Vermont's Forests 2007

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Abstract

The first full annual inventory of Vermont's forests reports more than 4.5 million acres of forest land with an average volume of more than 2,200 cubic feet per acre. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 70 percent of total forest land area. Sixty-three percent of forest land consists of large-diameter trees, 27 percent contains medium-diameter trees, and 9 percent contains small-diameter trees. The volume of growing stock on timberland has been rising since the 1980s and currently totals nearly 9 billion cubic feet. The average annual net growth of growing stock on timberland from 1997 to 2007 is approximately 180 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, timber products, and forest health. Detailed information on forest inventory methods and data quality estimates is included in a DVD at the back of the report. Tables of population estimates and a glossary are also included.

Acknowledgments

The authors would like to thank Vermont's inventory crew members over the 2003-2007 inventory cycle: Aaron Clark, Robert Gregory, John Higham, Paul Kelley, Katherine Locke, Jason Morrison, Joyce Quinn, Ann Quinion, Keith Raymond, Jennifer Thompson, Bryan Tirrell, and Ashley Zickefoose. Thanks also to Virginia G. Anderson, Barbara Burns, Charles Canham, Paul Frederick, Chris Matera, and George McCaskill for serving as reviewers and providing insightful, constructive comments.

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Foreword

Forests dominate Vermont's landscape, covering over 75 percent of the state. Our forested ecosystem provides the basis for biological diversity, natural communities, scenic landscapes, and recreational opportunities. As a natural resource, forests provide an important economic base supporting a diverse forest products industry, as well as a myriad of ecosystem services such as clean water, clean air, and carbon storage.

In Vermont, we recognize that sustainable forests begin with healthy forests. And we recognize that managing forests sustainably involves the recognition of connections among ecological, social, and economic systems to maintain forest health while preserving options for future generations and meeting the needs for the present.

To make informed decisions about forest resources, it is important to have accurate and timely forest resource information. The Department of Forests, Parks and Recreation is pleased to partner with the U.S. Forest Service in the Forest Inventory and Analysis (FIA) of Vermont. The more we know and understand of the wonderful resources of Vermont's forests, the better we can sustain our forests. Decisions and actions we make today will influence our forests for years to come. Livable communities, functioning natural systems, and our quality of life depend on healthy, sustainable forests. We must accept and embrace responsibility as stewards of this valuable resource.

Steven J Sinclair

Steven Sinclair, Vermont State Forester

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Vermont fall color. Photo by Randall Morin, U.S. Forest Service.

Highlights

On the Plus Side

Vermont's forest land base has remained stable since 1997 at 75 percent of total land area, making it the fourth most forested state in the United States.

Timberland makes up 98 percent of Vermont's forest land.

Ninety-seven percent of Vermont's forest land is in patches larger than 100 acres, a size preferred by many wildlife species.

Only 3 percent of forest land in Vermont is near population centers that exceed 150 people per square mile, the density at which the probability of commercial forestry drops to zero.

Most of Vermont's forest land is well stocked with trees of commercial importance. Changes in stand stocking indicate that forest management practices over the past three decades may have improved the general stocking condition across the State.

The quality of saw logs in Vermont has remained stable since the last inventory, but the value of sawtimber has increased based upon the increase in available board-foot volume.

Most of the wood-processing facilities in Vermont are sawmills processing primarily State-grown saw logs. These mills provide woodland owners with an outlet to sell timber and provide jobs in some of the rural areas.

Lichen species richness scores fell into the medium and high categories across Vermont; this is likely to be related to levels of sulfate deposition.

In Vermont and New Hampshire, the presence of invasive plant species is relatively low compared to neighboring New England states.

Decreases in foliar injury from ozone have occurred as ozone exposure rates have also decreased.

Areas of Concern

People at least 65 years old make up 24 percent of Vermont's family forest owners and own 36 percent of family forest acreage. Because of the large change in ownership that is likely to occur in the next two decades, it will be important to watch how the new owners manage their lands.

Due to the continuing increases in volume, Vermont's timber resource is at record levels. However, this increase has leveled off and may continue to do so as the forest continues to mature, reducing future growth rates.

The mortality rate (0.9 percent) for 1997 to 2007 is the highest ever reported in an FIA inventory of Vermont, but this rate is comparable to those in surrounding states.

Twenty percent of the American beech basal area had poor crowns; this condition is likely to be related to the impacts of beech bark disease.

Issues to Watch

Reversion of farmland to forest land continues to outpace the loss of forest land to development. Vermont's forest base has remained stable since 1997.

The small parcels held by many landowners complicate the economics of forest management and the delivery of government programs. The trend toward more landowners with smaller parcels will only increase this problem.

Cumulative ecological impacts on forest land from roads should be a very real consideration.

A statistically significant decrease in area of small-diameter stands and a statistically significant increase in area of large-diameter stands have both occurred over the past three decades. There needs to be continued monitoring as the forest matures and less area contains stands of small-diameter trees.

The 1997 to 2007 period is the first time that the growth-to-removal ratio dropped below 2.0:1.0 since the 1960s. Even with the slower growth rate, the current level of removals appears to be sustainable barring any increases in mortality.

Vermont's forests are continuing to accumulate biomass as the forests mature. Because most of the biomass is in the boles of growing-stock trees, and most of the gains in biomass stocks are found in the high value sawtimber-size trees, only a fraction of the accumulated material is available for use as fuel.

Changes in species composition point toward potential reductions in tree quality for sawtimber into the future. Two of the species with a high proportion of low grade volume, American beech and red maple, are the same species that are showing large increases in saplings.

An important consideration for landowners actively managing their land is the ability of the primary wood-products industry to retain pulp mills, sawmills, and veneer mills. The number of wood-processing mills has been steadily declining across the region.

The scarcity of large coarse woody debris resources may indicate lower quality habitat for some wildlife species.

Invasive insect pests that may impact abundant tree species in Vermont in the future include the emerald ash borer and Asian longhorned beetle.

The presence of invasive plants may have caused a reduction in seedling cover based upon data collected in Vermont and New Hampshire.

Background

Photo by Randall Morin, U.S. Forest Service.

Data Sources and Techniques

The forests of Vermont are one of the State's most valuable assets due to their importance to Vermont's economy and the quality of life for its residents. Accurate and statistically defensible information is critical for understanding the current conditions, interpreting trends over time, and projecting future scenarios. In this report we highlight the current status and trends observed in Vermont's forests.

This inventory was a cooperative effort of the Northern Research Station, the Vermont Department of Forests, Parks and Recreation, and landowners of Vermont, and is the culmination of the first complete inventory of Vermont's forests using FIA's annualized forest inventory system. Previous forest inventories, completed in 1948 (McGuire and Wray 1952), 1965 (Kingsley and Barnard 1968), 1973 (Kingsley 1977, Frieswyk and Malley 1985), 1983 (Frieswyk and Malley 1985, Frieswyk and Widmann 2000), and 1997 (Frieswyk and Widmann 2000), were collected under a different inventory system in which states were inventoried periodically with no measurements made between inventories. The annualized system was implemented to provide updated forest inventory information every year based on a 5-year cycle. The FIA program is the only source of data collected from a permanent network of ground plots from across the Nation that allows for comparisons among states and regions.

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), of FIA's multi-phase inventory, the population of interest is stratified and plots are assigned to strata to increase the precision of estimates. In Phase 2 (P2), tree and site attributes are measured for forested plots established in each hexagon. Phase 2 plots consist of four 24-foot fixed-radius subplots on which standing trees are inventoried. During Phase 3 (P3), forest health indicators are measured on a 1/16th subset of the entire FIA ground plot network so that each plot represents approximately 96,000 acres. The forest health indicators are tree crown condition, lichen communities, forest soils, vegetation diversity, down woody material, and ozone injury.

A Beginners Guide to the Forest Inventory

What is a tree?

The FIA program of the U.S. Forest Service defines a tree as a perennial woody plant species that can attain a height of at least 15 feet at maturity.

What is a forest?

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

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

From an FIA perspective, there are three types of forest land: timberland, reserved forest land, and other forest land. In Vermont, almost all (98 percent) of forest land is classified as unreserved and productive timberland, 1.5 percent is reserved and productive forest land, and the remaining 0.5 percent is unproductive reserved or unreserved forest land.

- Timberland is unreserved forest land that meets the minimum productivity requirement of 20 cubic feet per acre/year.

- Reserved forest land is land withdrawn from timber utilization through legislation or administrative regulation.

- Other forest land is commonly found on low-lying sites or high craggy areas with poor soils where the forest is incapable of producing 20 cubic feet per acre. In earlier inventories, FIA measured trees only on timberland plots and did not report volumes on all forest land. Since the implementation of the new annual inventory in Vermont in 2003, FIA has been reporting volume on all forest land.

- The second remeasurement of Vermont is in its fourth field season, and by 2012, FIA will be able to compare two sets of growth, mortality, and removal data. Much of the trend reporting in this publication is focused on timberland, because comparing current data to data from older periodic inventories requires timberland estimates.

How many trees are in Vermont?

Vermont's forest land contains about 835 million live trees that are at least 5 inches in diameter at breast height (d.b.h., diameter of the tree at 4.5 feet above the ground). We do not know the exact number of trees because the estimate is based upon only a sample of the total population. The frequency estimates are calculated from field measurement of 802 forested plots classified by ownership. For information on sampling errors, see the Statistics and Quality Assurance DVD at the back of this report.

