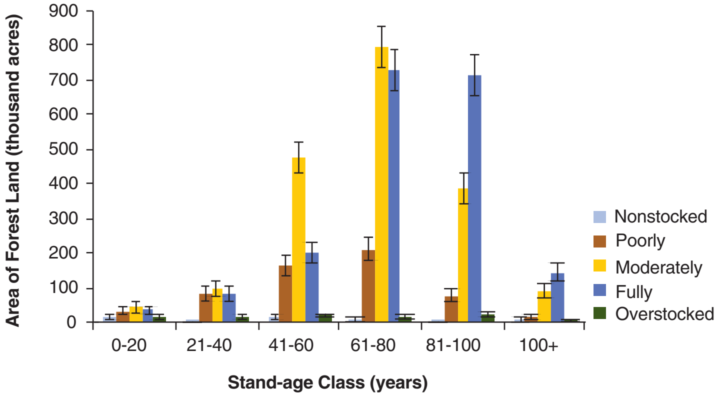

Figure 19.—Area of forest land by stand-age class and stocking class of growing-stock trees, Vermont, 2017. Error bars represent a 68 percent confidence interval around the mean.

What this means

The continuing trend of increasing forest land area in large diameter stands demonstrates the maturation of Vermont forests to stands of larger, older trees. An important component of forest biodiversity is complex structural features. The area of forest in smaller diameter stands, which is important for biodiversity and many wildlife species, is decreasing, which is a concern. Mature stands provide diverse structures due to gap dynamics and the presence of shade tolerant species in the understory, but some wildlife species depend on the habitat that is provided by young forests. The diversity of tree ages and sizes in mature forests provides a broad range of habitats for wildlife and other organisms and makes forests more dynamic and better able to recover from disturbance.

The shifts in forest area from 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). These shifts also suggest that forest management practices over the past three decades may have improved the general stocking condition across Vermont. Most 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, Vermont has a low percentage of older 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. Even though Vermont has more than one-half million acres of forest land that are poorly or nonstocked with commercially important species, which represents a loss of potential growth, these forests do contribute to biodiversity. However, the higher light levels and open growing conditions in these poorly or nonstocked stands may make them more susceptible to invasion by nonnative plant species (e.g., common barberry [*Berberis vulgaris*] and 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 growing-stock 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. 20). In general, the percentage increase in the number of trees by diameter class increased with diameter class other than for the largest class (Fig. 21).

For growing-stock trees with a d.b.h. of 5 inches and larger, the most numerous tree species continues to be sugar maple.[3] Among the most abundant species in Vermont, sugar maple, red maple, eastern hemlock, American beech, red spruce, eastern white pine, and paper birch decreased slightly in overall numbers between 2012 and 2017. Balsam fir and white ash increased slightly in number while yellow birch remained stable. Paper birch and American beech had the largest decreases in number of growing-stock trees by percentage; both species decreased by more than 10 percent (Fig. 22).

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[3] Scientific names for all tree species are listed in the appendix.

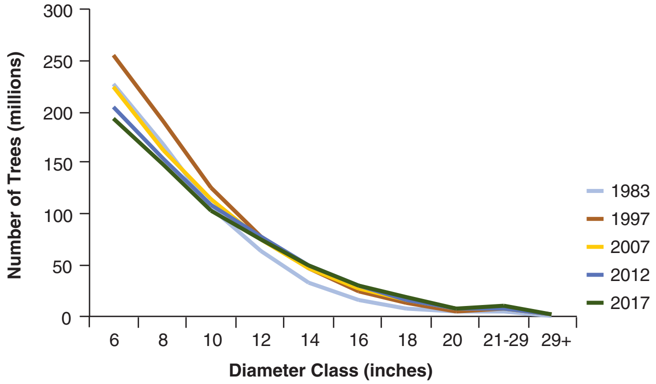


Figure 20.—Number of growing-stock trees on timberland by diameter class and inventory year, Vermont.

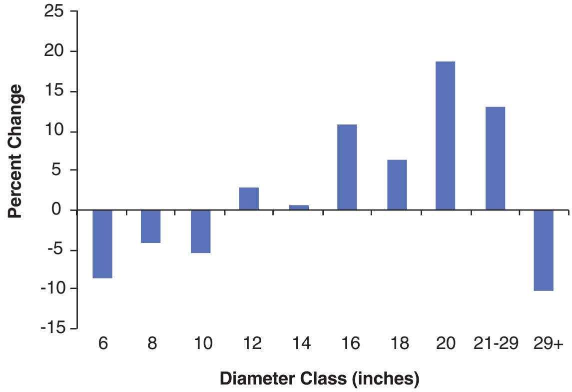


Figure 21.—Percentage change in the number of growing-stock trees by diameter class, Vermont, 2012 to 2017.

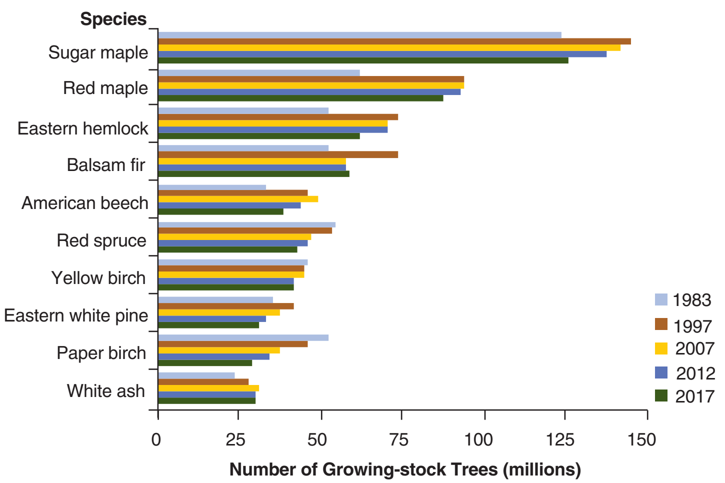


Figure 22.—Number of growing-stock trees on timberland and percent change from 2012 to 2017 by species and inventory year, Vermont.

Numbers of sapling-size trees (1 to 4.9 inches d.b.h.) also decreased for most of the abundant tree species in Vermont, but balsam fir and white ash saplings increased. All noncommercial species collectively continue to be the most abundant saplings, though their numbers decreased by 7 percent between 2012 and 2017. American beech is the most abundant individual sapling species in Vermont but after many years of increases the number has remained stable since 2012. The largest proportional increase in number of saplings was in balsam fir (6 percent). Tree species that decreased in number of saplings were sugar maple, red maple, eastern hemlock, yellow birch, and paper birch. Most species followed the same pattern that was observed between 2007 and 2012 (Morin et al. 2011). The exception was red spruce where the number of saplings decreased by 5 percent between 2012 and 2017 after increasing by 5 percent between 2007 and 2012 (Fig. 23).

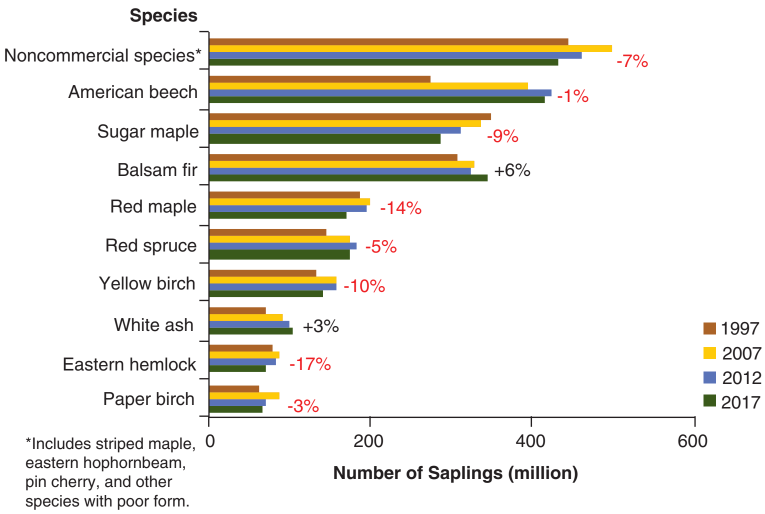


Figure 23.—Number of saplings (1 to 4.9 inches in d.b.h.) on timberland and percentage change 2012 to 2017, by species and inventory year, Vermont.

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 die. The increasing dominance of American beech in Vermont will have an impact on the future species composition of Vermont forests. Similarly, balsam fir is increasing in understory dominance. The high relative sapling abundance of noncommercial species may be a concern for timber management. Additionally, with the threat of emerald ash borer

(*Agrilus planipennis*) impacting ash survival in the future, increases in ash saplings may be an emerging issue for forest resources.

Carbon Stocks

Background

Among terrestrial ecosystems, forests contain the largest reserves of stored carbon. The accumulation of carbon in forests helps to mitigate emissions of carbon dioxide to the atmosphere from sources such as wild fires 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. About 50 percent of tree biomass is carbon, based on dry weight of the tree components. 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 Vermont are an estimated 540.3 million short tons. This represents a 1 percent decrease in total forest carbon stocks since 2012. Soil organic carbon and live trees are the largest pools and collectively account for 90 percent of forest carbon (Fig. 24). Sixty-nine percent of Vermont's forest carbon stocks are in stands between 61 and 100 years old. Considerably less carbon is found in stands younger than 61 years old (25 percent) and older than 100 years (6 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. 25). The maple/beech/birch forest-type group contains most of the total forest carbon (73 percent or more than 390 million short tons), as it covers a large amount of the forest land (Fig. 26A). On a per-acre basis, however, carbon density is highest in the oak/hickory forest-type group (127 short tons per acre), followed by the maple/beech/birch forest-type group (123 short tons per acre) (Fig. 26B).

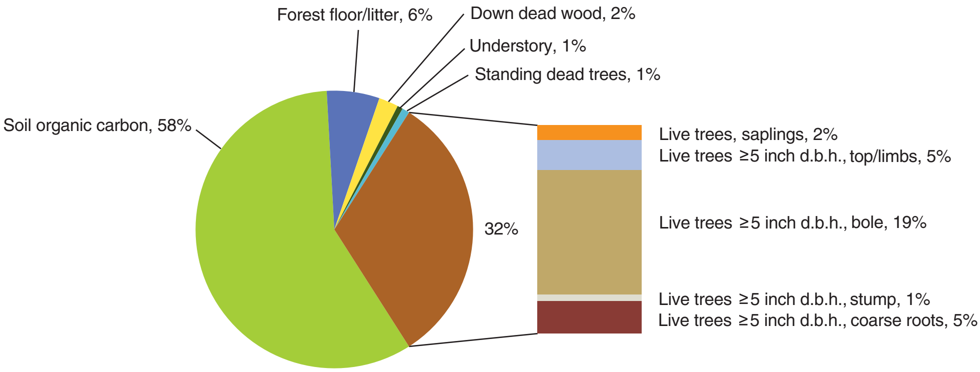


Figure 24.—Carbon stocks on forest land by forest ecosystem component, Vermont, 2017.

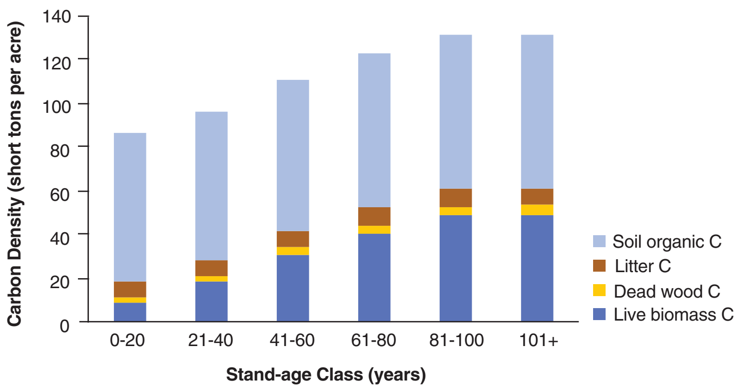


Figure 25.—Carbon density of live biomass and dead wood and litter components on forest land by stand-age class, Vermont, 2017.

What this means

Forest carbon stocks in Vermont have decreased slightly since 2012, with the main driver being the loss of forest land. 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. 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.

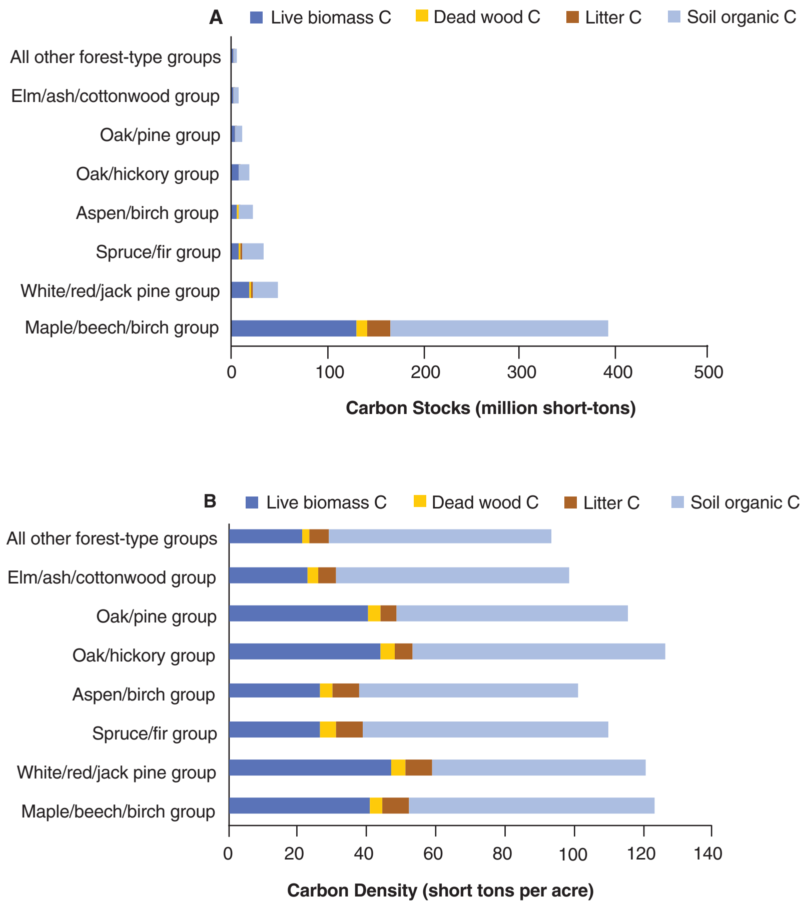


Figure 26.—Carbon stocks by forest-type group (A), and carbon density by forest-type group (B), Vermont, 2017.

Biomass

Background

Estimates of biomass are a critical component of the FIA program because of the increasing interest in carbon dynamics for issues related to carbon sequestration, emission reduction targets, production of biofuels, and forest fire fuel loadings. 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, Vermont forests contribute significantly to the sequestration uptake) and storage of carbon.

What we found

The forest land of Vermont has an estimated 286.8 million dry tons of aboveground tree biomass, with biomass averaging 63.8 tons per acre of forest land. The distribution of biomass on forest land is generally highest in southern Vermont (Fig. 27). Sixty-three percent (~275 million tons) of the aboveground biomass is in the boles of growing-stock trees, but this is also the part of the tree resource that can be converted into valuable wood products. The other 37 percent of the biomass is in tops, limbs, stumps, cull trees, or trees of noncommercial species (Fig. 28).

Total live dry biomass on timberland has increased by 48 percent since 1983 (131.4 to 193.9 million dry tons), primarily due to the increasing size of sawtimber trees in Vermont. By contrast, biomass decreased in the smaller, poletimber-size trees during this time period (Fig. 29).