How do we estimate a tree's volume?

The volume for a specific tree species is usually determined by the use of volume equations developed specifically for a given species. Sample trees are felled and measured for length, diameter, and taper. Several volume equations have been developed at the Northern Research Station for each tree species found in the region. Models have been developed from regression analysis to predict volumes within a species group. We produce individual tree volumes based upon species, diameter, and merchantable height. Tree volumes are reported in cubic-foot and International ¼-inch rule board-foot scale.

How much does a tree weigh?

Specific gravity values for each tree species or group of species were developed at the U.S. Forest Service's Forest Products Laboratory and applied to FIA tree volume estimates for developing merchantable tree biomass (weight of tree bole). To calculate total live-tree biomass, we have to add the biomass for stumps (Raile 1982), limbs and tops (Hahn 1984), and belowground stump and coarse roots (Jenkins et al. 2004). We do not currently report live biomass for foliage. FIA inventories report biomass weights as oven-dry short tons. Oven-dry weight of a tree is the green weight minus the moisture content. Generally, 1 ton of oven-dry biomass is equal to 1.9 tons of green biomass.

How do we compare data from different inventories?

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

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

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

A word of caution on suitability and availability

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

Forest Features

Vermont fall color. Photo by Sandy Wilmot, Vermont Department of Forests, Parks & Recreation

Dynamics of the Forest Land and Timberland Base

Background

Vermont hosts the transition of the maple/beech/birch forests of the northeastern United States to the spruce/fir forests of northern New England. Because forests are so important for wood products, tourism, clean water, wildlife habitat, and biomass energy, evaluating change in the status and condition of those forests is important. The amounts of forest land and timberland are vital measures for assessing forest resources and making informed decisions about their management and future. Gains or losses in forest area are an indication of forest sustainability, ecosystem health, and land use practices, and they have a direct effect on the ability of forests to provide goods and services. Additionally, these measures are the basis for FIA's estimates of numbers of trees, and amounts of wood volume and biomass.

What we found

Forests are the dominant 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 northwestern Vermont. When FIA completed its first inventory (1948) within Vermont, only 63 percent of the State's area was forested. Subsequent inventories showed a steady increase in forest cover as lands were re-forested due to the abandonment of farmland. Vermont's forested land base increased rapidly between the 1940s and 1970s and continued to increase at a decreasing rate until the 1990s (Fig. 2). By contrast, the amount of farmland decreased by nearly 1.6 million acres over that period (Fig. 3). Much of the nearly 1 million acre increase in forest land is 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 have increased the total forest land area in Vermont and nearly offset losses of forest land to development. Since 1997 the amount of forest cover has remained relatively stable (Figs. 2, 4). Currently, Vermont is about 75 percent forested.

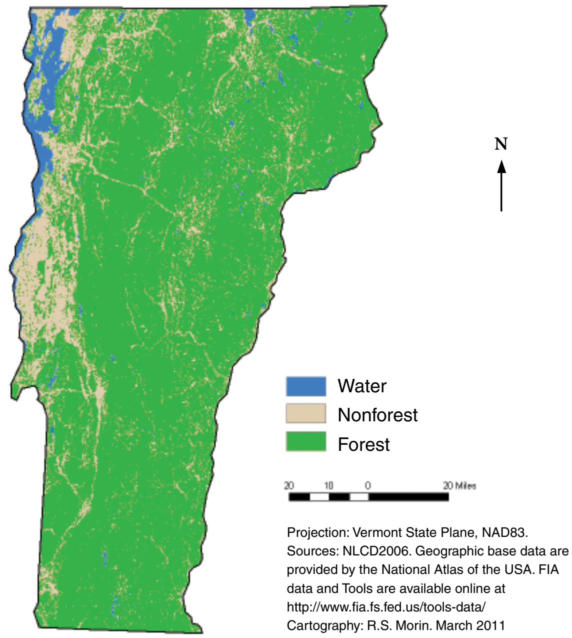


Figure 1.—Distribution of forest land in Vermont, 2006.

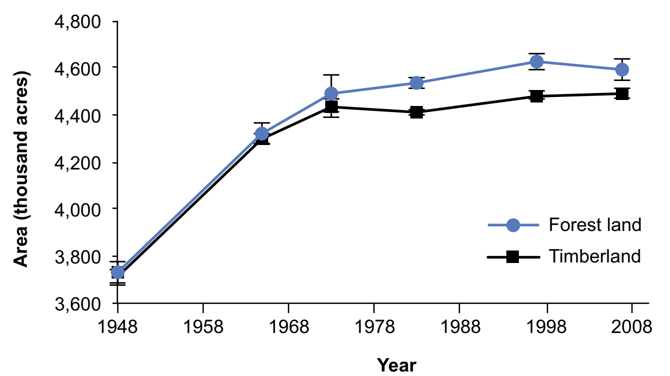


Figure 2.—Area of forest land and timberland, Vermont, 1948, 1966, 1973, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

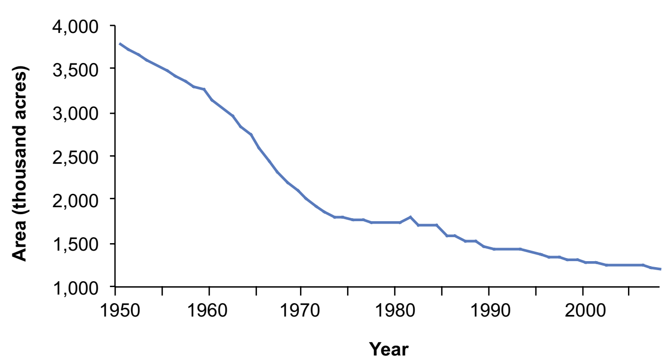
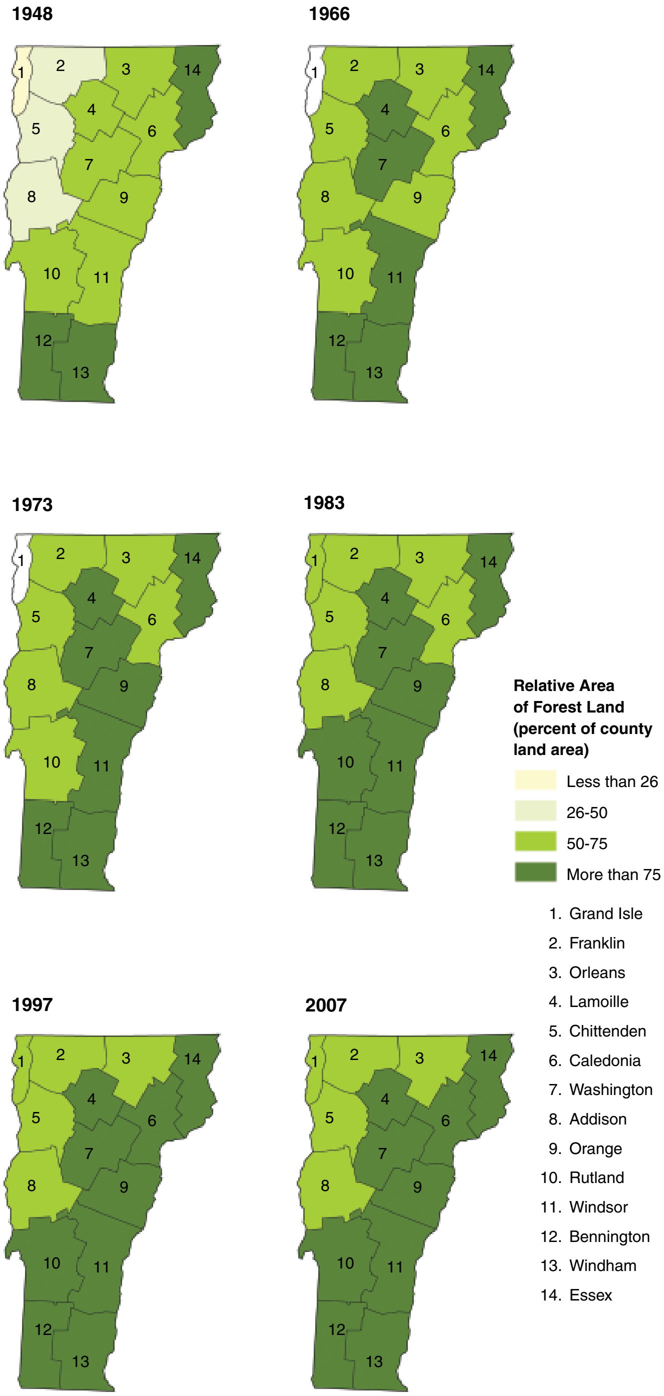


Figure 3.—Area of farmland (includes farm woodlots), Vermont, 1940-2008. (source: National Agriculture Statistics Service)



Projection: Vermont State Plane, NAD83.
Sources: U.S. Forest Service, Forest Inventory and Analysis Program, 1948, 1966, 1973, 1983, 1997, and 2007 data. Geographic base data are provided by the National Atlas of the USA. FIA data and Tools are available online at http://www.fia.fs.fed.us/tools-data/
Cartography: R.S. Morin. May 2011

Figure 4.—Distribution of relative area of forest land by county and inventory year, Vermont, 1948, 1966, 1973, 1983, 1997, and 2007. (Grand Isle County not reported in 1966 or 1973 inventories and combined with Franklin County in 1983 and 1997 inventories.)

What this means

At 75 percent, Vermont is the fourth most forested state in the United States. The current statewide estimate of forest land remains statistically unchanged since 1997 (Fig. 1). 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, and the economics of farming.

Availability and Productivity of Forest Land

Background

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

What we found

Ninety-eight percent of Vermont's forest land meets the definition of timberland (Figs. 2, 5). The current statewide estimate of timberland has remained statistically unchanged since 1997. Most of the land in the reserved class is designated natural areas on the Green Mountain National Forest. Other forest land (i.e., unreserved and unproductive) is rare in Vermont and only accounts for less than 1 percent of total land area (Fig. 5).

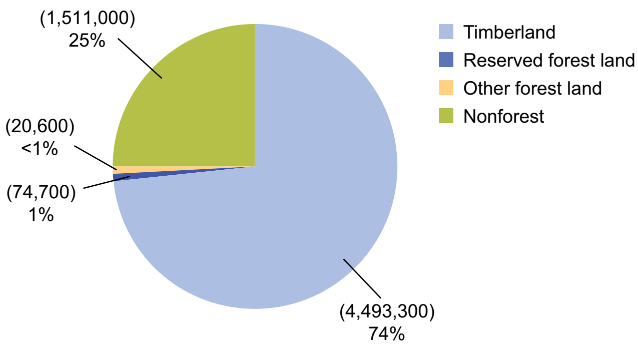


Figure 5.—Land area (acres) by major use, Vermont, 2007.

What this means

Because the vast majority of Vermont's forest land is classified as timberland, it is potentially available for harvesting timber or other forest products. It also means that trends observed on timberland are likely to apply to forest land as well. The demand for forest products will increase 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 the amount of forest land actively managed for forest products and a more accurate estimate of the amount of timberland truly available for harvesting.

Ownership of Forest Land

Background

Forest land owners are a primary factor in determining how the distribution, composition, structure, and health of forest ecosystems will change into the future. Different types of owners (e.g., private, public) have varying objectives, opportunities, and constraints that govern their decisions about forest management practices. FIA conducts the National Woodland Owner Survey (NWOS) to further our understanding of who owns forest land, why they own it, and what they intend to do with it. The NWOS collects data on forest holding characteristics, ownership histories, ownership objectives, forest uses, forest management practices, preferred methods for receiving information, concerns, future intentions, and demographics (see Butler 2008).

What we found

A relatively small proportion of Vermont's forest land is owned by the public (20 percent; Fig. 6). The Federal Government holds 489,000 acres (11 percent) of forest land, most of which is administered by the Green Mountain National Forest (424,900 acres of forest land). The State of Vermont holds 382,600 acres of forest land (8 percent) in various state agencies including state parks and forests, and local governments hold another 42,700 acres of forest land (1 percent; Fig. 7). Public land increased by about 160,000 acres between 1997 and 2007 after remaining stable between 1983 and 1997 (Fig. 8).

Vermont's forest land is primarily held by private landowners (80 percent). Approximately 3 million acres, 64 percent, of forest land is owned by 87,000 families and individuals (Butler 2008). Other kinds of private owners (e.g., corporations, nonfamily partnerships, nongovernmental organizations, clubs, and other nonfamily private groups) hold another 723,600 acres of forest land (16 percent; Fig. 7).

The number of family or individual forest owners in Vermont increased by 40 percent over the past two decades, from 62,000 to 87,000 (Butler 2008, Widmann and Birch 1988), during which the average forest landholding size decreased from 65 acres (Widmann and Birch 1988) to 37 acres (Butler 2008). The majority of family forest owners (53 percent) hold less than 10 acres of forest land, but represent only 6 percent of the total family forest land base in Vermont (Fig. 9). Family forest owners have a wide variety of reasons for holding forest land and objectives for land management. The most widely cited reason for forest land ownership in Vermont is that the forest land is part of residential property. Other common reasons are related to aesthetics, recreation, and family legacy (Fig. 10). Although only 8 percent of individual or family forest owners listed timber production as an important reason for owning forest land, 53 percent of family forest owners (holding 81 percent of family forest area) had harvested trees from their properties and 32 percent (holding 67 percent of family forest area) had harvested saw logs (Fig. 11).

Only 15 percent of family forest owners have a written management plan, but 50 percent of the family owned forest land is governed by one (Fig. 12). However, 26 percent of the owners holding 54 percent of the family forest acreage have sought management advice. Private consultants and the Vermont Department of Forests, Parks and Recreation were most often contacted for advice. Additionally, about 30 percent of eligible privately

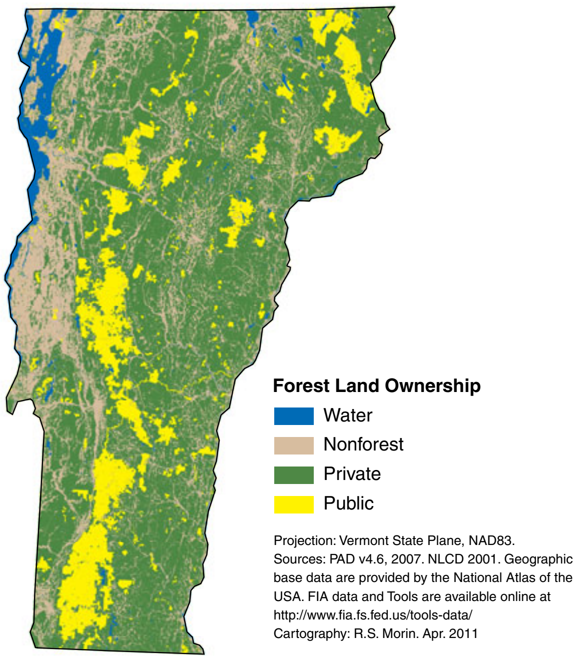


Figure 6.—Distribution of forest land by owner group, Vermont, 2007.

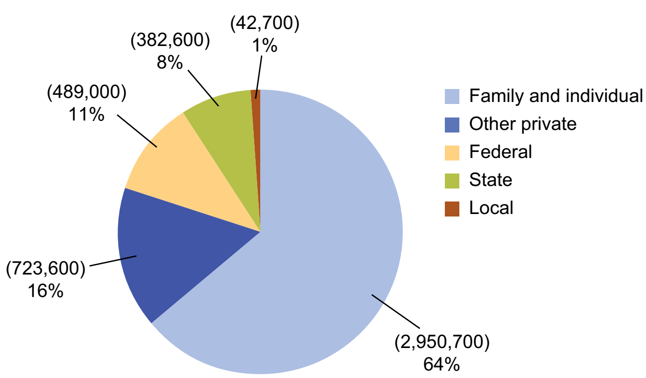


Figure 7.—Forest land area (acres) by major ownership category, Vermont, 2007.

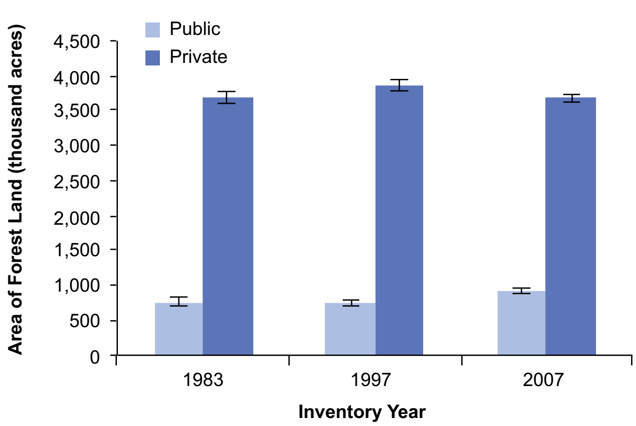


Figure 8.—Forest land area by major ownership category, Vermont, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

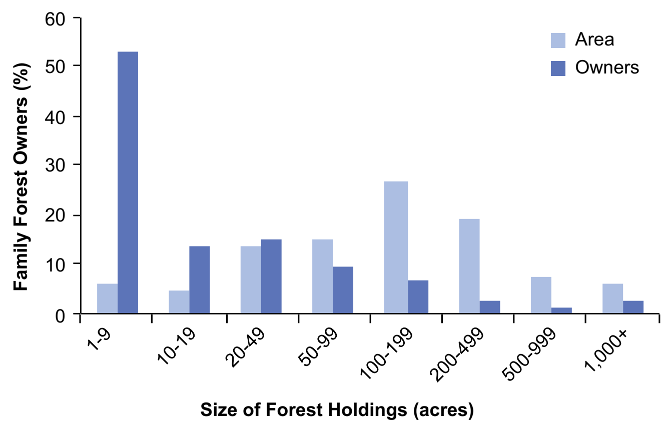


Figure 9.—Area of family or individual owned forests and number of family or individual forest owners by size of forest landholdings, Vermont, 2006.