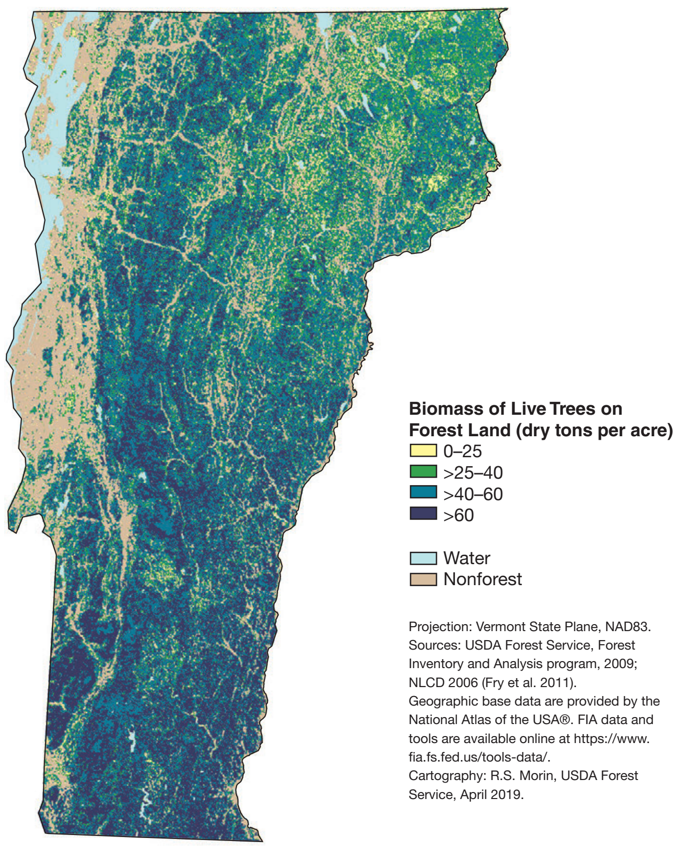


Figure 27.—Live-tree biomass density of trees at least 1 inch d.b.h., Vermont, 2009.

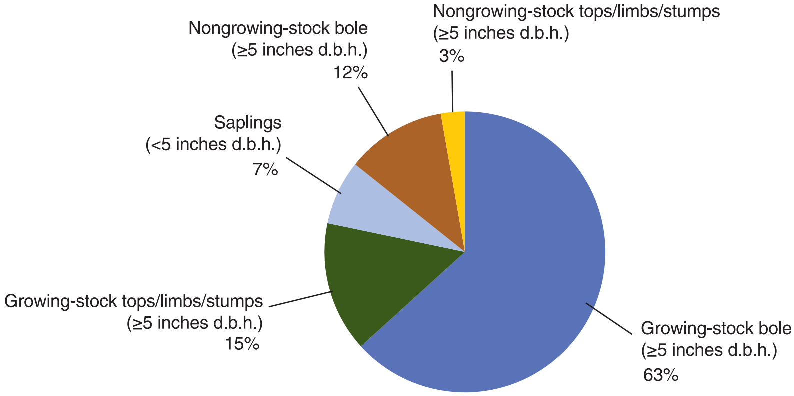


Figure 28.—Percentage of live-tree biomass (trees 1 inch d.b.h. and larger) on forest land by aboveground component, Vermont, 2017.

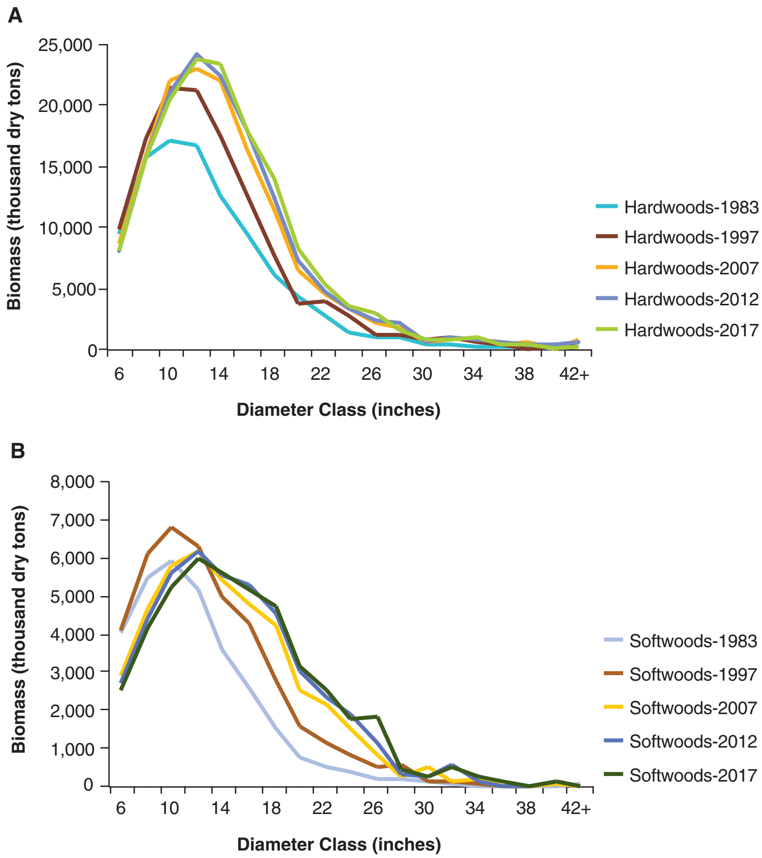


Figure 29.—Distribution of live-tree biomass (trees at least 1 inch d.b.h.) in hardwoods (A) and softwoods (B) on timberland by diameter class, and inventory year, Vermont.

What this means

The forests of Vermont 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 suitable and available for use as whole tree chips for large wood fuel users. If the demand for wood fuel increases with higher demand for heating, power production, and (potentially) the production of liquid fuels, the wood-using market would become more competitive. This would create an opportunity for enhancing forest management practices to benefit both traditional forest products supplies and those for bioenergy. The Biomass Energy Resource Center (BERC) produced a detailed report on supply and sustainability of available low grade wood for Vermont and the adjacent counties in New Hampshire, Massachusetts, and New York (BERC 2019).

Private forest landowners are the holders of 77 percent of the forest biomass in Vermont. Thus they play an important role in sustaining this resource. Currently, forest landowners are not financially compensated for the carbon sequestration and storage 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 wood fuel 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 merchantable volume up to a 4-inch top for commercial trees 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 valuable 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 Vermont has increased steadily since the 1960s. The 2017 estimate of 8.7 billion cubic feet is a substantial increase from the 1983 inventory, although the trend has levelled off over the past two decades and is now beginning to decline. The slight decrease in growing-stock volume between 2012 and 2017 is in contrast to the 1 to 4.5 percent annual increases in previous decades (Fig. 30). Distribution of growing-stock volumes by diameter class from the current and four previous inventories reveal a steady shift toward larger diameter trees (Fig. 31). The current (2017) inventory data indicate that volume increased in nearly all d.b.h. classes greater than 14 inches, but decreased in the 6-, 8-, 10-, and 12-inch diameter classes (Fig. 32).

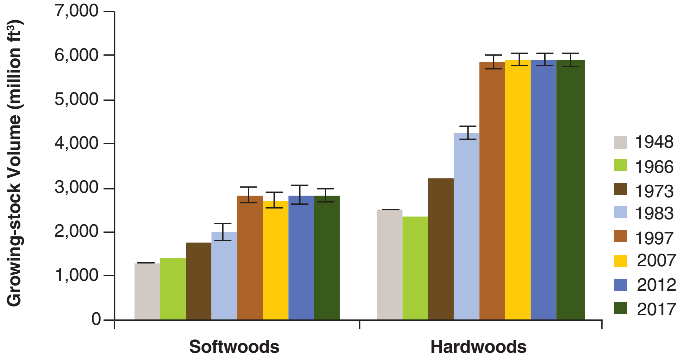


Figure 30.—Growing-stock volume on timberland by species group and inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

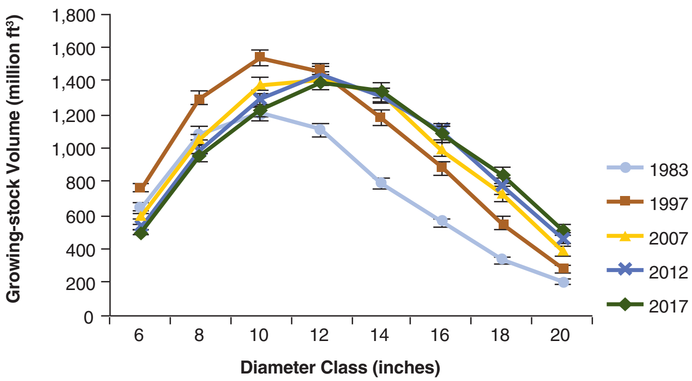


Figure 31.—Growing-stock volume on timberland by diameter class and inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

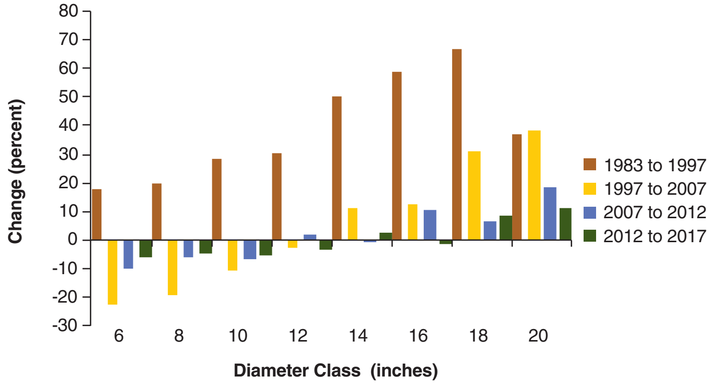
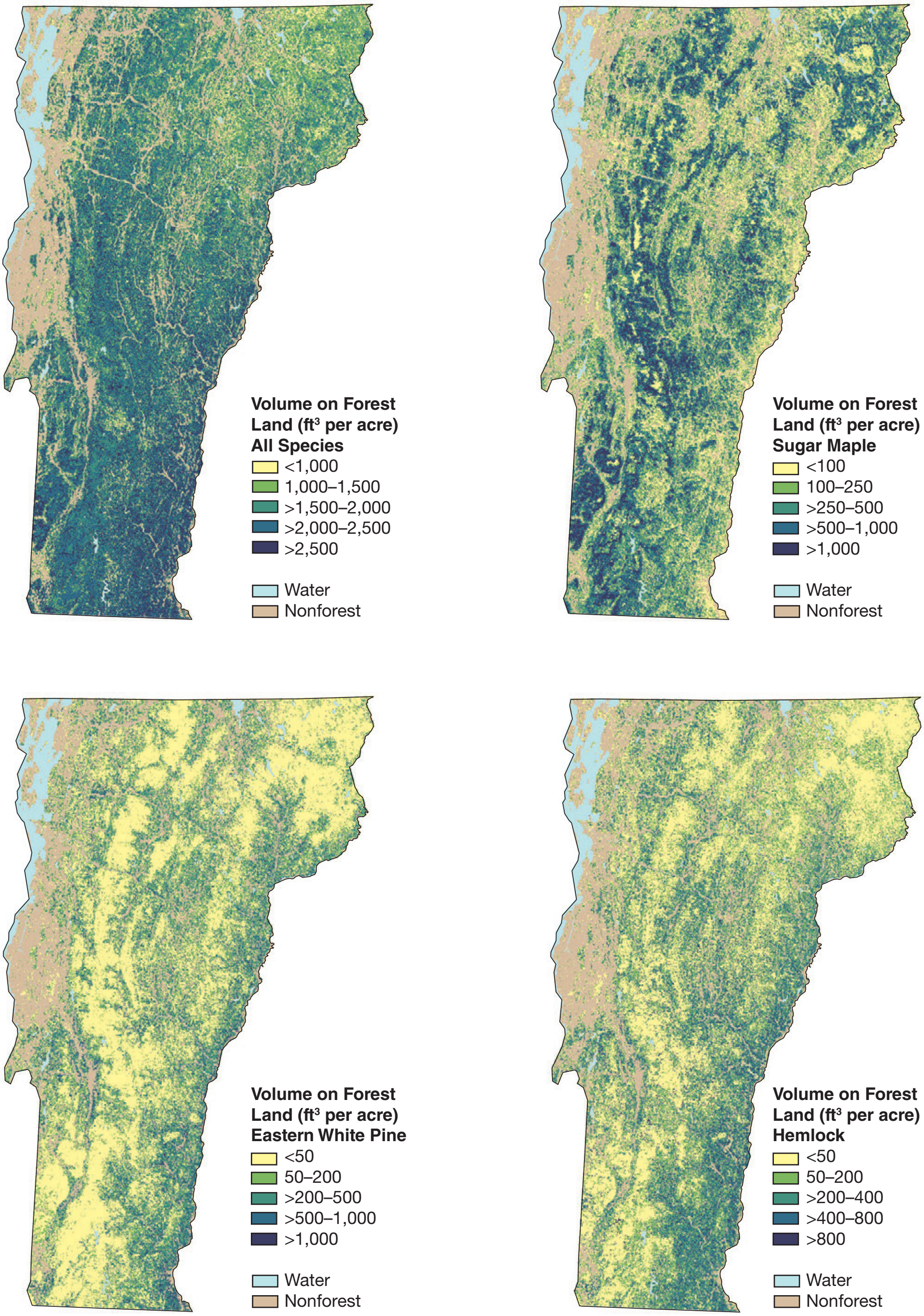


Figure 32.—Percentage change in growing-stock volume on timberland by diameter class and inventory year, Vermont.

In general, volume for each species increases from north to south, with higher volumes in the southern portion of Vermont and along the ridges of the Green Mountains to the north (Fig. 33). Per-acre volume varies spatially by species. Sugar maple density is highest in the Green Mountains of Vermont. 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 Vermont.

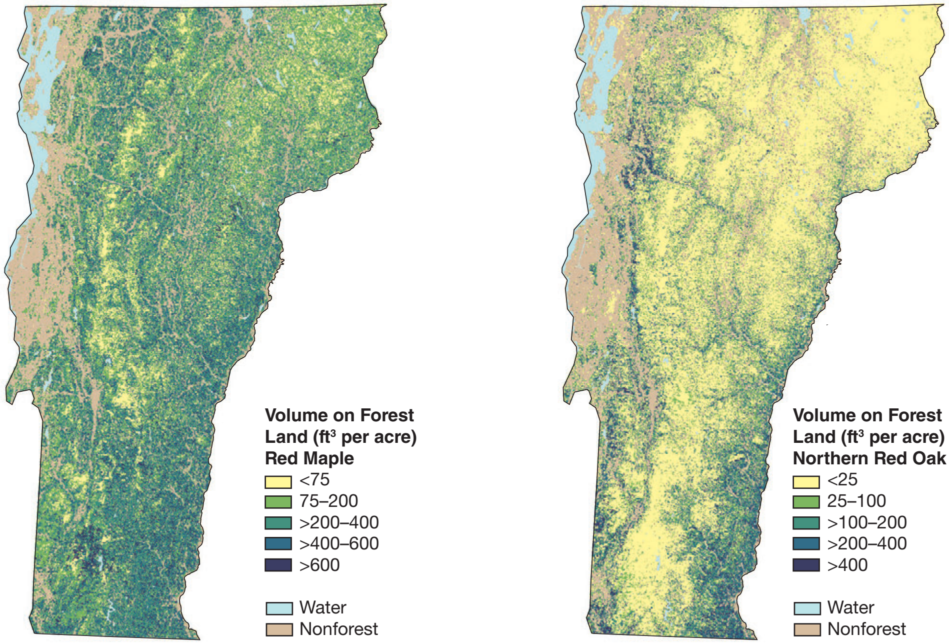
The distribution of growing-stock volume on timberland in Vermont averages 2,050 cubic feet per acre. Of this volume, 68 percent is in hardwood species and 32 percent is in softwood species. Sugar maple (34 percent), red maple (19 percent), yellow birch (10 percent), and white ash (9 percent) make up over 70 percent of the hardwood growing-stock volume. Eastern hemlock (34 percent), eastern white pine (31 percent), red spruce (16 percent), and balsam fir (13 percent) account for over 90 percent of softwood growing-stock volume.

Overall, sugar maple has nearly twice the amount of growing-stock volume as the next most abundant species, red maple, followed by eastern hemlock and eastern white pine. These four species make up 57 percent of the total growing-stock volume in Vermont. Species that showed modest increases in growing-stock volume between 2012 and 2017 were black cherry, balsam fir, and white ash, which all increased by about 2 percent. By contrast, quaking aspen and sugar maple both decreased by more than 5 percent (Fig. 34).



Projection: Vermont 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, December 2019.

Figure 33.—Volume per acre on forest land for major tree species (for trees at least 5 inches d.b.h.), 2009. (Continued on next page.)



(Figure 33.—Continued.)