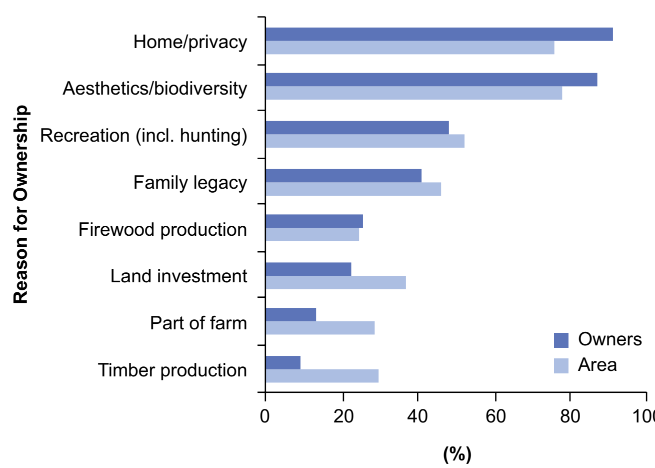


Figure 10.—Percentage of area and owners of family forests by reason for owning forest land, Vermont, 2006. (Numbers include landowners who ranked each objective as very important (1) or important (2) on a seven-point Likert scale. Categories are not mutually exclusive.)

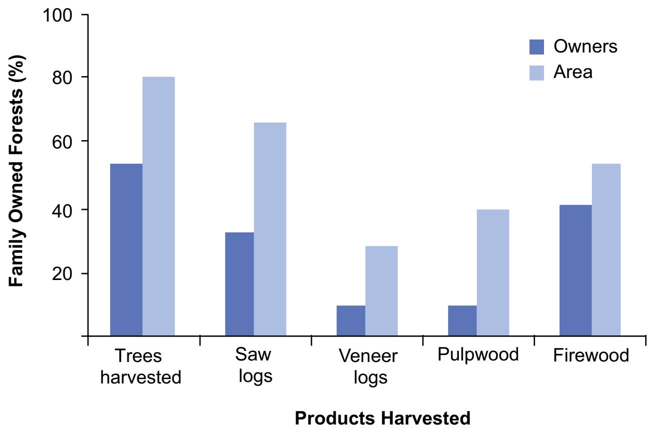


Figure 11.—Percentage of area and owners of family forests by harvesting experience and products harvested, Vermont, 2006. (Categories are not mutually exclusive.)

Nearly one-quarter of Vermont's family forest owners are at least 65 years old. This group of owners also controls more than 35 percent of the family forest acreage (more than 2 million acres) in the State (Fig. 13). The 25 percent of family forest owners who have owned their forest for less than 10 years presumably reflects the increase in the number of owners over the past decade. On the other hand, the tenure of family forest ownership is generally much longer. More than 40 percent of the family forest acreage has been under the same ownership for more than 25 years (Fig. 14). The majority of family forest owners (51 percent) have minimal activity planned for their forest land over the next 5 years. The most common activity planned is harvesting firewood (Fig. 15).

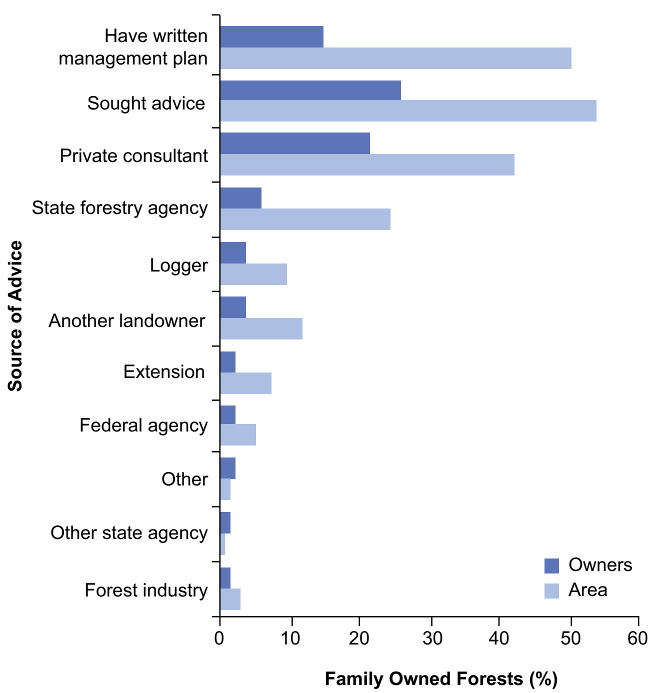


Figure 12.—Percentage of area and owners of family forests who have a written management plan, who have sought advice, and advice source, Vermont, 2006. (Categories are not mutually exclusive.)

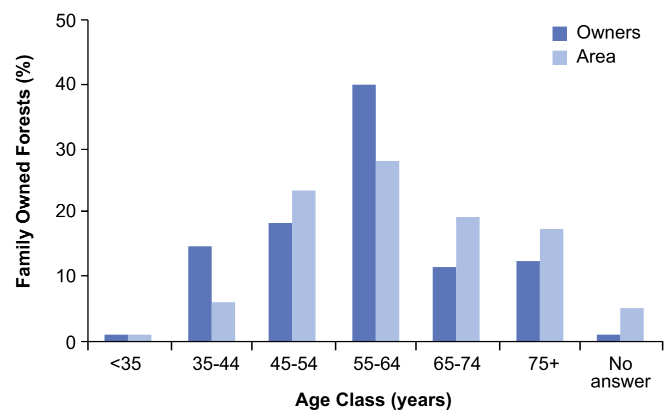


Figure 13.—Percentage of area and owners of family forests by age of primary decisionmaker, Vermont, 2006.

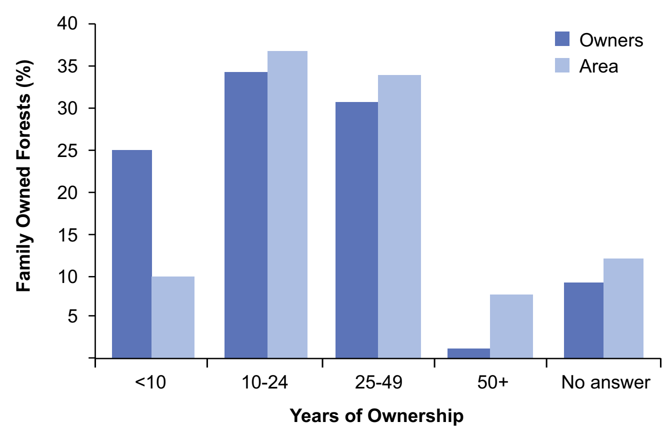


Figure 14.—Percentage of area and owners of family forests by ownership tenure, Vermont, 2006.

owned forest land is currently enrolled in Vermont's Use Value Appraisal (UVA) program (VFPR 2010). The UVA program, also called "Current Use" or "Land Use," enables landowners who practice long-term forest management to have their enrolled land appraised for property taxes based on its value for forestry, rather than its fair market (development) value.

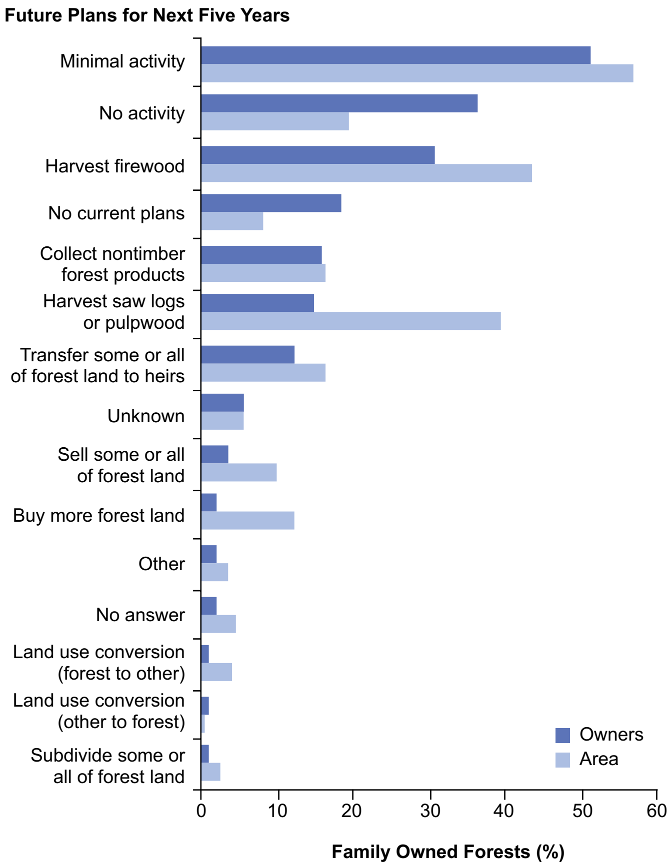


Figure 15.—Percentage of area and owners of family forests by plans for next 5 years, Vermont, 2006.

What this means

Public ownership of forest land has increased in Vermont over the past 25 years. This increase reflects increases in forest land ownership on the Green Mountain National Forest and within State and local governments. The number of forest land acres in public ownership is likely to increase in the coming years as more lands are conserved.

Because the majority of Vermont's forest land is held by private landowners, future forest conditions will be greatly influenced by the decisions these owners make. The small parcels held by many landowners complicate the economics of forest management and the delivery of government programs. The trend of greater numbers of landowners controlling smaller parcels will only increase this problem into the future. If this trend continues, access to Vermont's timber resources by the forest industry could decrease. Furthermore, landowners of smaller tracts of forest are less likely to allow access to their lands for recreation, which could lead to a decrease in forest-related recreation opportunities for people in Vermont.