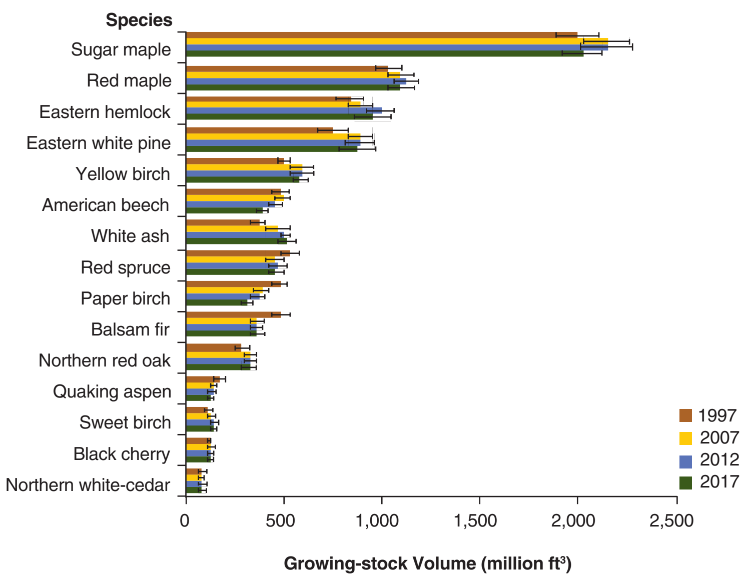


Figure 34.—Growing-stock volume on timberland by species and inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

When sawtimber volume is estimated, the order of the top four species by board-foot volume is slightly different from the order for growing-stock volume. Sugar maple remains the leading species by a large margin, but eastern white pine replaces red maple as the second most voluminous. Sugar maple makes up nearly 25 percent of the total sawtimber volume in Vermont (Fig. 35). Black cherry had the largest gain in sawtimber volume between the 2012 and 2017 inventories (8 percent). Total board-foot volume has decreased by 2 percent since 2012.

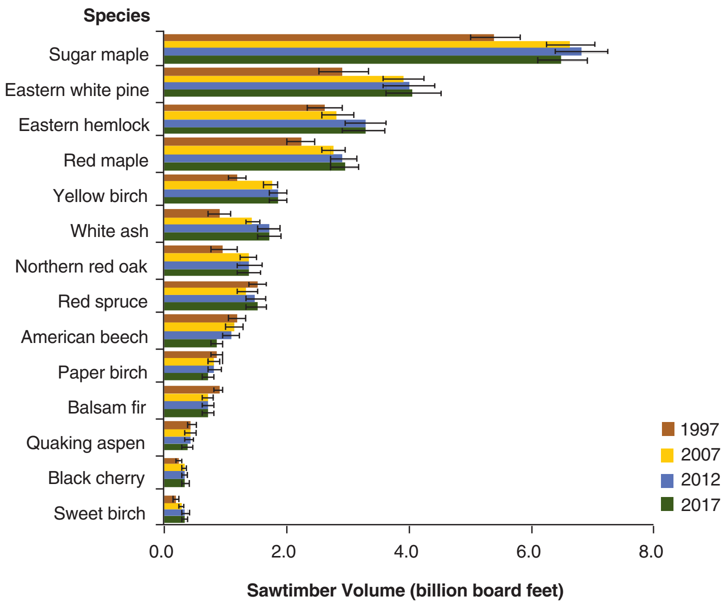


Figure 35.—Sawtimber volume on timberland by species and inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

What this means

The total volume of timber resources in Vermont has started to decrease for the first time since FIA began forest inventories in Vermont in 1948. The slight decrease in timberland area along with slowing rate of increase in 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 Vermont 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 poletimber-size trees replace 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 materials 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 by about 1.3 billion board feet in Vermont between 2012 and 2017. There are currently 6 billion board feet in tree grades 1 and 2 in Vermont. The proportion of volume in tree grades 3 and 4 increased by 5 percent between the two latest inventories (Fig. 36).

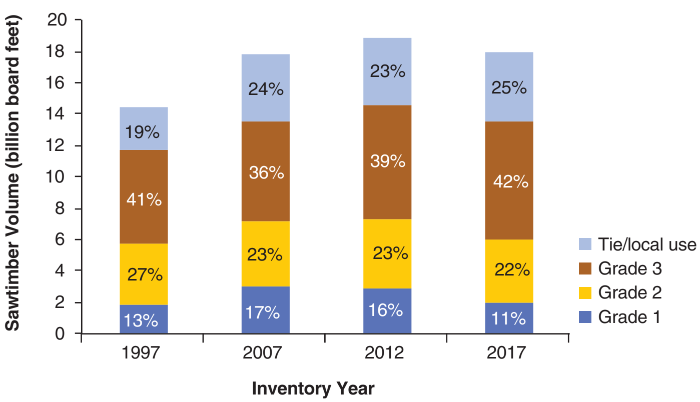


Figure 36.—Hardwood sawtimber volume by inventory year and tree grade, Vermont.

Northern red oak, eastern hemlock, red spruce, white ash, and balsam fir are the only species with more than 50 percent of their sawtimber volume in tree grades 1 and 2. Sugar maple, eastern white pine, and yellow birch have at least 30 percent of their sawtimber volume in grades 1 and 2. By contrast, red maple has less than 25 percent in grades 1 and 2, and American beech has than less than 1 percent of its sawtimber volume in grades 1 and 2 (Fig. 37).

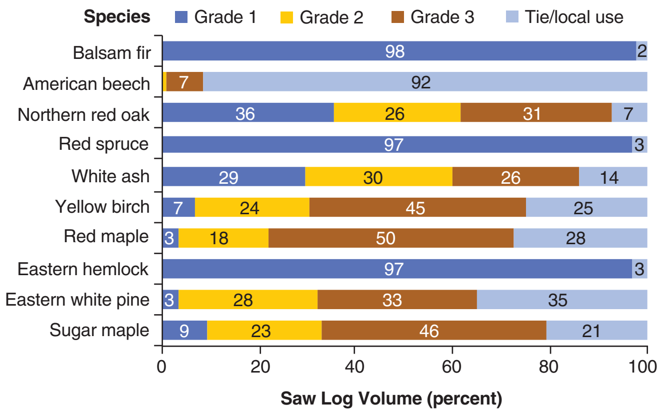


Figure 37.—Percentage of saw log volume on timberland by species and tree grade, Vermont, 2017.

What this means

The quality and volume of saw logs in Vermont have declined slightly since the last inventory, and volume also has started to decrease for most species. Changes in species composition portend 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 a highest proportion of low-grade volume, American beech, is also the most abundant sapling species in the State. Red maple has the second highest proportion of low-grade volume and is also historically a low value species.

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 impacting 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 Vermont (Fig. 38). Net growth of growing-stock trees averaged 175 million cubic feet annually as of 2017, about 1.8 percent of current growing-stock volume on timberland. In comparison to previous inventories, annual net growth as a percentage of growing-stock volume has been decreasing from 1983 to 2017 (Fig. 39). In 2017, about 66 percent of net annual growth was in hardwoods and 90 percent was on privately owned land.

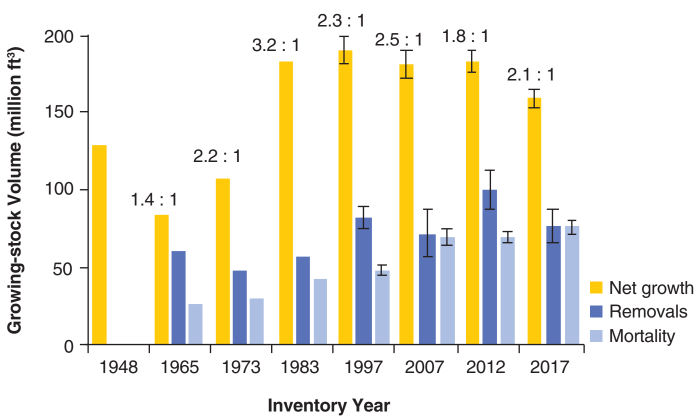


Figure 38.—Growing-stock volume and growth-to-removals ratio (above the bars) on timberland by inventory year and growth category, Vermont. Error bars represent a 68 percent confidence interval around the mean.

The nine species with the greatest growing-stock volume accounted for 89 percent of the average annual net growth of growing stock on timberland as of 2017. The ratio of net growth-to-removals averaged 2.1:1.0, which is a small increase from what was reported for 2012 (1.8:1.0). Variation between species was considerable. Net growth exceeded removals for all major species except balsam fir (Fig. 40). Northern red oak, yellow birch, eastern hemlock, and sugar maple had the highest growth-to-removals ratios at 7.5:0.0, 4.8:1.0, 3.4:1.0, and 3.3:1.0, respectively. The greatest positive changes in growth-to-removals ratio between 2012 and 2017 were in balsam fir (from -0.8:1.0 to 1.8:1.0) and yellow birch (from 1.7:1.0 to 4.8:1.0). By contrast, negative changes in growth-to-removals ratio were observed for red maple (from 2.7:1.0 to 2.4:1.0) and eastern hemlock (from 5.5:1.0 to 3.4:1.0) (Morin et al. 2015a).

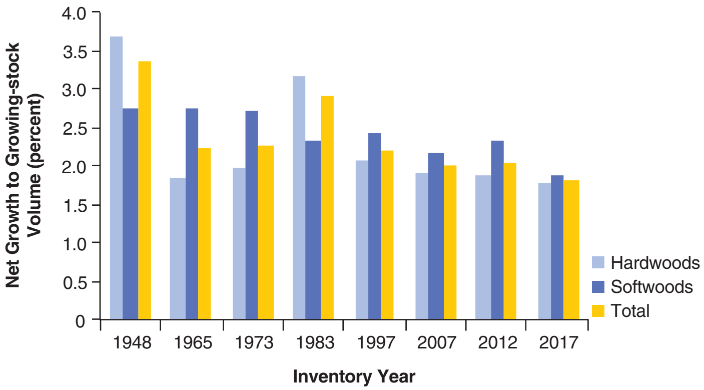


Figure 39.—Net growth of growing stock on timberland as a percentage of growing-stock volume, by inventory year and species group, Vermont.

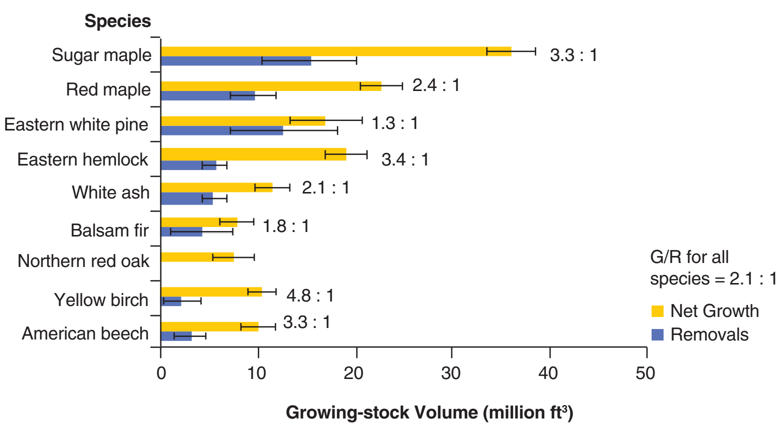


Figure 40.—Average annual net growth, removals, and growth-to-removals (to the right of the bars) ratio of growing stock for major species on timberland, Vermont, 2017. Error bars represent a 68 percent confidence interval around the mean.

What this means

The well-stocked stands in the current forests of Vermont developed as a result of the growth-to-removal ratios well above 1.0:1.0 for most of the second half of the 20th century. More recently, the forests of Vermont have matured and the rate of growth has slowed (Fig. 39). At the current rates of growth, mortality, and removals, the forests of Vermont 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 volume of removals 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 eastern white pine (1.3:1.0) suggests that this species could be decreasing in abundance. By contrast, balsam fir 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 Vermont was 76 million cubic feet, which is approximately 0.9 percent of growing-stock volume. While this is one of the highest mortality rates reported in the record of FIA inventories of Vermont, it is a small decrease compared to the rate reported for 2007. In most inventory periods, softwoods have a higher mortality rate than hardwoods, but in 2012, the hardwood mortality was higher (Fig. 41). The mortality rates are similar to other states in the region including Maine (1.0 percent) (McCaskill et al. 2011) and New York (0.9 percent) (Widmann et al. 2012).

Mortality increased for nearly all species between 1997 and 2007, but the increases were generally not statistically significant. However, between 2007 and 2017 mortality decreased back to or below 1997 levels for some species, including red spruce, sugar maple, and American beech (Fig. 42). Mortality continues to increase for paper birch,

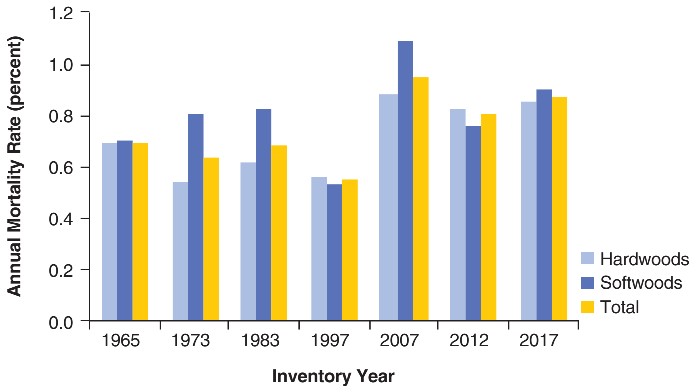


Figure 41.—Mortality of growing stock on timberland as a percentage of growing-stock volume by inventory year and species group, Vermont.

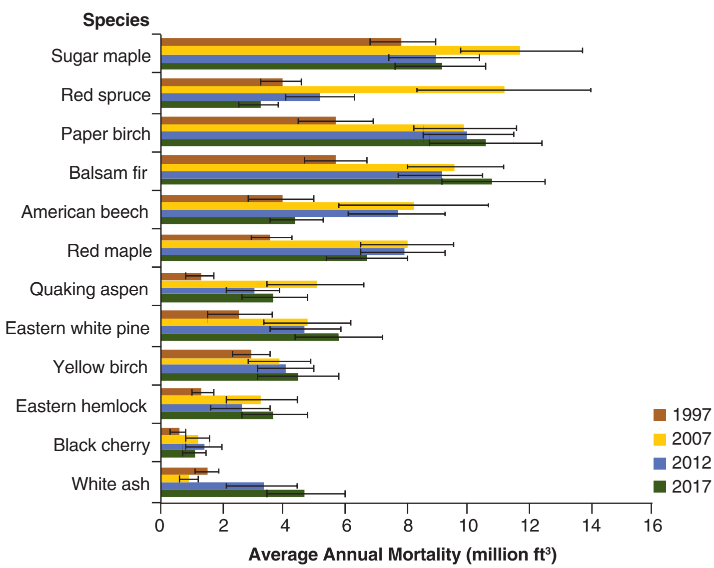


Figure 42.—Average annual mortality of growing stock on timberland for major species by inventory year, Vermont. Error bars represent a 68 percent confidence interval around the mean.

balsam fir, eastern white pine, yellow birch, and white ash (Fig. 42). Most of the abundant species in Vermont have relatively low mortality rates that are below the 0.9 percent annual average for all tree species combined. By contrast, balsam fir, paper birch, and quaking aspen have mortality rates that are more than triple the statewide averages (Fig. 43).

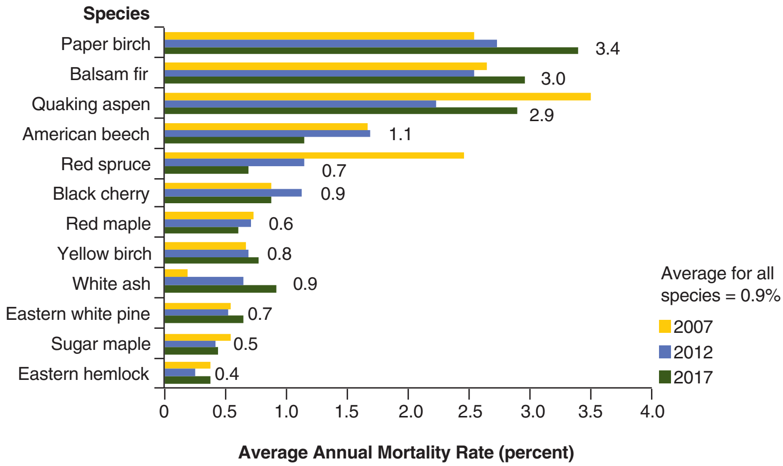


Figure 43.—Average annual mortality rate for major species by inventory year, Vermont. Mortality rate for 2017 inventory appears to the right of the bars for each species.

What this means

Tree mortality rates in Vermont 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 competition 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 Vermont have low mortality rates. But some species, such as balsam fir and paper birch, have increased mortality rates. American beech has been heavily impacted by beech bark disease for many decades and is now showing reduced mortality rates. Weather-related events that severely affected tree health during this time period 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 likely growing 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 piceaea*). 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 trees species. Causes of forest disturbance in Vermont 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 composition.

What we found

In Vermont, beech is the most numerous sapling species on forest land accounting for 16 percent of all saplings (from 1 to 4.9 inches d.b.h.), followed by sugar maple at 12 percent (Fig. 44). Noncommercial hardwoods also represent a large portion of saplings at 17 percent, which is a 1 percent increase since the 2012 inventory (Morin et al. 2015a). Striped maple is the most numerous of the noncommercial species, followed by eastern hophornbeam and pin cherry. Sugar maple is the dominant species in all diameter classes 6 inches d.b.h. and larger. Eastern white pine is poorly represented in the sapling classes (less than 1 percent), although it makes up a large portion of trees larger than 20 inches d.b.h. (Fig. 45). Other species that have a lower representation in the sapling classes compared to the larger diameter classes include eastern hemlock, red maple, and sugar maple. In addition to American beech, balsam fir, and red spruce make up a higher proportion of total saplings relative to their share of larger trees (Fig. 44).

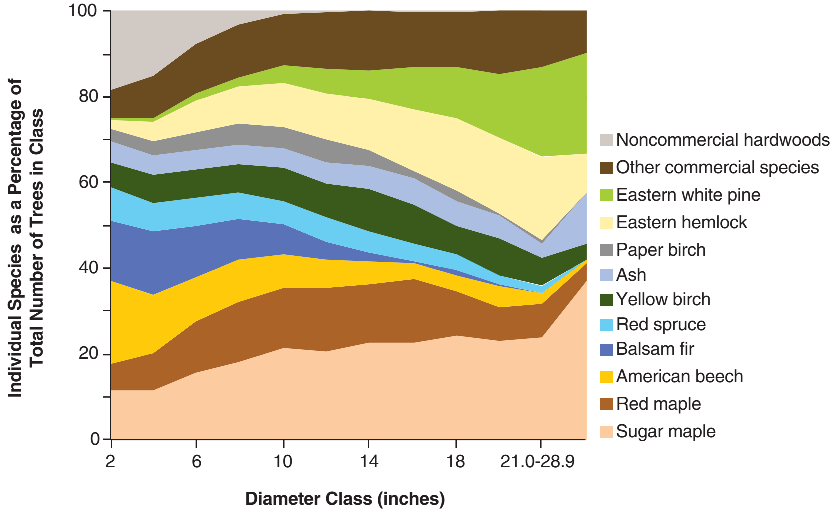


Figure 44.—Species composition by diameter class on forest land, Vermont, 2017.

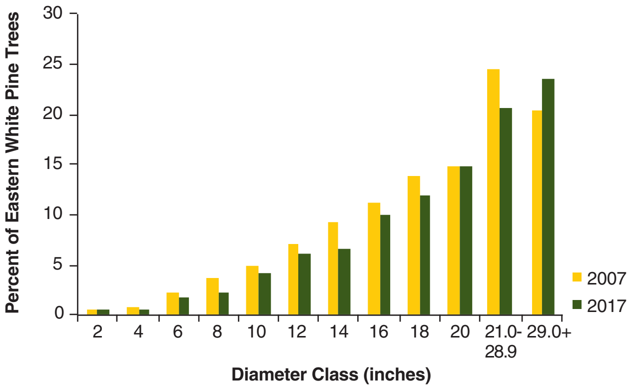


Figure 45.—Percentage eastern white pine on forest land by diameter class and inventory year, Vermont.

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 in Vermont. Besides being shade tolerant, American beech saplings may be present in large numbers as the result of root sprouts following harvesting and mortality by 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 other more valuable species. By 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 Vermont. 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 13 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 is well represented in the large diameter classes, ranking second statewide in sawtimber volume in Vermont (Fig. 35). However, it continues to decrease in numbers in all but the largest diameter classes (Fig. 45) so it will probably be replaced by other species as the larger eastern white pine trees die or are harvested. Red maple and balsam fir represent large proportions of trees in diameter classes from 4 to 14 inches. Those two species are positioned to increase in dominance in forests of Vermont 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 Vermont, but increases in those species will likely 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 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.

Ecosystem Indicators and Services

Mature maple trees on Dave Potter's property near Clarendon, VT. Photo by Erica Houskeeper, Vermont Sustainable Jobs Fund, used with permission.

Tree Crown Health and Damage

Background

The crown condition of trees is influenced by various biotic and abiotic stressors. Biotic stressors include native or introduced insects, diseases, invasive plants, 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. Vermont's 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.

Seasonal or prolonged drought periods have long been a significant and historical stressor in Vermont. Over the past 20 years, droughts have occurred in some regions during 1995, 1999, and 2001; alternatively, some of the wettest years on record were 2006, 2008, and 2011 (Fig. 46) (National Climate Data Center 2019). These extreme precipitation events directly impact tree health and can produce conditions that exacerbate insect and/or disease outbreaks.

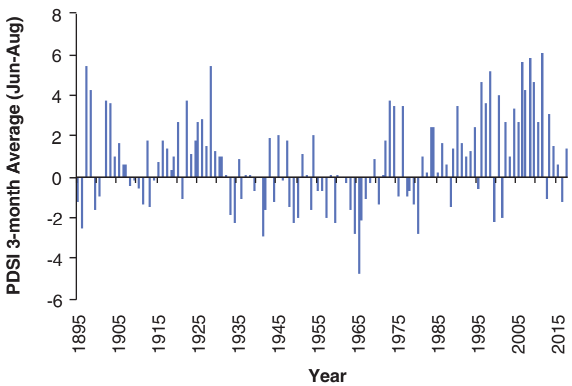


Figure 46.—Palmer Drought Severity Index (PDSI) 3-month average (June-August) showing deviation from historical average (0), Vermont, 1895 to 2017.

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 greater than 20 percent. This threshold is based on findings by Steinman (2000) that associates 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.[4]

What we found

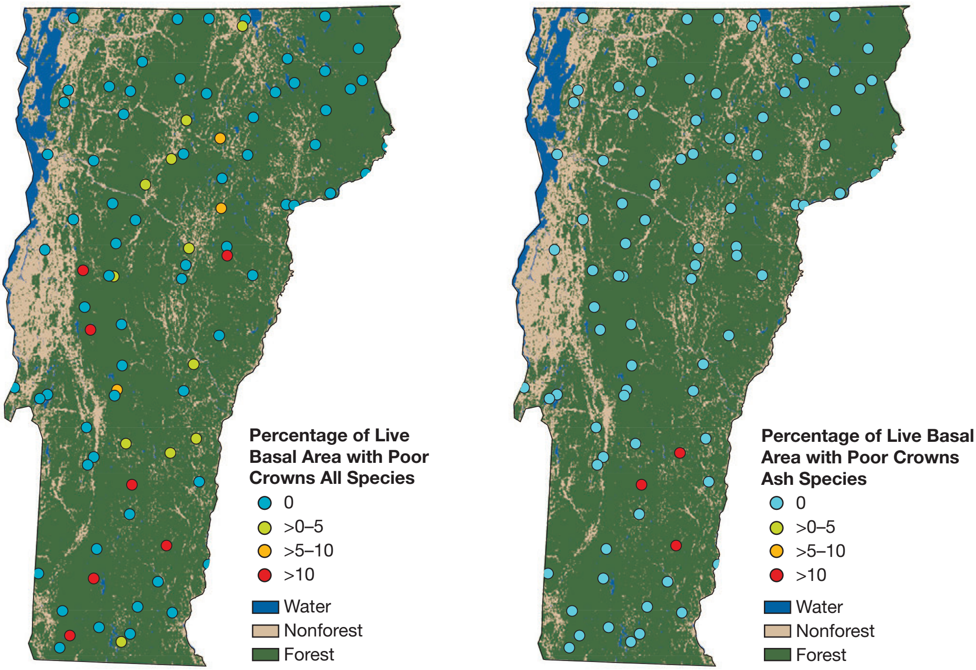
The species with the highest proportion of live basal area containing poor crowns is white ash at 6 percent. Conversely, other species have very low occurrence of poor crowns (Table 1). The incidence of poor crown condition is more common in southern Vermont (Fig. 47), particularly for ash species. Additionally, since 2012, the proportion of basal area with poor crowns only increased substantially for white ash while the proportion of basal area with poor crowns has decreased substantially for American beech since 2007 (Table 1).

Table 1.—Percent of live basal area with poor crowns by year, Vermont.

	Percent of Basal Area with Poor Crowns		
Species	**2007**	**2012**	**2017**
American beech	10.5	3.0	2.4
White ash	1.2	2.4	6.0
Eastern hemlock	2.4	1.8	1.6
Paper birch	2.5	1.2	1.5
Balsam fir	2.0	1.0	0
Red maple	2.6	1.0	0.1
Eastern white pine	0.0	0.9	0.2
Red spruce	3.5	0.6	1.1
Sugar maple	2.5	0.0	0.9
Yellow birch	1.1	0.0	0.8
Northern red oak	0.0	0.0	0.0

Average crown dieback ranged from less than 1 percent for balsam fir to 3.6 for paper birch and American beech (Table 2) and did not vary substantially over time for any species. The proportion of the trees that die increases with increasing crown dieback. Twenty-five percent of trees with crown dieback greater than 20 percent during the 2012 inventory were dead when visited again during the 2017 inventory Fig. 48).

4 USDA Forest Service. 2017. Forest inventory and analysis national core field guide: field data collection procedures for P2 plots, version 7.1. Unpublished information on file at https://www.nrs.fs.fed.us/fia/data-collection/.



Projection: Vermont 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, April 2019.

Figure 47.—Percentage of live basal area on plots with poor crowns, Vermont, 2017. Plot locations are approximate.

Table 2.—Mean crown dieback and other statistics for live trees (>5 inches d.b.h.) on forest land by species, Vermont, 2017.

Species	Trees	Crown Dieback				
		Mean	SE	Minimum	Median	Maximum
	number	---------------------------- *percent* ----------------------------				
Paper birch	80	3.6	0.5	0	5	20
American beech	236	3.6	0.5	0	0	70
White ash	105	2.9	1.0	0	0	99
Yellow birch	199	2.6	0.5	0	0	99
Northern red oak	20	2.3	0.6	0	0	5
Red maple	392	1.8	0.3	0	0	85
Eastern hemlock	314	1.5	0.4	0	0	80
Sugar maple	460	1.3	0.1	0	0	30
Red spruce	209	0.8	0.3	0	0	40
Eastern white pine	99	0.6	0.3	0	0	30
Balsam fir	136	0.3	0.1	0	0	10

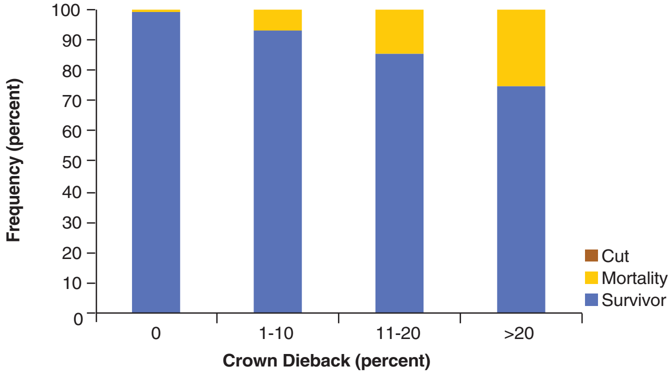


Figure 48.—Frequency of tree mortality and harvesting in 2017 by proportion of crown dieback recorded in 2012.

Damage was recorded on approximately 32 percent of the trees in Vermont, but there was considerable variation between species (Fig. 49). The most frequent damage recorded for all species was decay (12 percent of trees), ranging from less than 3 percent on conifer species up to 24 percent on American beech. Notably, cankers were present on 87 percent of American beech trees, 46 percent of white pine trees suffered branch or shoot damage from insects, and 12 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 strobi* (Peck), which typically causes stem deformities. The occurrence of all other injury types was very low.

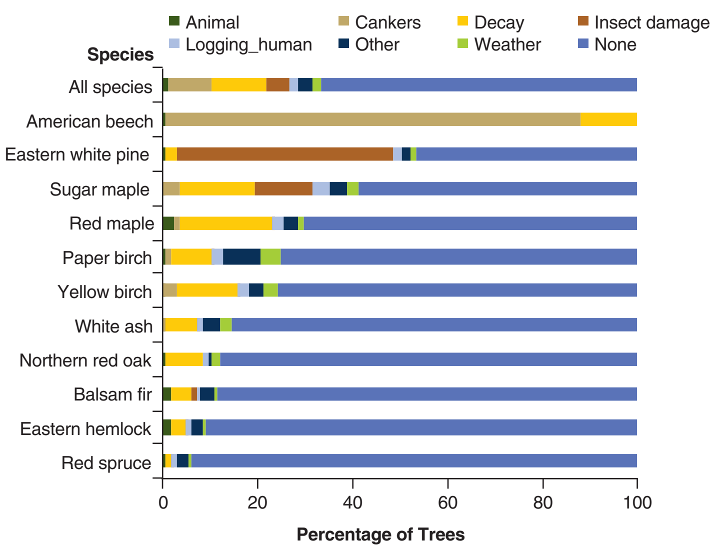


Figure 49.—Percentage of trees with damage, by species and damage type, Vermont, 2017.

What this means

Ash is a minor component in most forests across Vermont but 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 continues to increase in Vermont, but to date the rate is still low (Fig. 43). The relatively unhealthy crowns of ash sampled on several plots in the southern part of the State 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) (see “Emerald Ash Borer” on page 66).

American beech contains a substantial volume of wood in Vermont 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 pulp and firewood species. American beech mortality decreased substantially between 2007 and 2017 inventories. The decrease in mortality and occurrence of poor crowns is likely 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” on page 63).

Decay is the most commonly observed damage, which is not unexpected given that mature trees dominate the majority of Vermont. The high frequency of cankers on American beech is due to the long history of BBD in the region (see “Beech Bark Disease” on page 63). Although the incidence of weevil damage on white pine is quite common, it does not typically kill trees; however the form and quality of saw logs is impacted. Finally, the native sugar maple borer, *Glycobius speciosus* (Say), 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 Vermont. Down woody materials provide valuable wildlife habitat, seedling browse protection, stand structural diversity, a store of carbon/biomass, and contribute towards 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 Vermont's forest land exceeded 14 million tons in 2017, which is roughly equivalent to what was estimated in 2010. Downed woody debris carbon was positively related to the amount of live tree basal area with forests having more than 120 square feet per acre of basal area having the highest amounts of downed dead wood carbon (~10.5 million tons) (Fig. 50). The downed dead wood biomass within Vermont's forests is dominated by coarse woody debris (Fig. 51) at approximately 19 million tons with fine woody debris representing 32 percent of statewide totals. No piles of coarse woody debris (i.e., harvest residue piles) were sampled during the 2017 inventory. The total volume of coarse woody debris was highest in the private ownership category at about 1.6 billion cubic feet in Vermont's forests (Fig. 52). Federal forests had the second largest total of coarse woody debris volume (373 million cubic feet) compared to private ownerships.

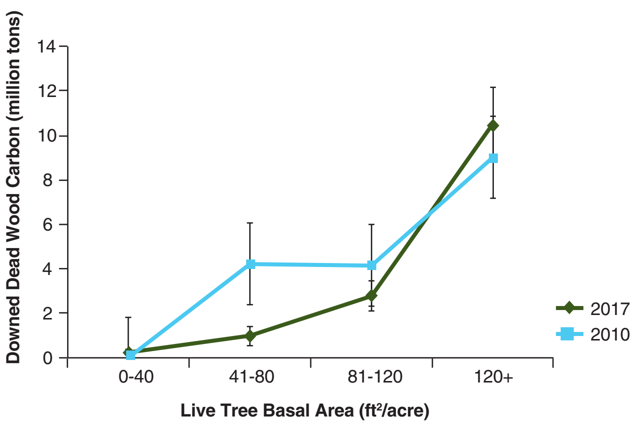


Figure 50.—Total carbon in down woody materials (fine and coarse woody debris and piles) by stand-age class and inventory year on forest land in Vermont. Error bars represent a 68 percent confidence interval around the mean.