Although the vast majority of landowners did not give a high priority to timber production, most appear to be willing to harvest when conditions are right. Because most owners do not have a written management plan, many harvests are unlikely to be a part of long-term planning.

The large number of landowners who are 65 years or older are likely to represent a large turnover of forest land ownership in the future. When forest land changes owners, parcelization and unsustainable harvesting practices are more likely to occur. In addition, increasing numbers of new landowners may make it more difficult for government agencies to provide advice, education, and services to family forest owners.

Urbanization and Fragmentation of Forest Land

Background

Forest fragmentation and habitat loss diminish biodiversity (Honnay et al. 2005). Fragmentation of forests is also recognized as a major threat to animal populations worldwide (Rosenberg et al. 1999a), particularly for bird species that are sensitive to habitat fragmentation (Donovan and Lamberson 2001) and for species that are wide ranging, slow moving, and/or slow reproducing (Forman et al. 2003, Maine Audubon 2007).

The expansion of urban lands that accompanies human population growth often results in the fragmentation of natural habitat (Wilcox and Murphy 1985). Honnay et al. (2005) point out that spatial/physical fragmentation of habitats is only one of the human-induced processes affecting natural habitats and their biodiversity. Urbanization, increasing the proximity of people, development, and other anthropogenic pressures to natural habitats, and changing the ways in which humans use those natural habitats, can also lead to overexploitation of species, environmental/habitat deterioration, and introduction of exotic species. In addition to the negative effects on forested ecosystems, the fragmentation and urbanization of forest land may have direct economic and social effects. For example, smaller patches of forest or those in more populated areas are less likely to be managed for forest products (e.g., Kline et al. 2004, Wear et al. 1999) and are more likely to be "posted" (i.e., not open for public use) (Butler et al. 2004), potentially affecting forest industries as well as outdoor recreation opportunities and local culture. Forest land is also a significant factor in the protection of surface and groundwater, and fragmentation and urbanization of that forest land have been observed to affect both water quality and quantity (e.g., Hunsaker et al. 1992, McMachon and Cuffney 2000, Riva-Murray et al. 2010).

The metrics presented here relate to some aspect of urbanization or fragmentation that is or has been documented to have or suspected of having an effect on the forest, its management, or on its ability to provide ecosystem services and products (Riemann et al. 2008). These measures are forest edge versus interior, proximity to roads, patch size, local human population density, and intermixed house densities.

What we found

In Vermont, 73 percent of the forest land is more than 300 feet from an agriculture use or developed edge. This ranges from 39 percent in more fragmented Grand Isle County to 92 percent in Essex County (Table 1).

Figures 16 and 17 show where and to what extent forest land is affected by roads. As both Forman (2000) and Riitters and

Table 1.—The distribution of forest land with respect to several urbanization and fragmentation factors, expressed as a percent of the forest land in each county, Vermont, 2007

County	% forest land in county[a]	Forest land with house density > 15.5 per square mile[b]	Forest land > 295 feet from an ag or developed edge[c]	Forest land > 980 feet from a road[d]	Forest land located in patches > 100 acres in size[e]	Forest land located in a block with population densities > 150/square mile[f]
Addison	56	25	71	58	92	3
Bennington	86	21	81	59	98	3
Caledonia	80	21	70	43	98	2
Chittenden	64	53	66	47	93	14
Essex	93	6	92	61	99	1
Franklin	62	24	64	54	95	4
Grand Isle	38	87	39	41	77	6
Lamoille	84	30	77	56	98	3
Orange	81	27	68	38	98	2
Orleans	75	19	69	51	97	2
Rutland	78	28	73	54	97	4
Washington	83	41	73	45	98	5
Windham	87	43	72	42	98	3
Windsor	83	38	69	39	97	3
State Total	78	29	73	49	97	3

[a] Percent forest estimate based on NLCD 2001. Values are generally higher than estimates from FIA plot data.
[b] Approximating the forest land potentially affected by underlying development.
[c] Approximating the forest land undisturbed by edge conditions.
[d] Approximating the forest land outside the effects of roads.
[e] Approximating the forest land with potentially enough core area for sustainable interior species populations.
[f] Approximating the forest land not available for commercial forestry.

Wickham (2003) reported, this effect can be quite extensive, even in areas that appear to be continuous forest land from the air. In Vermont, for example, 22 percent of the forest land is within 330 feet of a road of some sort and 48 percent is within 980 feet.

Forest land in Vermont occurs primarily as a relatively contiguous forest matrix within which urban development, agriculture, roads, and other nonforest areas occur (Riitters et al. 2000). Forested areas containing higher proportions of small patches (<100 acres) occur along the river valleys in northwestern Vermont (Fig. 18). Most counties have a very low proportion of forest land in small patches (Fig. 19).

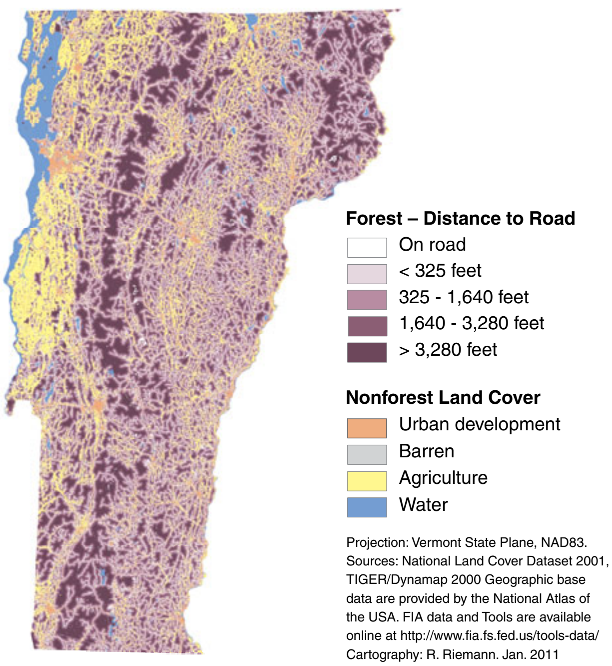


Figure 16.—Distribution of forest land in distance to the nearest road classes (includes all roads), Vermont, 2000 and 2001.

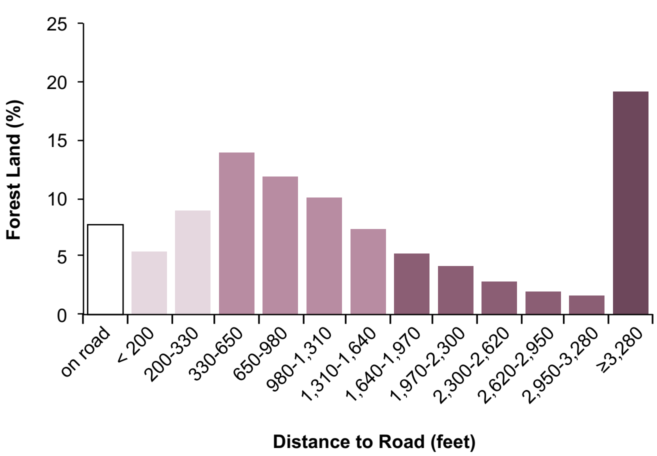


Figure 17.—Distribution of forest land in distance to road classes (includes all roads), Vermont, 2000 and 2001.

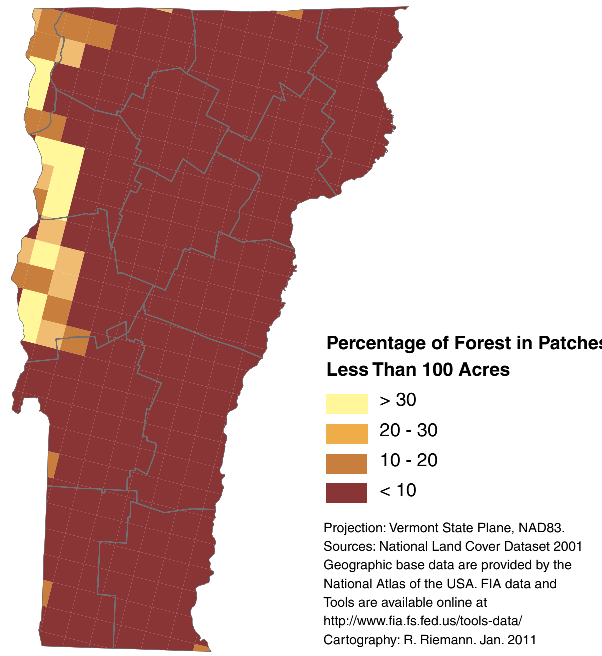


Figure 18.—Percent of forest cover in patches less than 100 acres, by 62.1-square mile grid cell, Vermont, 2000.

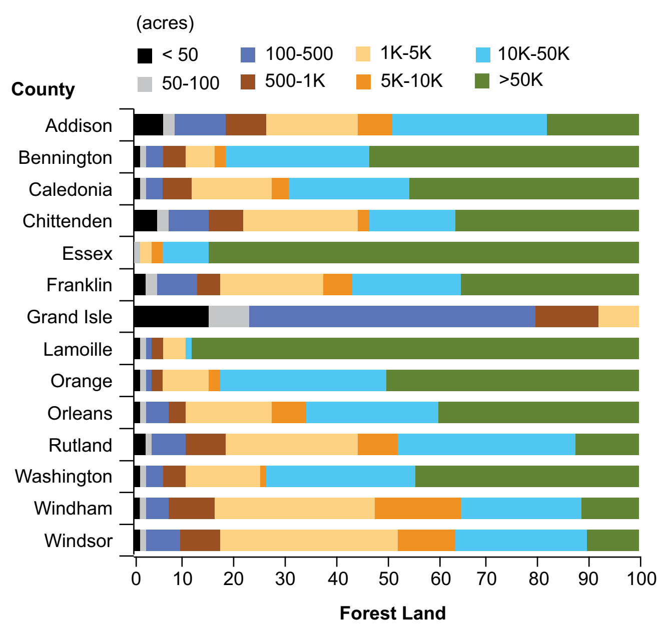


Figure 19.—Distribution of forest land by patch size by county, Vermont, 2000.

The Wildland-Urban Interface (WUI) is commonly defined as the zone of transition between unoccupied land and human development; here we use a house density of above 15.5 houses per square mile as the threshold for WUI. Figures 20 and 21 illustrate how much forest land is affected by house densities greater than 15.5 houses per square mile. Counties range from 6 percent (Essex) to 53 percent (Chittenden) of the forest intermixed with house densities of >15.5 per square mile, except for Grand Isle County at 87 percent (Fig. 21). Almost 25 percent of the live-tree basal area in Vermont is within the WUI, but this proportion is higher for eastern white pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*) (Fig. 22).

Table 1 brings many of these factors together and presents the extent to which the current forest land base is being influenced by one or more of the factors. For example, in Essex County, which is 93 percent forested, 6 percent of the forest land is potentially affected by house densities greater than 15.5 per square mile, and 92 percent of the forest land is far enough from an edge to be considered interior forest. Nearly all of the forest land is in large patches (>100 acres), but only 61 percent is more than 980 feet from a road. In Windham County, which is 87 percent forested, 43 percent of the forest land is potentially affected by house densities greater than 15.5 per square mile, and 72 percent of the forest land is far enough from an edge to be considered interior forest. Nearly all of that forest land is in large patches (>100 acres), but only 42 percent is more than 980 feet from a road. On the other end of the spectrum are the forests in Grand Isle County, which occupy 38 percent of the land area and occur largely mixed with housing densities above 15 per square mile (87 percent of the forest land). The forests tend to occur in smaller patches (77 percent of the forest is in patches >100 acres), and the county has correspondingly much less interior forest land than other areas (39 percent).

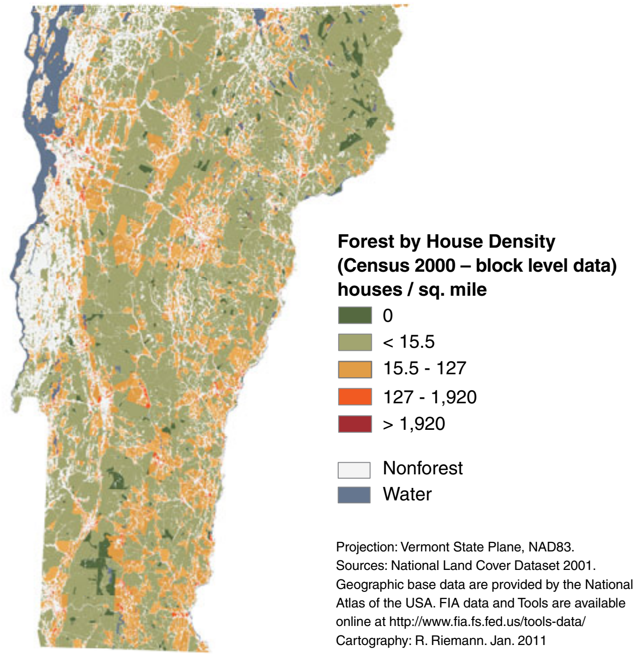


Figure 20.—Distribution of forest land by house density classes, Vermont, 2000 and 2001.

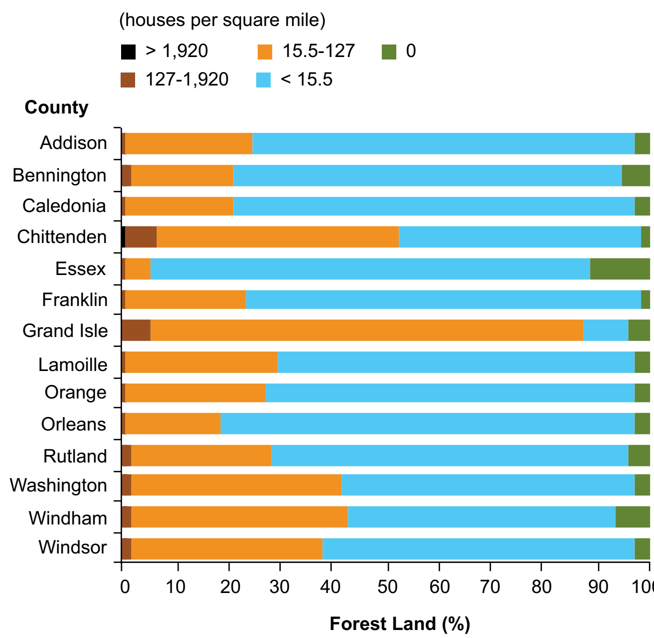


Figure 21.—Distribution of forest land by county and house density class, Vermont, 2000 and 2001.

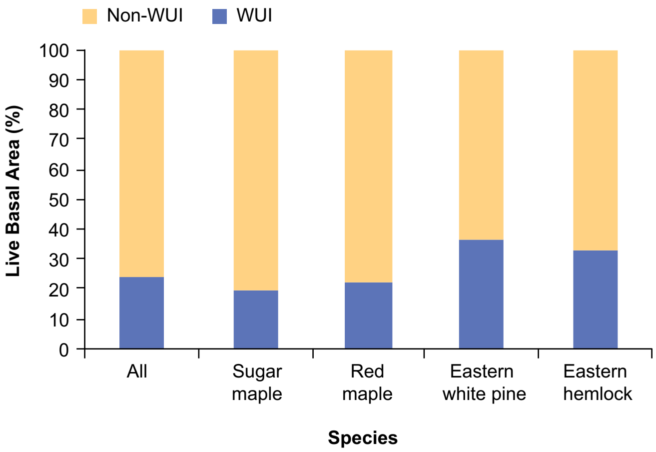


Figure 22.—Proportion of basal area in the Wildland-Urban Interface (WUI) by species, Vermont, 2007.

What this means

Edge effects vary somewhat with distance from forest edge, depending on the type of effect and species of vegetation or wildlife, (e.g., Chen et al. 2002, Flaspohler et al. 2001, Rosenberg et al. 1999a), but 100 to 300 feet is frequently used as a general range for the "vanishing distance" or the distance into a patch where the edge effect disappears and interior forest conditions begin.

Figures 16 and 17 depict the pervasiveness of roads in the landscape, even in Vermont. Road effects diminish when distance from road to forest reaches about 330 feet for secondary roads (a rough estimate of a highly variable zone), 1,000 feet for primary roads in forest (assuming 10,000 vehicles per day), and 2,650 feet from roads in urban areas (50,000 vehicles per day) (Forman 2000). Roads have a variety of effects, including hydrologic changes, chemical changes (salt, lead, nutrients), sediment load changes, noise level changes, introduction of invasive species, habitat fragmentation, increases in human access, impacts on forest ecosystem processes, wildlife movement and mortality, and human use of the surrounding area. Vermont and the northern New York-New England forest region are some of the few areas in the eastern United States with less than 60 percent of their land area within 1,250 feet of the nearest road (Riitters and Wickham 2003). With 62 percent of Vermont's forest land within 1,310 feet of a road statewide, cumulative ecological impacts from roads should be a very real consideration. Actual ecological impacts of roads will vary by the width of the road and its maintained right-of-way, number of cars, level of maintenance (salting, etc.), number of wildlife-friendly crossings, hydrologic changes made, perviousness of road surfaces, location with respect to important habitat, and other factors. These variables also suggest some of the changes that can be made to moderate the impact of roads (Forman 2000, Forman et al. 2003, Maine Audubon 2007).

Habitat requirements for wildlife vary by species, but for reporting purposes it is often helpful to summarize forest patch data using general guidelines. Many wildlife species prefer contiguous forest patches that are at least 100 acres. This patch area is often used as the minimum size that still contains enough interior forest to be a source rather than a sink for populations of some wildlife species. Excluding the impact of roads that do not break the tree canopy, the majority of Vermont's forest land is in patches larger than 100 acres.

Human population is generally recognized as having a negative effect on the viability and practice of commercial forestry (Barlow et al. 1998, Kline et al. 2004, Munn et al. 2002, Wear et al. 1999). Working in Virginia, Wear et al. (1999) identified a threshold of 150 people per square mile as the population density at which the probability of commercial forestry drops to practically zero. Only 3 percent of forest land in Vermont is near population centers that exceed the threshold of 150 people per square mile, but this proportion is higher in northwest Vermont in Chittenden (14 percent) and Grand Isle (6 percent) counties (Table 1).