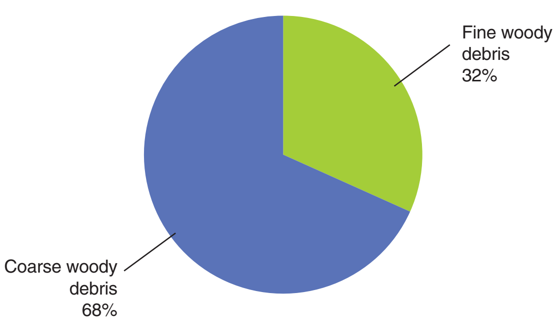


Figure 51.—Proportion of down woody material biomass on forest land by dead wood component, Vermont, 2017.

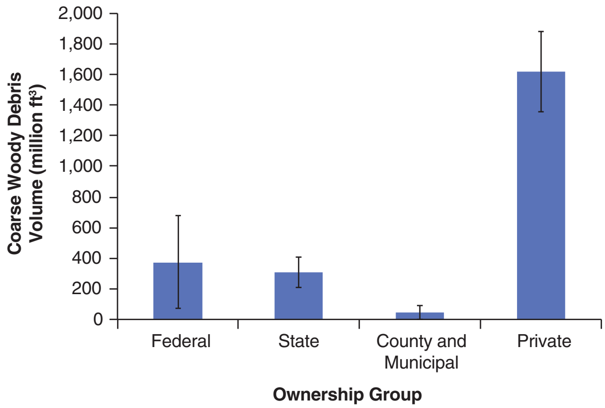


Figure 52.—Total volume of coarse woody debris and deadwood piles on forest land by ownership group, Vermont, 2017. Error bars represent a 68 percent confidence interval around the mean.

What this means

Given the relatively moist temperate forests across the Vermont, only in times of drought would the biomass of down woody materials be considered a fire hazard, especially since no residue piles were sampled during the 2017 inventory. This contrasts to forests in southeastern states (Woodall et al. 2013) where industrial forest management is more pervasive with higher rates of residue pile detection. Although the carbon stocks associated with Vermont's down woody materials are relatively small compared to those of soils and standing live biomass, it is still a critical component of the carbon cycle as a transitory stage between live biomass and other detrital pools such as the litter (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 Vermont's private forests that may affect the future of down woody material contributions to statewide forest carbon stocks and wildlife habitat (i.e., stand structure). Because fuel loadings are estimated to be not exceedingly high across the State, potential fire dangers are likely outweighed by the numerous ecosystem services provided by down woody materials.

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 Vermont 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. 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 comprises 75 percent of the forest resource in Vermont (Fig. 3). American beech is an important pulpwood and firewood species and is also important for wildlife because of the hard mast that it produces. Beech bark disease (BBD) is an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga* Lind.) and the exotic canker fungus (*Neonectria coccinea* [Pers.:Fr.] var. *faginata* Lohm.), or a native fungus (*Neonectria galligena* Bres.) that kills or injures American beech. Three phases of BBD are generally recognized: 1) the advancing front, which corresponds to areas recently invaded by scale populations; 2) the killing front, which represents areas where fungal invasion has occurred, typically 3 to 5 years after the scale insects appear, but sometimes as long as 20 years, and tree mortality begins; and 3) the aftermath forests, which are areas where the disease is endemic (Houston 1994, Shigo 1972). BBD 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 Vermont counties were infested.

What we found

Currently, the annual mortality rate for American beech is similar to that of all trees in Vermont (1.1 percent) (Fig. 43). This represents a decrease from 1.7 percent reported in previous inventories (Morin et al. 2015a). Since 1983, the impacts of BBD on mortality of large diameter beech have steadily skewed the diameter distribution of beech toward smaller trees (Fig. 53). The number of beech seedlings per acre increased slightly between 2007 and 2012 and has since remained stable.

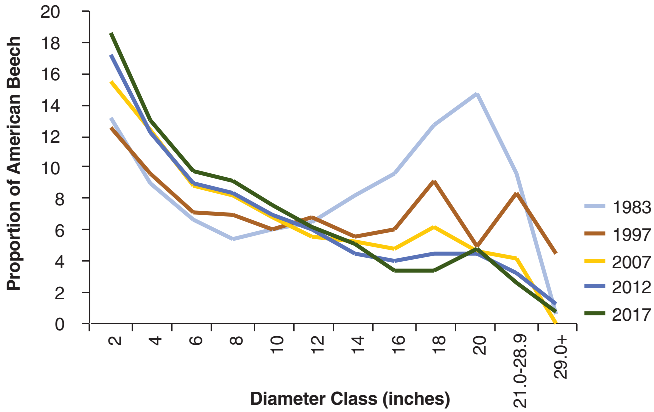


Figure 53.—Proportion of American beech on timberland, by diameter class and inventory year, Vermont

What this means

Since Vermont has been infested by BBD for over 30 years, 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 mortality, which is associated with large amounts of beech seedlings and saplings. This condition, often referred to as "beech brush," can interfere with regeneration of other hardwood species such as sugar maple (Hane 2003) and 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 that is important for wildlife.

Hemlock Woolly Adelgid

Background

Eastern hemlock is a major component of the forest resources in Vermont. 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, Orwig et al. 2002).

What we found

Forests with the highest proportion of hemlock volume are located in southern Vermont (Fig. 33). Hemlock woolly adelgid was first observed in Windham County, Vermont, in 2007. By 2016, the insect had been discovered in Bennington and Windsor Counties. Unlike many other states that have been impacted by HWA, Vermont has experienced no significant change in hemlock annual mortality rate (Fig. 43), crown health (Table 1, 2), or incidence of insect damage (Fig. 49). 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 Vermont where hemlock is the most abundant. Morin et al. (2009) estimates 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 Vermont may be impacted by temperature. Although the health of eastern hemlock in the forests of Vermont 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 increases in hemlock mortality were not substantial until HWA had infested counties for more than 20 years (Morin and Liebhold 2015), suggesting impacts in Vermont will not be apparent for another 5 to 10 years.

Emerald Ash Borer

Background

EAB was first detected in North America in 2002, where it was found near Detroit, Michigan (Herms and McCullough 2014). As EAB is difficult to detect at low-levels, natural spread was enhanced by human-mediated transportation of infested materials; therefore, spread of EAB has outpaced detection, with population establishment averaging 3 to 8 years prior to identification (Herms and McCullough 2014). EAB was not was detected in Vermont during the 2017 inventory period; however, EAB has been confirmed in five counties in 2018. Continued spread has resulted in EAB detections across most of the State. All North American ash (*Fraxinus* spp.) are hosts of EAB. Although EAB shows some preference for stressed trees, all trees 1 inch d.b.h. or greater are susceptible regardless of vigor (Herms and McCullough 2014). While mortality due to EAB varies by infestation level, 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 165 million ash trees greater than or equal to 1 inch d.b.h., a 3 percent increase from 2012; ash represents 5 percent of all species on forest land. White ash is the most prevalent ash species (85 percent), followed by black ash (10 percent) and green ash (5 percent). Found across the State, ash is most densely concentrated in southwestern Vermont (Fig. 54). Ash is present on 2.4 million acres, or 47 percent of forest land, however, it generally makes up less than 25 percent of total live-tree basal area (Fig. 55). While average annual mortality of ash on forest land increased from 3.9 million cubic feet in 2012 to 5.8 million cubic feet in 2017, these estimates are not statistically different from one another. Ash mortality represented 5 percent of total mortality in 2017. Between 2012 and 2017, there was a slight increase in the mortality-to-gross growth ratio for ash, which went from 0.19 to 0.28 (Fig. 56).

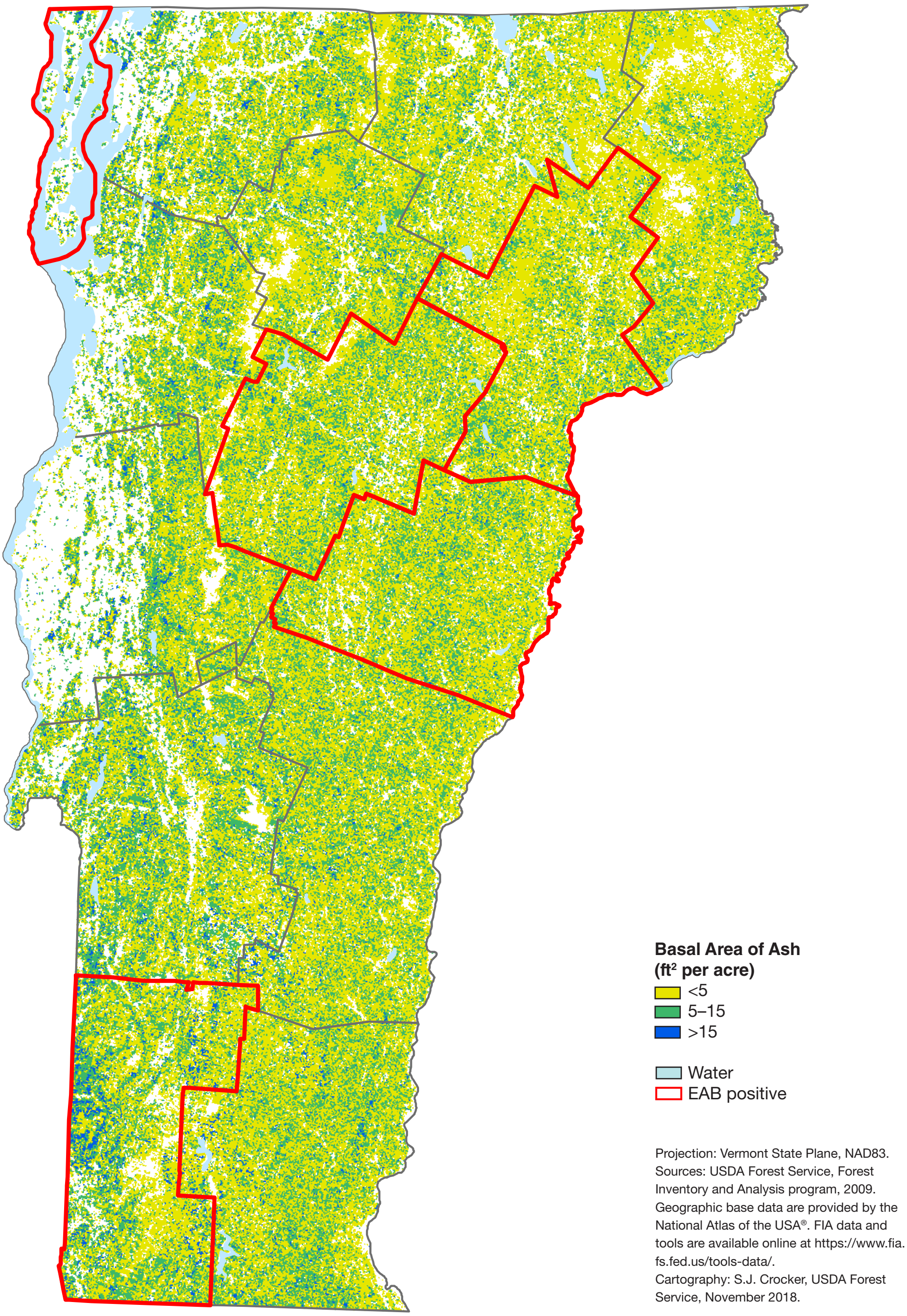


Figure 54.—Distribution of ash on forest land, Vermont, 2009 (EAB positive counties as of March 2019).

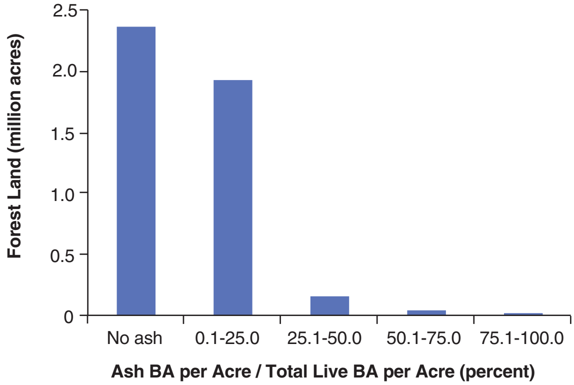


Figure 55.—Distribution of ash on forest land as a percentage of total live-tree basal area (BA), Vermont, 2017.

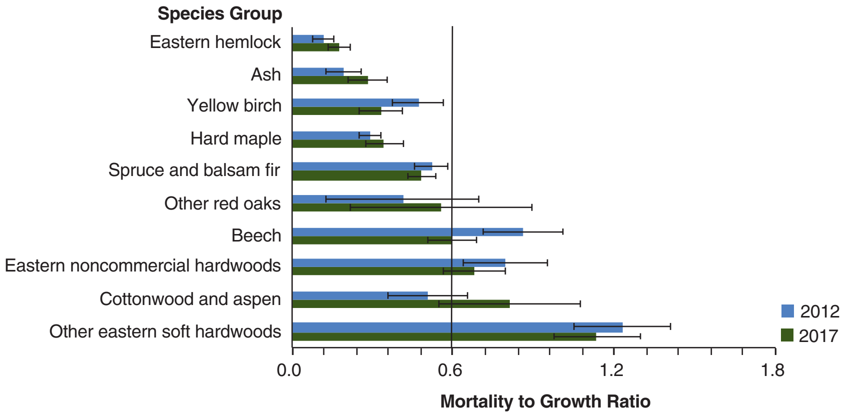


Figure 56.—Ratio of average annual mortality volume to gross growth volume for selected species groups on forest land, Vermont. Error bars represent a 68 percent confidence interval. Vertical line indicates 0.6 threshold for acute health issue (Conkling et al. 2005).

What this means

Ash makes up an important component of Vermont's woodland, riparian, and urban forest resource. Currently, ash abundance and mortality are stable. Given the predominance of ash in low density stands and the recent detection of EAB in the State, the likelihood is fairly low that changes in ash mortality (mortality-to-gross growth ratio <0.6) are related to the presence of EAB. However, EAB has caused extensive ash mortality throughout the eastern United States and therefore represents a significant threat to the ash resource in Vermont. Ash mortality 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 identify the long-term impacts of EAB in forest 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, productive forests (Smith et al. 1997). The Wildlife Society's recently issued policy statement for managing forest biodiversity in the northeastern United States 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 under-representation of both early- and late-successional habitat, and a predominance of secondary growth (40- to 100-year-old forests).

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, e.g., changing climate, invasive plants, herbivory, and wildfire exclusion.

In 2012, FIA implemented a set of regeneration indicator (RI) measurement protocols on a subset of core sample plots measured during the growing season (P2+) to identify contemporary challenges for managers and policymakers (McWilliams et al. 2015). The results in this report are based on measurements of 89 sample plots measured from 2013 to 2017. The procedures measure all established tree seedlings at least 2 inches tall 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 in height and softwood stems at least 6 inches in height.

What we found

The 0- to 20-year stand-age class is FIA's primary indicator for young forest extent, condition, and health. Only 3 percent of Vermont forest land is 20 years or younger. The four most extensive forest-type groups, which make up 92 percent of the total forest land in Vermont, have relatively low amounts of young forest (Table 3) with percentages ranging from 0 for white/red/jack pine (no samples found) to 14 for

Table 3.—Summary of young forest[a] resource for the top four forest-type groups, Vermont, 2017.

Forest-type Group	Forest land	Young forest	Young forest	Young Forest Confidence Interval
	percent	*percent*	*acres*	*acres*[b]
Maple/beech/birch	71	2	54,100	16,046
White/red/jack pine	9	0	-	-
Spruce/fir	7	9	28,194	13,169
Aspen/birch	5	14	30,859	12,881

[a]Young forest is defined here as the area of forest land in the 0- to 20-year age class.
[b]Confidence intervals based on 68 percent sampling errors.

aspen/birch. It should be emphasized that the percentages for maple/beech/birch and white/red/jack pine are very low. Estimates of forest land in the 0- to 20-year age class have become so uncommon that the P2 sample results in large confidence intervals around the mean.

The impacts of large ungulate browsing of young tree seedlings is a paramount impediment to establishing viable forest regeneration (Russell et al. 2001). Forest land with at least moderate browse impacts requires consideration of the potential need for ameliorative treatments as part of regeneration management prescriptions (Brose et al. 2008). Seventy percent the samples had at least moderate impacts that are spread evenly across the Vermont's forest landscape (Fig. 57). Thirty percent of the samples were classified as low.

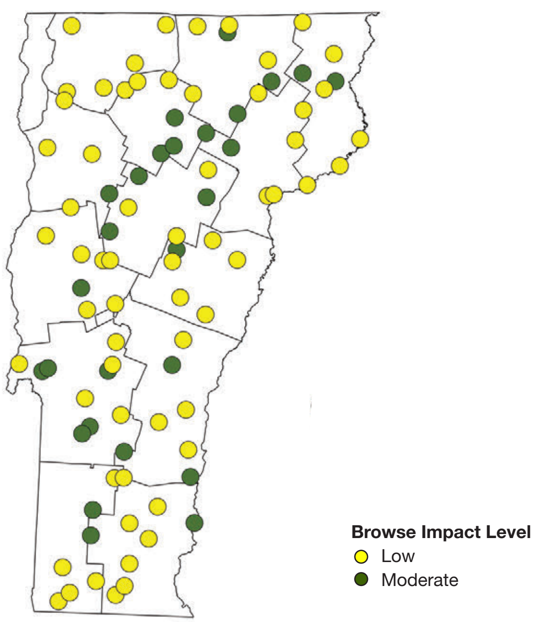


Figure 57.—Browse impact on sample plots, Vermont, 2017.

The RI estimate of the number of established seedlings at least 2 inches tall is 24.8 billion, or 5,014 per acre. Comparing seedling composition and abundance (numbers of stems) by size class with total aboveground biomass for dominant and codominant mature trees sheds light on trends in recruitment (Fig. 58). Prospective "gainers" are species with relatively high percentages of stems in the reproduction pool. Sugar maple, balsam fir, and American beech are showing high percentages across all seedling size classes. Eastern white pine seedling abundance is proportionally less than the species' 15 percent of canopy aboveground biomass. Findings for northern red oak also indicate under-representation 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 Vermont. Long-term trends for the small stand-size class reveals how large stands have come to dominate today's forest. Stand age was not recorded in the earliest FIA report for 1948 (McGuire and Wray 1952). However, the small stand-size class for timberland is a rough surrogate for young forest because it represents conditions dominated by saplings and seedlings. Timberland is used for comparison because estimates of forest land were not published for 1948.

In 1948, nine percent of the timberland was classified as small. Timberland in the small stand-size class more than doubled to 23 percent by 1966, an increase that coincided with farm land reverting to forest (Kingsley and Barnard 1968). This was followed by a gradual decline to 7 percent posted for 2012 and 2017.

From 1948 to 2017, large stand-size stands increased from 46 to 69 percent of timberland. The trends toward larger, older stands will likely continue as today's medium size stands grow to large size and sources of young stands are rare. Fostering older stands through future stand-initiation disturbances and establishing healthy, young forest will be pivotal for securing future canopy trees that support the many values Vermonters have come to expect.

The 0- to 20-year age class is a better indicator of brushy seedling-dominated habitat than stand size because the small stand-size class is classified primarily using saplings. This seedling-dominated habitat supports early-succession forest obligate and facultative wildlife species, such as American woodcock (*Scolopax minor*), golden-winged warbler (*Vermivora chrysoptera*), and snowshoe hare (*Lepus americanus*). With only 3 percent of the State's forest land in this 0- to 20-year age class, managers and policymakers should consider this when making plans to enhance forest biodiversity.

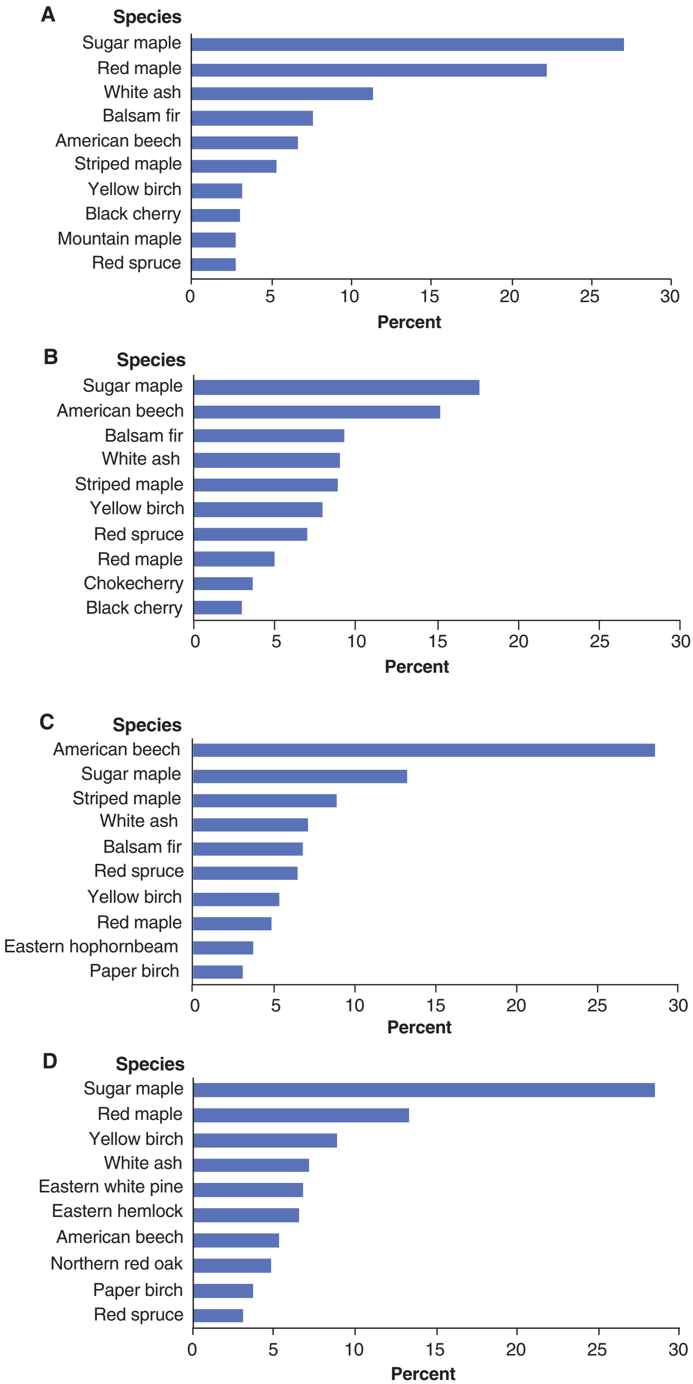


Figure 58.—Percentage of seedlings observed on sample plots for the 10 most common tree species, by height class: A) seedlings 2 to 11.9 inches; B) seedlings 1.0 to 4.9 feet; C) seedlings >5 feet; D) dominant and codominant trees, Vermont, 2017.

The RI seedling inventory shows possible future shifts in composition of canopy trees. Positive indications for sugar maple, balsam fir, and red spruce seedlings indicate a sustainable future as canopy dominants. It appears that American beech will expand its dominance, but beech bark disease and the viability of root sprouts leave this issue unresolved and something to watch in future inventories. Red maple appears to have a deficit of seedlings, but this will probably be offset by a population of saplings that is about the same as its current canopy percent. Northern red oak is ranked the 8th most dominant adult, but no seedlings have showed up in the RI sample yet. The signal that eastern white pine has a low reproduction pool tells us that species-specific stand management is needed across the different associations where it occurs. The results for northern red oak and eastern white pine do not have a significant cohort of saplings or young adults to offset the deficit of seedlings.

The ecological implications of browsing have acute long-term impacts on forest composition, structure, and function (Côté et al. 2004, Russell et al. 2001). The results of the browse evaluation confirms that forest regeneration management will need to consider local browse conditions during the stand-initiation phase across much of the Vermont. The situation today is similar to that described in 2012 by a state-level working group: "deer damage to forest regeneration is neither necessarily widespread nor limited to one region of the State. Instead, deer damage is typically localized within those portions of the State where deer habitat carrying capacity is greatest and winter severities are lower" (Vermont Fish and Wildlife Department 2012).

Vermont forests face a variety of forest health risks and establishing desired tree seedlings is an opportunity for 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 desired taxa. The RI results tell us that sugar maple regeneration is secure and should continue its dominant role. The future of young forest and related resources will depend on the number of stand-initiation disturbances and the relative mix 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 the 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 general public.

What we found

During the 2017 inventory, 101 P2 invasive plots in Vermont 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. Eleven different IPS were observed in Vermont. Nonnative bush honeysuckle was the most commonly observed IPS (13.9 percent of plots). Common buckthorn was the second most commonly observed invasive plant, occurring on 8.9 percent of plots (Table 5). Nonnative bush honeysuckle and common buckthorn are found throughout the State (Fig. 59). The percentage of plots each of the 11 observed IPS was present remained similar to what was observed in 2012 (Morin et al. 2015a).

Invasive plant species were found on 23.8 percent of the plots. This result is similar to what was found in 2012 when 24.5 percent of plots had one or more IPS (Morin et al. 2015a). Plots had between zero and five invasive plants per plot (Fig. 60) with the northeastern part of the State having fewer monitored invasive plant species observed than the rest of the State. The percentage of plots invaded in Vermont is about double that of neighboring New Hampshire.

Table 4.—The list of 39 invasive plant species and one undifferentiated genera monitored by the Northern Research Station on Forest Inventory and Analysis P2 invasive plots, 2007 to present.

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

Table 5.—Invasive plant species observed on Forest Inventory and Analysis P2+ invasive plots in Vermont, 2017.

Name	Percentage of plots
Nonnative bush honeysuckle	13.9
Common buckthorn	8.9
Glossy buckthorn	5.0
Common barberry	5.0
Multiflora rose	4.0
Oriental bittersweet	4.0
Black locust	4.0
Japanese barberry	4.0
Reed canarygrass	3.0
Creeping jenny	1.0
Purple loosestrife	1.0

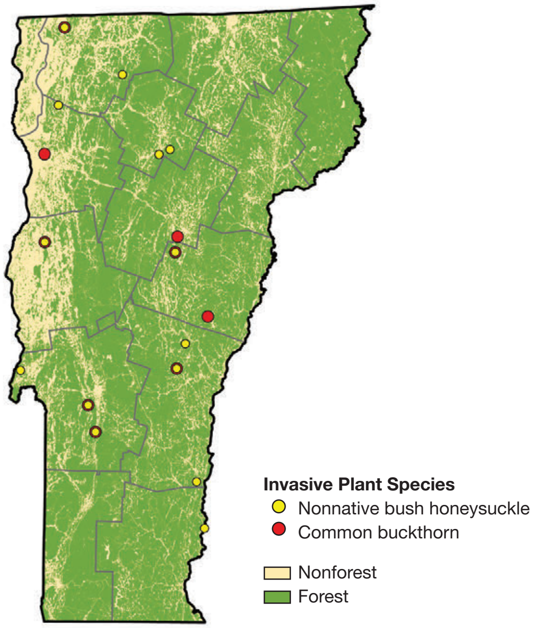


Figure 59.—Distribution of the two most common invasive plant species, nonnative bush honeysuckle and common buckthorn, Vermont, 2017. Plot locations are approximate.

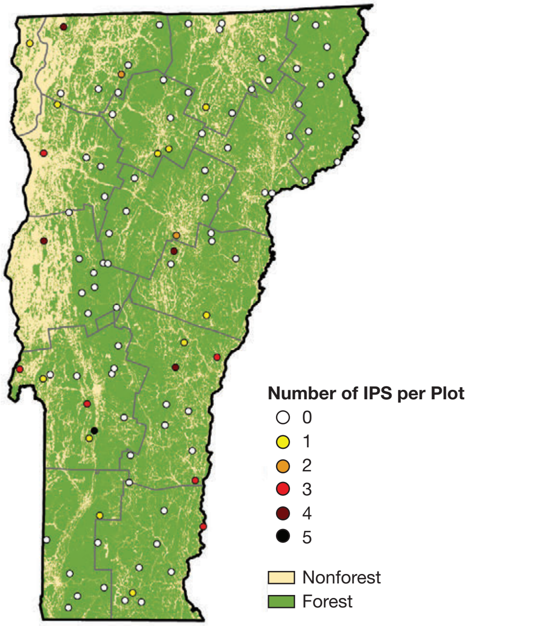


Figure 60.—Number of invasive plant species observed on plots in Vermont, 2017. Plot locations are approximate.

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 any new IPS are observed. Invasive plants are a concern because they can cause detrimental forest changes. These plants can change hydrology, displace native species, and reduce the aesthetics 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

Vermont 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 Vermont Wildlife Action Plan, "The lack of either late, mid or early successional habitat in appropriate patch size and/or juxtaposition can be a problem for some species of greatest conservation need" (Vermont Fish and Wildlife Department 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 Vermont decreased very slightly between 1983 and 2017, from 4.4 to 4.3 million acres. During that same period, small stand-size class area decreased from 13 percent to 7 percent, and distribution of large size forest increased steadily from 56 percent to 69 percent of total timberland area (Fig. 61).

Eighty-five percent of Vermont forest land is in stand-age classes between 40 and 100 years. Only 6 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, with forests of 41 to 60 years nearly evenly dominated by medium and large diameter stand-size classes (Fig. 62).

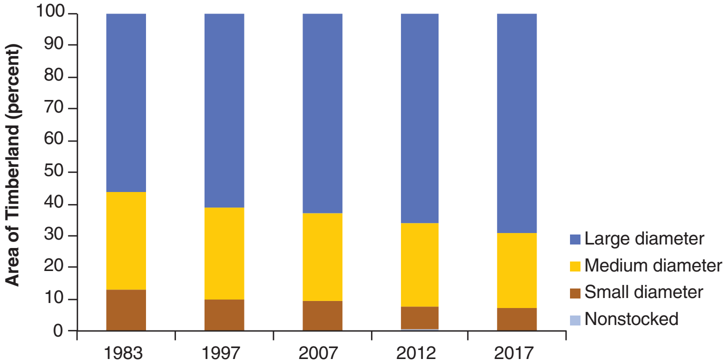


Figure 61.—Percentage of timberland area by stand-size class and inventory year, Vermont.

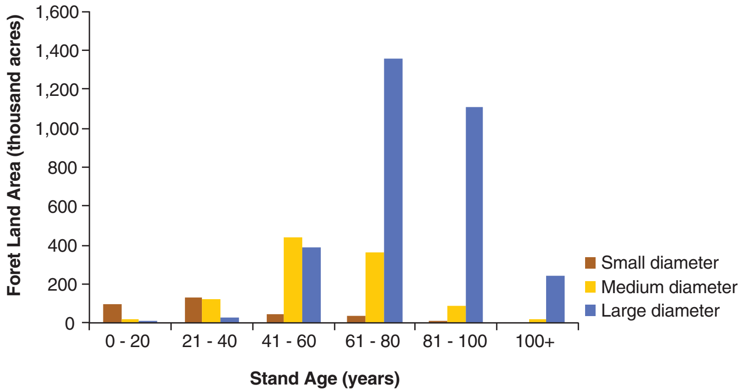


Figure 62.—Area of forest land by age class and stand-size class, Vermont, 2017.

What this means

Decreasing abundance of both small- and medium-diameter stand-size classes is offset by increasing abundance in large-diameter class. However, 92 percent of stands in the large-diameter class 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. In Vermont, ruffed grouse (*Bonas umbellas*) and American woodcock prefer early successional forest stands, American marten (*Martes americana*) prefers late-successional stands, and Canada lynx (*Lynx canadensis*) and snowshoe hare (*Lepus americanus*) depend on a mix of forest stages. These known preferences point to the need to monitor and maintain forest conditions in multiple stand-size and stand-age classes, including both early (young) and late (old) successional stages, to provide habitats for these and other 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. Habitat degradation is one of the high ranking conservation concerns in Vermont. Specifically, the Vermont Wildlife Action Plan (Vermont Fish and Wildlife Department 2015) emphasizes "loss of key feeding areas (beech stands, riparian areas, snags, cavity trees, etc.), and loss of dead and down material, fragmentation of contiguous forests." The number and density of standing dead trees (≥5 inches d.b.h.), together with decay classes, species, and sizes, define the snag resource in Vermont forests.