Forest intermixed with houses represents areas of forest cover most likely to be in nonforest land use and more likely to be experiencing pressures from recreation, invasive plant species, and other local human effects. This intermix area also represents a challenge to managing forest fires. A threshold of 15.5 houses per square mile represents the approximate density at which firefighting switches from "wildland" to "structure" techniques and costs (Radeloff et al. 2005). Although the other pressures from high housing densities are likely to be more of an issue than forest fires in Vermont, thresholds for those issues are less developed at this point. Therefore, Figure 20 should be interpreted as identifying where areas of increased pressure from intermixed residential development are likely to occur. Nationwide, increases in lower density, "exurban" development have been forecast by both Theobald (2005) and Hammer et al. (2004), particularly at the urban fringe and in amenity rich rural areas.

Forest health, sustainability, management opportunities, and the ability of forest land to provide needed products and ecosystem services are affected to varying degrees, and in different ways, by changes in the fragmentation of forests and urbanization.

Stand Size and Structure – A Growing, Maturing Forest

Background

Tree diameter measurements are used by FIA to assign one of three stand-size classes to sampled stands, which give a general indication of stand development. The categories are determined by the 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 fewer than in the large-diameter stands. Large-diameter stands consist of a preponderance of trees at least 9 inches in 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 in Vermont are examined using all live trees and growing-stock trees only to identify the amount of growing space being used to grow trees of commercial value as opposed to the amount occupied by trees of little to no commercial value. For a tree to qualify as growing stock, it cannot be a noncommercial species (e.g., striped maple (*Acer pensylvanicum*), eastern hophornbeam (*Ostrya virginiana*), and pin cherry (*Prunus pensylvanica*)) or 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 poor 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

The distribution of forest land by size class has changed substantially since 1983 (Fig. 23). A statistically significant decrease in area of small-diameter stands and a statistically significant increase in area of large-diameter stands have both occurred. Area of medium-diameter stands has remained unchanged. The trend is even more evident when the current estimates are compared with

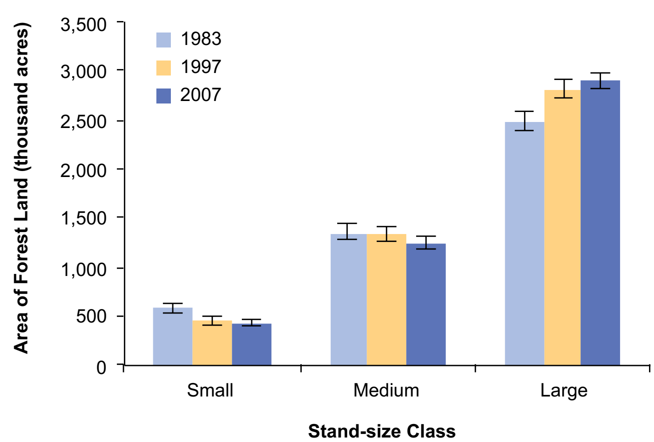


Figure 23.—Area of forest land by stand-size class, Vermont, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

those from the 1948 inventory (McGuire and Wray 1952; Fig. 24). Timberland area in medium-diameter stands decreased from 40 percent in 1948 to only 27 percent in 2007, and timberland area in large-diameter stands increased from 51 percent in 1948 to 64 percent in 2007.

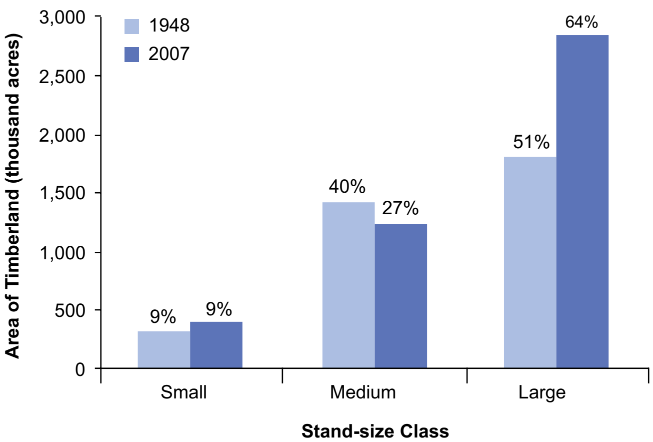


Figure 24.—Area of timberland by stand-size class, Vermont, 1948 and 2007.

Since 1983, forest land area in the moderately and fully stocked classes for all live trees and growing-stock trees has increased by 1.5 million acres for all trees and by 400,000 acres for growing-stock trees; at the same time overstocked area has decreased by 1.4 million acres for all trees and by 500,000 acres for growing-stock trees. Only about 30 percent of stands are less than fully stocked as of 2007. A comparison of nonstocked or poorly stocked stands for all live trees and growing-stock trees in 2007 reveals that the area is 2.5 times greater for growing-stock trees (489,000 to 198,000 acres) (Figs. 25, 26). Out of the nearly one-half million acres that are poorly or nonstocked with growing-stock trees, nearly 33 percent are less than 40 years old and 80 percent are less than 80 years old (Fig. 27).

What this means

The trend of increasing forest land area in large-diameter stands demonstrates clearly the continuing maturation of Vermont's forests to stands of larger, older trees. An important component of forest biodiversity is complex structural features. Although the area of forest in smaller diameter stands is decreasing, mature stands do provide

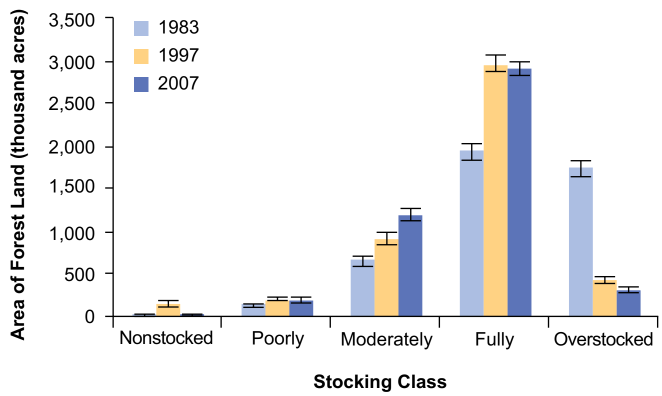


Figure 25.—Area of forest land by stocking class of all live trees, Vermont, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

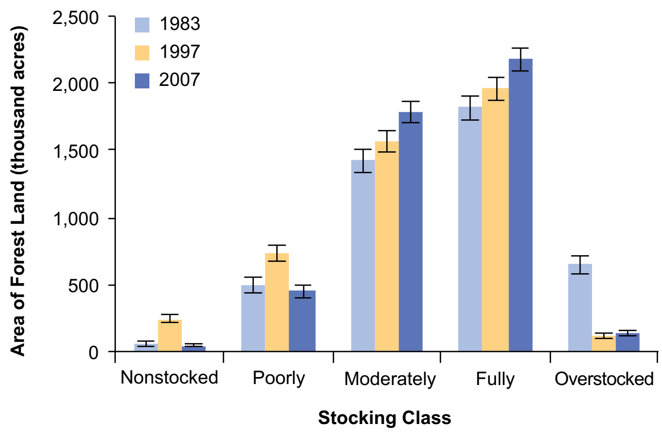


Figure 26.—Area of forest land by stocking class of growing-stock trees, Vermont, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

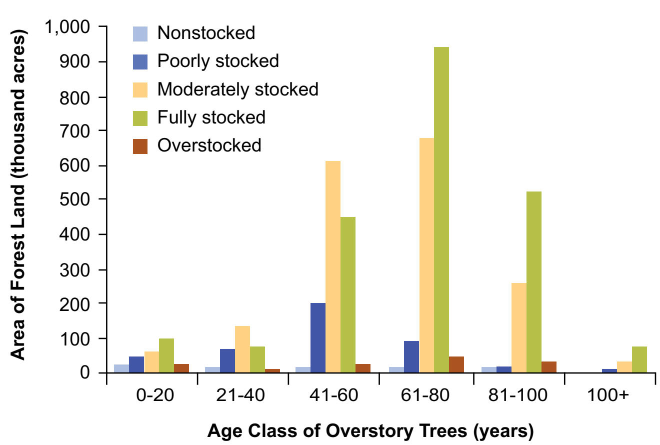


Figure 27.—Area of forest land by stocking class of growing-stock trees and stand-age class, Vermont, 2007.

diverse structures because of gap dynamics and the presence of shade-tolerant species in the understory. The diversity of tree ages and sizes present in mature forests provides a broad range of habitats for wildlife and other organisms and makes forests more dynamic and better able to recover from disturbance.

The shifts in forest area out of nonstocked, poorly stocked, and overstocked stands into moderately and fully stocked stands indicate that forest management practices over the past three decades have improved the general stocking condition across the State. The majority of Vermont's forest land is well stocked with tree species of commercial importance. From a commercial perspective, continued management of these stands should keep them growing optimally by preventing them from becoming overstocked. From an ecological perspective, Vermont has a very low percentage of older forests, so consideration may be given to allowing some areas to continue growing beyond commercial benchmarks, which would allow the development of some ecologically mature forests that support certain wildlife species and ecological processes. Although the nearly one-half million acres of forest land that is poorly or nonstocked with commercially important species represents a loss of potential growth, these forests do contribute to biodiversity. However, the higher light levels and open growing conditions in these poorly stocked or nonstocked stands may make them more susceptible to invasion by nonnative plant species (e.g., common barberry (*Berberis vulgaris*), multiflora rose (*Rosa multiflora*)).