What we found

There are over 94 million standing dead trees on the 4.5 million acres of forest in Vermont. This represents an overall density of 22 standing dead trees per acre of forest land, ranging from 20 per acre on private lands to 31 per acre on national forest lands. Species groups with the largest percentages of standing dead trees include other eastern softwoods (23 percent), eastern white and red pine (22 percent), cottonwood and aspen (17 percent), and spruce and balsam (15 percent) (Fig. 63).

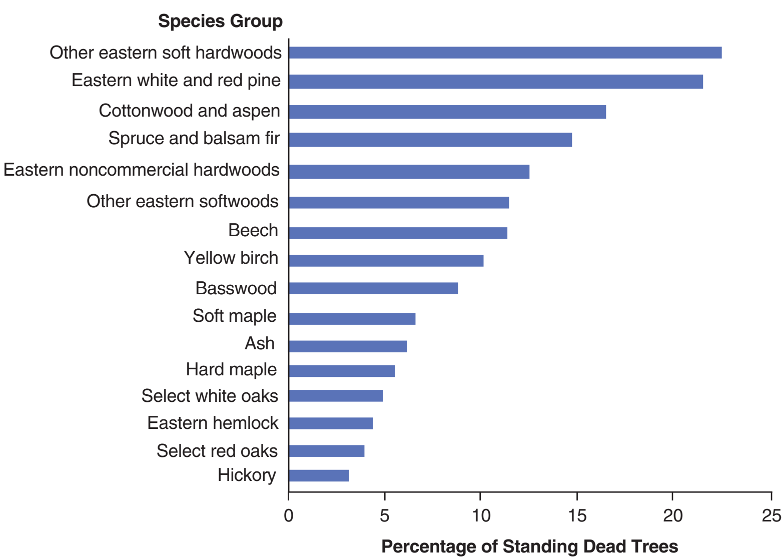


Figure 63.—Percentage of standing dead trees by species group, Vermont, 2017.

Across Vermont, more than 77 percent of standing dead trees were smaller than 11 inches d.b.h. The greatest number of standing dead trees (83 percent) was estimated for the three intermediate decay classes, with the fewest (2 percent) in the class of most decay (Fig. 64).

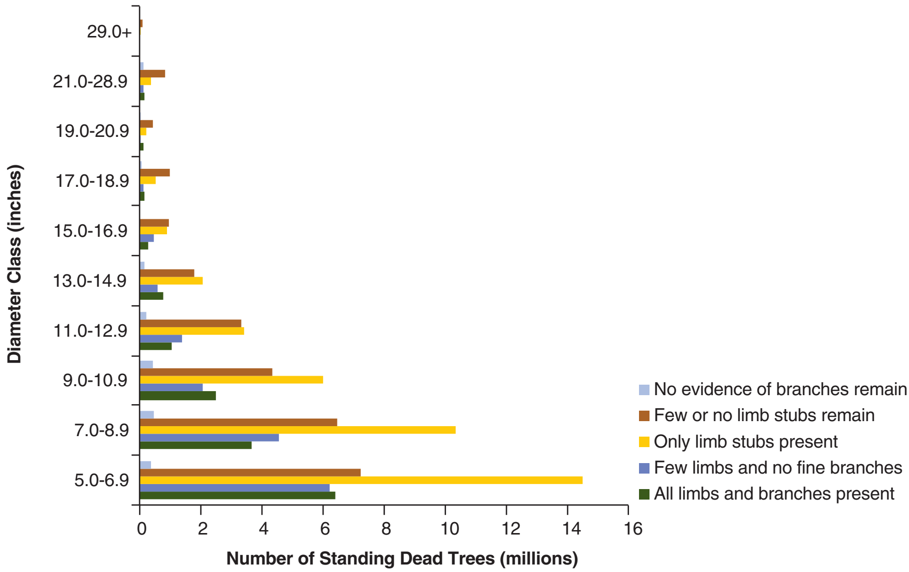


Figure 64.—Distribution of standing dead trees by decay and diameter classes Vermont, 2017.

What this means

Snags result from a variety of potential causes, including diseases and insects, weather damage, fire, flooding, drought, and competition. Spruce and balsam fir species group contained the greatest number of standing dead trees (over 20 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. In Vermont, this diverse array of snag-dependent species include five-lined skink (*Plestiodon fasciatus*), eastern ratsnake (*Pantherophis alleghaniensis*), chimney swift (*Chaetura pelagica*), the federally endangered Indiana bat (*Myotis sodalist*), small-footed bat (*Myotis leibii*), silver-haired bat (*Lasionycteris noctivagans*), according to the 2015 Vermont Wildlife Action Plan (Vermont Fish and Wildlife Department 2015). Providing a variety of forest structural stages and retaining specific features such as 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 Vermont.

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; 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 that include 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 one of the top six current major stressors and threats to forest ecosystems, and two of the other threats—invasion by nonnative species, and forest diseases and insect pests—are themselves heavily influenced by forest fragmentation and urbanization.

The 2012 report on Vermont forests (Morin et al. 2015a), 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.

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 housing density and forest land at a finer spatial resolution and with greater accuracy. In this report, we use this data to identify changes in WUI status via the following categories: forest land in census blocks that have had housing densities above established WUI thresholds for 30 years or more (from 1990 or before), forest that reached WUI house density levels in the 1990s, forest that 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. 65). In Figure 65 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.

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 conditions occur in forest land that might otherwise be considered high integrity or core forest land, 4) whether differences in forest type, ownership, and stand size have been affected by urbanization levels above the low (6-49 houses per square kilometer), medium (49-741) and high (>741) WUI housing density thresholds.

What we found

Both the area and proportion of Vermont forest that is non-WUI continues to shrink, from 3.6 to 3.0 million acres in Vermont (from 79 to 67 percent of total forest land) between 1990 and 2010 (Fig. 66). By 2020, 0.9 million acres of Vermont forest land will have been in WUI conditions for at least 30 years with an additional 0.5 million acres of forest land crossing into the WUI threshold between 1990 and 2010. Some areas experienced more forest urbanization in the 1990s, some in the 2000s, and some both decades. Most counties experienced additional urbanization at rates greater than 5 percent per decade (Fig. 67).

Urbanization affected forest types to differing degrees in 2010, from 15 percent of the balsam fir forest area to 66 percent of the eastern white pine/northern red oak/white ash forest area (Table 6). Three additional forest types had >40 percent of their area in WUI as of 2010 (red maple/upland, eastern hemlock, and eastern white pine). The aspen and red maple/upland forest types had the greatest proportion (15 percent) of their area converted to WUI intermix between 1990 and 2010, and six forest types had >10 percent of their forest area converted to WUI intermix during that time (Table 6). Seven percent of the total forest area in WUI in Vermont in 1990 was in the eastern hemlock type, which itself only represents 3 percent of the total forest area in Vermont (Table 7). In general, all forest types, except the sugar maple/beech/yellow birch type, were disproportionately affected by WUI through 1990, but WUI development between 1990 and 2010 occurred more frequently in sugar maple/beech/yellow birch type than in earlier decades.

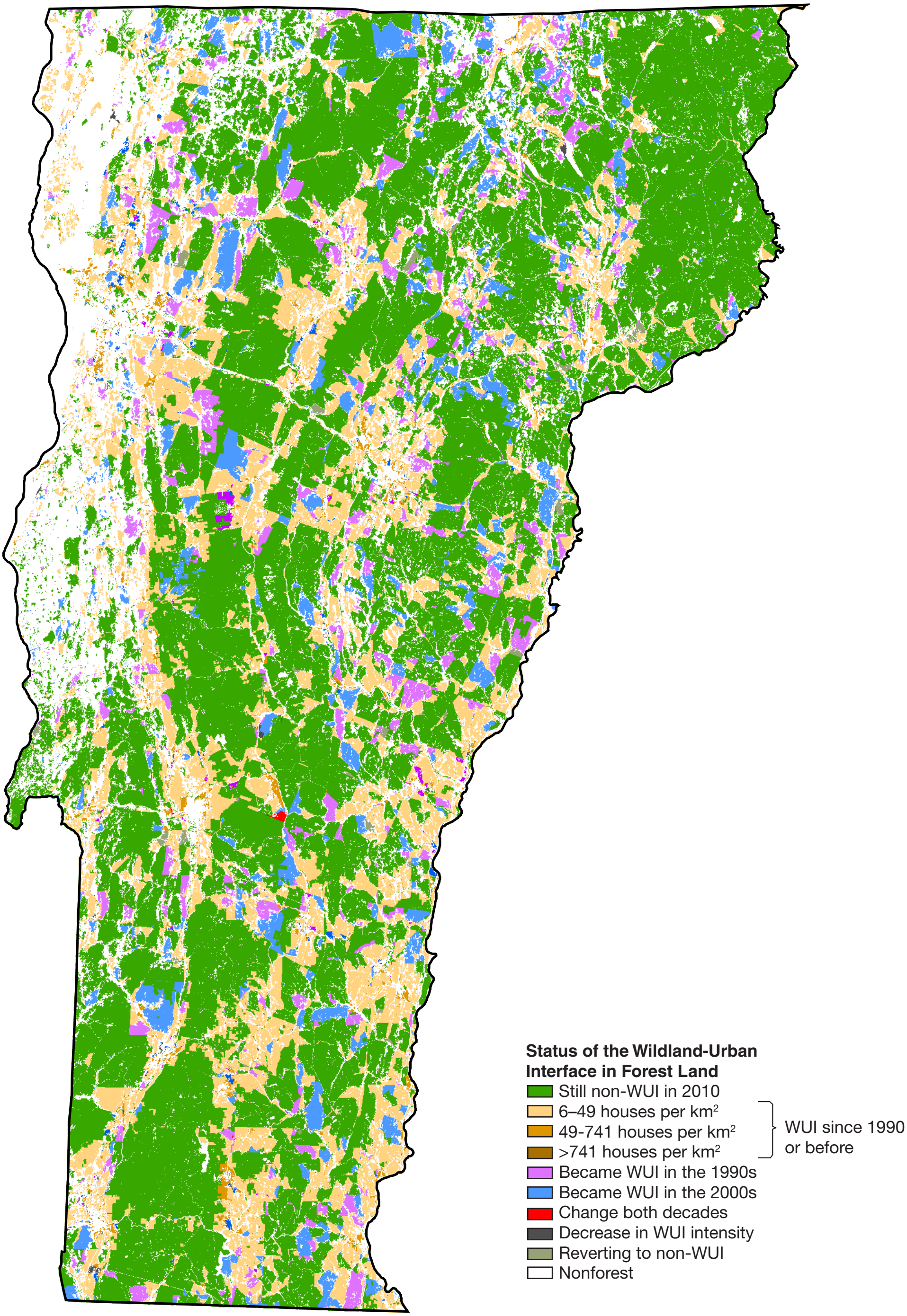


Figure 65.—Map of changes in WUI status, Vermont, 1990 to 2010.

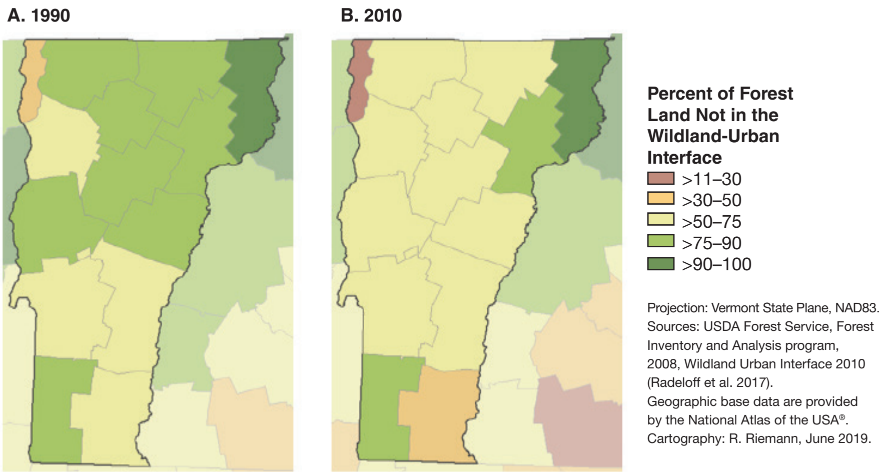


Figure 66.—Proportion of forest in Vermont that is non-WUI in A) 1990, and B) 2010.

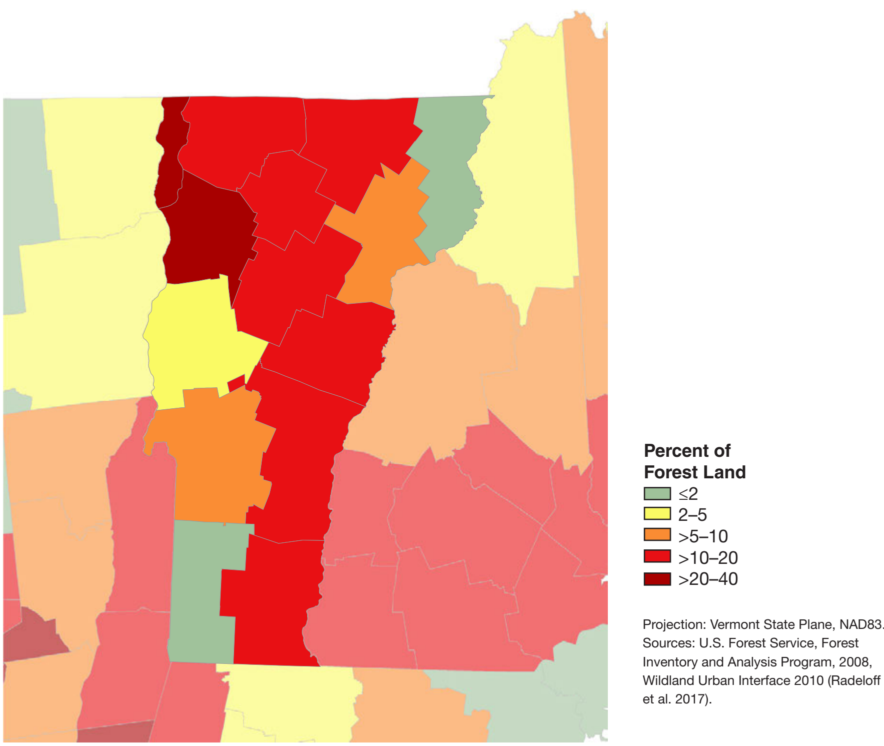


Figure 67.—Proportion of forest land in each county of Vermont that changed from non-WUI to WUI between 1990 and 2010.

Table 6.—Wildland-urban interface change class breakdown by forest type, Vermont.

Forest type	Total acres	All classes	WUI change group[a]				Percent of area in WUI in 2010[b]
			WUI from 1990 or before	New WUI 1990-2010	Still non-WUI as of 2010	Potential WUI decrease	
		percent					
Total	4,514,169	100	21	11	67	1	33
Eastern white pine/red oak/white ash	89,353	2	56	9	34	0	66
Red maple/upland	267,113	6	28	15	57	0	43
Remaining forest types (<75,000 acres)	541,171	12	33	10	55	1	43
Eastern hemlock	146,762	3	43	0	57	0	43
Eastern white pine	178,951	4	29	12	56	3	41
Hard maple/basswood	380,171	8	23	8	70	0	30
Paper birch	103,868	2	17	11	70	1	28
Sugar maple/beech/yellow birch	2,491,432	55	15	13	72	0	28
Red spruce/balsam fir	101,639	2	20	5	75	0	25
Aspen	78,188	2	9	15	70	6	25
Balsam fir	135,518	3	3	12	80	5	15

[a] These four columns sum to 100 percent of area for each forest type; errors due to rounding are possible.
[b] Sum of percentages from columns 'WUI from 1990 or before' and 'New WUI 1990-2010'.

Table 7.—Forest type breakdown of wildland-urban interface change class, Vermont.

Forest type	Total acres	All classes	WUI change group			
			WUI from 1990 or before	New WUI 1990-2010	Still non-WUI as of 2010	Potential WUI decrease
Total (acres)	4,514,169		931,550	513,854	3,031,898	36,867
		percent				
Sugar maple/beech/yellow birch	2,491,432	55	40	61	59	30
Hard maple/basswood	380,171	8	9	6	9	0
Red maple/upland	267,113	6	8	8	5	0
Eastern white pine	178,951	4	6	4	3	16
Eastern hemlock	146,762	3	7	0	3	0
Balsam fir	135,518	3	0	3	4	19
Paper birch	103,868	2	2	2	2	4
Red spruce/balsam fir	101,639	2	2	1	3	0
Eastern white pine/red oak/white ash	89,353	2	5	2	1	0
Aspen	78,188	2	1	2	2	12
Remaining forest types (<75,000 acres)	541,171	12	19	11	10	19

The ownership groups with the greatest proportion of their forest land area remaining as non-WUI forest were State (94 percent, or 400,000 acres) and Federal (96 percent, 500,000 acres) (Fig. 68). The private ownership group had the lowest proportion of its forest land remaining in non-WUI conditions in 2010 (60 percent, 200,000 acres), followed by the county and local government ownership group (83 percent).

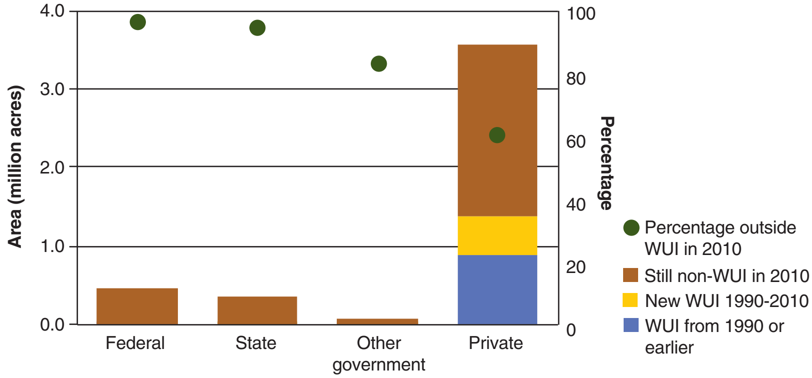


Figure 68.—Forest land by ownership and WUI change, Vermont, 1990-2010.

However, the large area of forest land in private ownership in Vermont meant that it had more than double the number of acres remaining in non-WUI conditions in 2010 as State and Federal land combined (Fig. 68). Almost all the forest land undergoing a change in WUI status between 1990 and 2010 was in private ownership (Fig. 69).

Eighty-five percent of Vermont forest land had a spatial integrity index value of "core" or "high integrity" at both the 30 m and 250 m scales (Fig. 70), as defined by patch size, local forest density, and connectedness (see Morin et al. 2015a). However, of that core or high integrity forest land, 28 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 3.5 percentage points per decade.

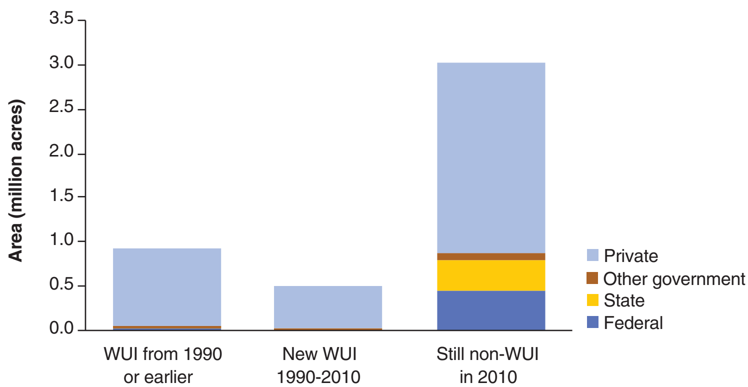


Figure 69.—Forest land by WUI change and ownership group, Vermont, 1990-2010.

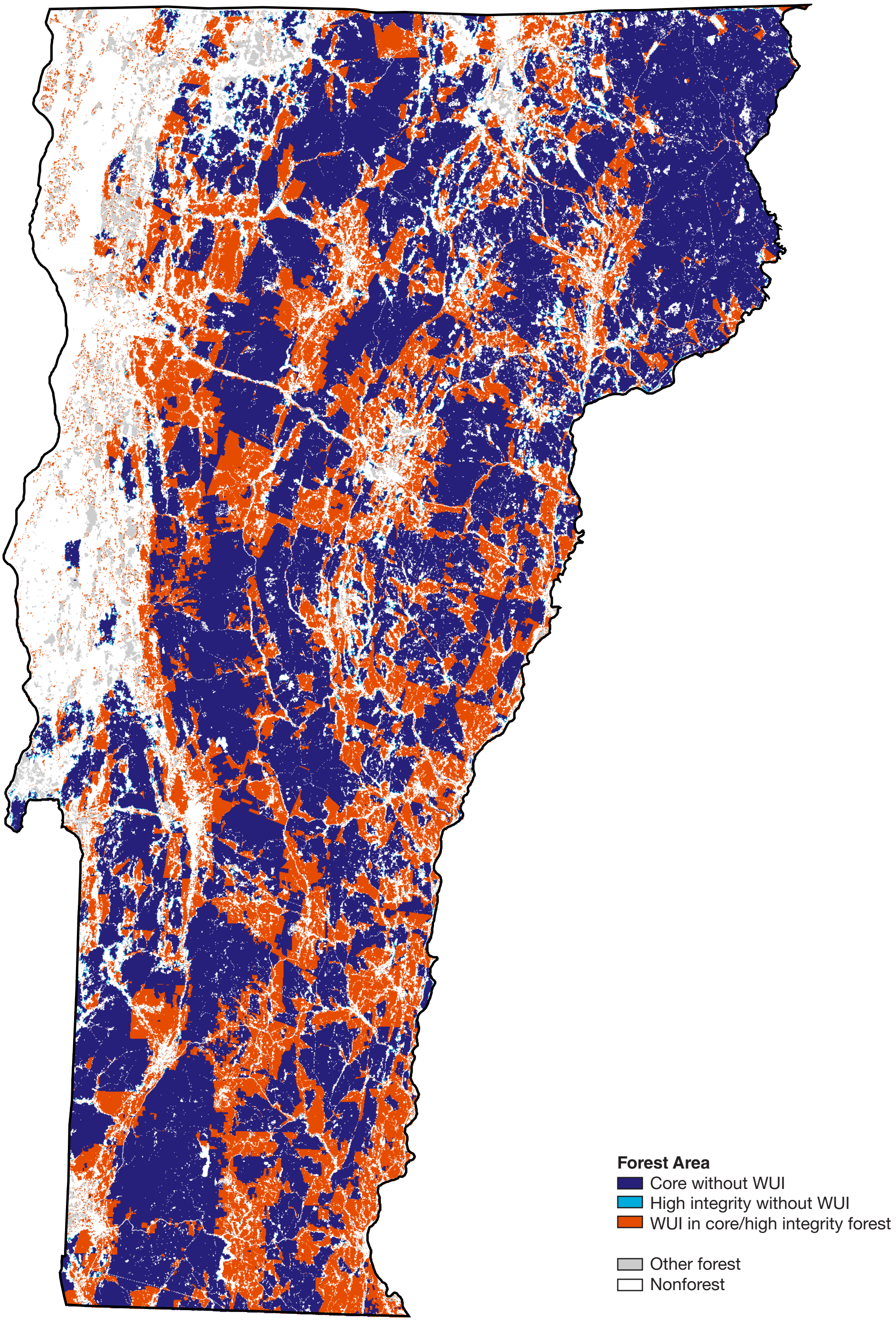


Figure 70.—Area where WUI occurred within forest land calculated to have core or high spatial integrity at the 30 m and 250 m scales, Vermont, 2010.

If we look only at core forest, 49 percent of the forest land in Vermont had a spatial integrity index value of "core" at both scales, however only 18 percent of that core forest occurred in WUI conditions in 2010. From 1990 to 2010 this core forest was still being converted to WUI at an average rate of 5.5 percentage points per decade.

What this means

Urbanization is affecting an increasing area of forest in Vermont, including unfragmented forest land in otherwise core or high spatial integrity situations. A total of 0.9 million acres (21 percent of Vermont forest land) was in WUI conditions by 1990, and between 1990 and 2010 forest land was being converted to WUI conditions in most counties at rates greater than 5 percentage points per decade. In addition, these changes were not limited to already fragmented forest land. Vermont forest land in otherwise core and high spatial integrity conditions was being converted to WUI conditions at an average rate of 5.5 percentage points per decade between 1990 and 2010.

Increasing urbanization has the potential to change how Vermont forests function, affecting their vulnerability to threats such as insect pests and diseases, nonnative species proliferation, and loss of native species, all of which hinders their overall resilience in the face of both these threats and the additional changes and disturbances expected due to climate change. Such changes also affect the inherent ecosystem services provided by forest land such as clean water, flood protection, clean air, wildlife habitat, and forest products (Vermont Department of Forests Parks and Recreation 2015). Many of the reported changes in forest ecosystems happen over time and thus forest land that has only recently become WUI may not look different yet. Forest land that has been in WUI conditions for over 30 years is more likely to exhibit changes.

Given the well-documented negative effects of residential development on forest land and the amount of forest land occurring in WUI conditions, it matters how we manage those residential areas. Strategies to reduce the effects of those residential land uses on surrounding forest land should be pursued. 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 an acre in size with a natural or unmaintained understory. Because many urban trees do not fall into this category, they weren't 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, Vermont has 100,000 acres of urban land, which covers 1.7 percent of the State's land area, (U.S. Census Bureau 2010). While this percentage of urban land is less than the 3.0 percent national average, 45 percent of the urban land in Vermont is concentrated in Chittenden County, the most populous county in the State. The city of Burlington and its suburbs in Chittenden County account for a large proportion of the State's urban area (Fig. 72). Urban area grew slightly in Vermont between 2000 and 2010 and is projected to increase 3.3 percent by the year 2060 (Nowak and Greenfield 2018b).

With the goal of characterizing Vermont's urban tree resource and its associated benefits and values, FIA has established inventory plots within the city of Burlington and in Census urban areas across the State (Fig. 71). Data collection on these plots occurs over a 7-year cycle, so one-seventh of the plots are visited each year and remeasurement occurs every 7th year (Fig. 71). In Vermont, annualized inventory

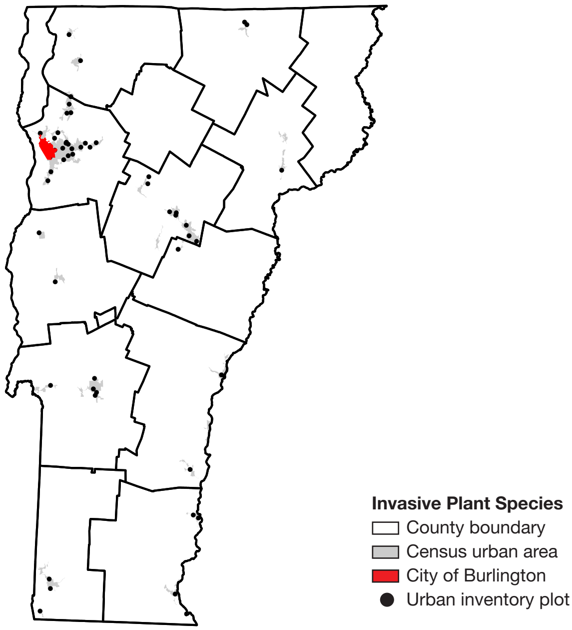


Figure 71.—Urban FIA monitoring is concentrated in the city of Burlington, with a lower intensity of sample plots distributed throughout the U.S. Census urban areas of Vermont. Plot locations are approximate.

monitoring began in the summer of 2016. Tree and site field data are being collected on a total of 211 sample plots within the city and 56 plots within urban areas across the State (Fig. 72).

The urban FIA inventory in Vermont is still being established, so it will be a couple of years before there are data published. However, there are other studies that have been used to derive urban forest attributes. Nowak and Greenfield (2018a) conducted a study to quantify urban forest cover and cover change in the United States using aerial photointerpretation methods. According to their data, forest cover in Vermont's urban areas in 2015 was 49.2 percent, which dropped slightly from 50.9 percent in 2010. This is an average decrease of 0.3 percent per year, which is greater than the national estimate of 0.2 percent per year decrease in urban forest cover.

Based on the forest cover data and various generalizations and assumptions using Vermont-specific data, the dollar value of ecosystem services associated with the urban forest (carbon sequestration, air pollution removal, avoided energy use, and avoided emissions) was estimated to be roughly $20 million per year (Nowak and Greenfield 2018b).

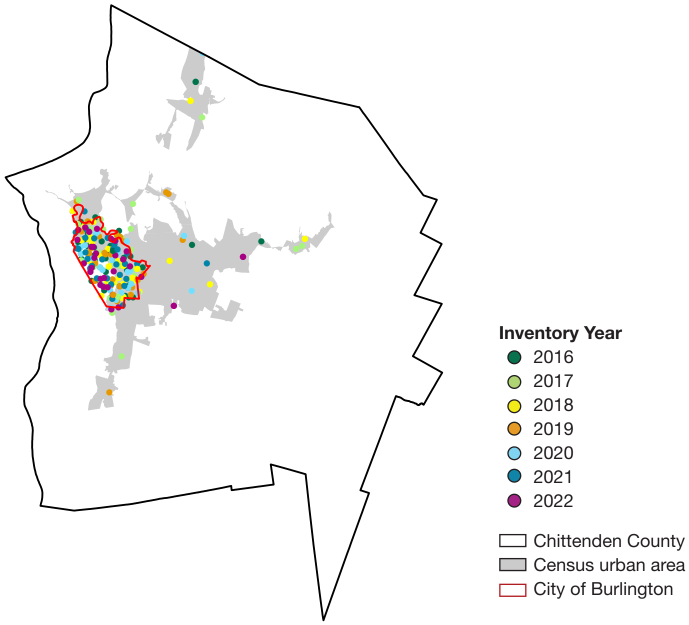


Figure 72.—Urban FIA inventory monitoring plots by year of initial sample collection in Burlington and in surrounding urban areas in Chittenden County, Vermont. Plot locations are approximate.

What this means

Trees cover nearly 50 percent of the urban land in Vermont and represent an important resource. With nearly a quarter of the State's urban land area in grass cover, there may be opportunities to increase urban forest cover in the future. Urban forests are important to the health and well-being of the people of Vermont and the ecosystem services these forests provide have both ecological and economic value. For these reasons, along with constant forest changes due to such forces as development, storms, aging and mortality, 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 FIA program in Vermont, FIA will soon be able to provide sample-based estimates of urban forest structure and associated ecosystem services and value data for the city 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/datamart/images/urbandatamart.html) and posted for interactive data exploration on the My City's Trees App (http://tfsfrd.tamu.edu/mycitystrees). More information on the FIA urban program, including field guides and a national implementation map, are available on the Urban FIA website (https://www.nrs.fs.fed.us/fia/urban/).

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Appendix

Appendix 1.—Scientific names for tree species.

Common Name	Scientific Name
Balsam fir	*Abies balsamea*
Red maple	*Acer rubrum*
Sugar maple	*Acer saccharum*
Yellow birch	*Betula allegheniensis*
Sweet birch	*Betula lenta*
Paper birch	*Betula papyfirous*
American beech	*Fagus americana*
White ash	*Fraxinus americana*
Red spruce	*Picea rubens*
Eastern white pine	*Pinus strobus*
Quaking aspen	*Populus tremuloides*
Black cherry	*Prunus serontina*
White oak	*Quercus alba*
Northern red oak	*Quercus rubra*
Northern white-cedar	*Thuja occidentalis*
Eastern hemlock	*Tsuga canadensis*

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The second full remeasurement of the annual inventory of the forests of Vermont was completed in 2017 and covers nearly 4.5 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 1,125 plots located across Vermont. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 71 percent of total forest land area. Of the forest land, 70 percent consists of large diameter trees, 23 percent contains medium diameter trees, and 7 percent contains small diameter trees. The volume of growing stock on timberland has continued to increase since the 1980s and currently totals nearly 9 billion cubic feet. The average annual net growth of growing stock on timberland from 2012 to 2017 was nearly 160 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, timber products, species composition, regeneration, and forest health. Sets of supplemental tables are available online at https://doi.org/10.2737/NRS-RB-120 and contain summaries of quality assurance data and 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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