Numbers of Trees

Background

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

What we found

Between 1983 and 1997, numbers of trees increased across all diameter classes with the greatest increases occurring in the smaller d.b.h. classes. Since 1997, the number of trees in the 12-inch and smaller d.b.h. classes has decreased while the number of trees in the larger classes has continued to increase. The curves of numbers of trees by diameter class have shifted to the right (Fig. 28). In general, the percentage increase in the number of trees by diameter class increased with increasing diameter class (Fig. 29).

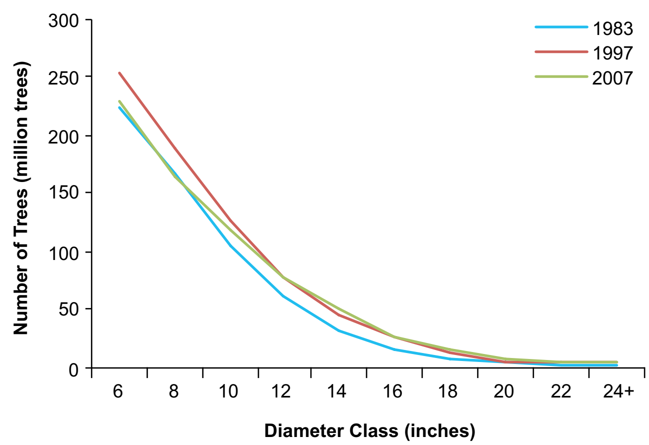


Figure 28.—Number of growing-stock trees on timberland by diameter class, Vermont, 1983, 1997, and 2007.

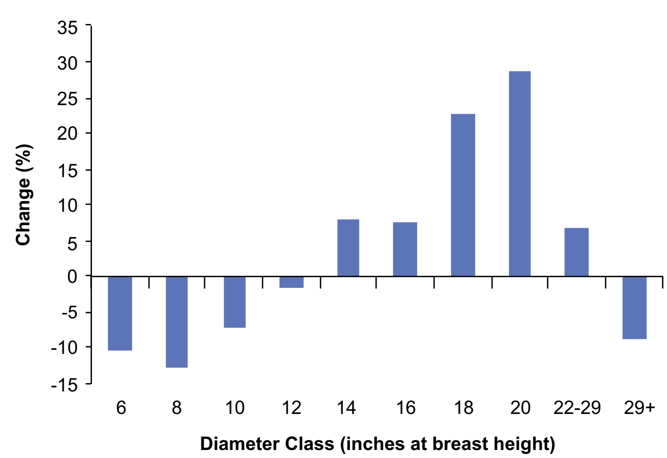


Figure 29.—Percent change in the numbers of growing-stock trees by diameter class, Vermont, 1997-2007.

When we look at growing-stock trees 5 inches and larger d.b.h., sugar maple (*Acer saccharum*) continues to be the most numerous tree species in Vermont even though it decreased in number between 1997 and 2007. Most other abundant species in Vermont also decreased in number during that period—eastern hemlock, balsam fir (*Abies balsamea*), red spruce (*Picea rubens*), yellow birch (*Betula alleghaniensis*), eastern white pine, and paper birch (*Betula papyrifera*). Red maple (*Acer rubrum*) numbers remained stable while American beech (*Fagus grandifolia*) and white ash (*Fraxinus americana*) actually increased in numbers (Fig. 30).

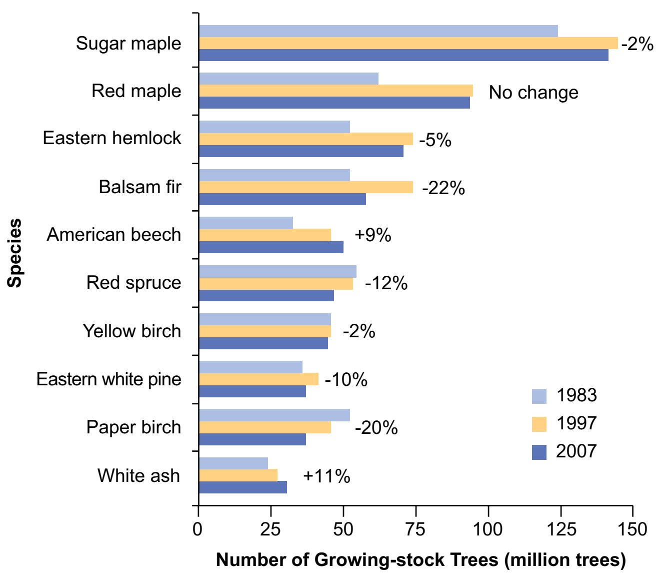


Figure 30.—Number of growing-stock trees on timberland by species, Vermont, 1983, 1997, and 2007, and percent change, Vermont, 1997-2007.

By contrast, most tree species increased in numbers of sapling-size trees (1 to 4.9 inches d.b.h.). Due to a large increase between 1997 and 2007, American beech saplings have surpassed sugar maple to become the most numerous of any species in Vermont. Other abundant tree species showing large increases in number of saplings during this period are white ash and paper birch. The only major species to show a decrease in number of saplings is sugar maple (Fig. 31).

What this means

Since 1983, the number of large-diameter trees has been increasing steadily in Vermont. More recently, the number of trees in the 6- through 12-inch d.b.h. classes has been

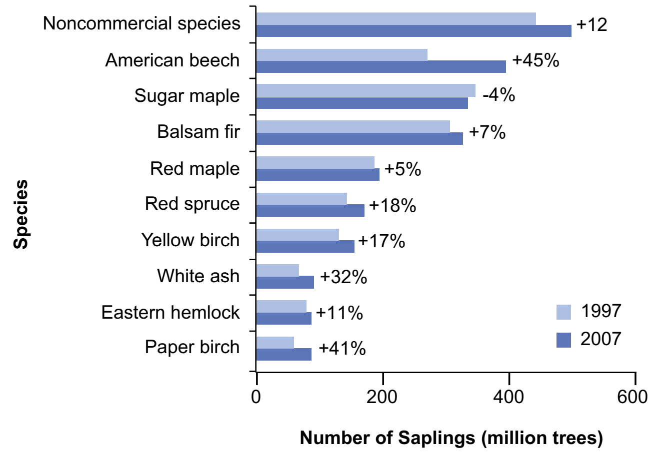


Figure 31.—Number of saplings (1 to 4.9 inches in d.b.h.) on timberland by species, Vermont, 1997 and 2007, and percent change, Vermont, 1997-2007. (Noncommerical species includes striped maple, eastern hophornbean, pin cherry, and other species with poor form).

decreasing, indicating that as trees grow into larger size classes they are not being replaced by smaller trees growing into the medium-diameter classes, but the number of trees in the medium-diameter category should increase when ingrowth from the small-diameter classes occurs (Fig. 32).

Saplings in today's forest are a prime indicator of the composition of the future forest. Saplings eventually replace large trees that are harvested or killed by insects, diseases, or weather events. The increasing dominance of American beech in the understory will have an impact on the future species composition of Vermont's forests. The lack of eastern white pine saplings may indicate a future problem with regeneration of white pine stands.

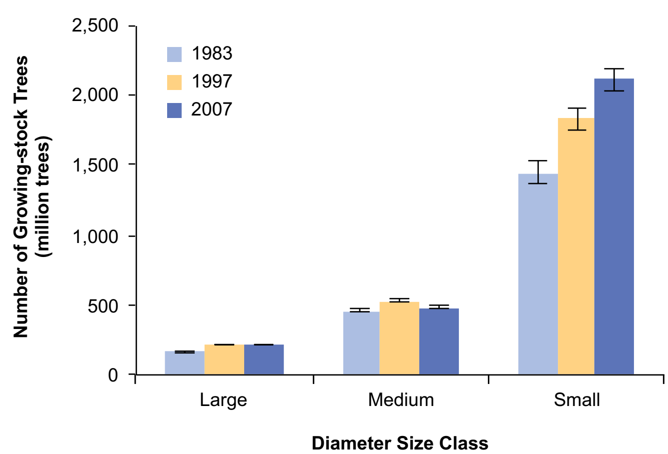


Figure 32.—Number of growing-stock trees by size class, Vermont, 1997 and 2007.

Biomass

Background

Due to the important role of trees in the carbon cycle, forests act as a major sink for carbon by removing carbon dioxide from the atmosphere and storing it in wood tissue. About half of a trees biomass is comprised of carbon. The increasing interest in carbon dynamics for questions related to carbon sequestration, emission reduction targets, production of biofuels, and forest fire fuel loadings makes estimates of biomass a critical component of the FIA program. Biomass is defined by FIA as the aboveground 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's forests contribute significantly to carbon sequestration (uptake and storage). Vermont has also been a leader in biomass heat and power for the past two decades and continues to increase use of energy derived from sustainably harvested biomass.

What we found

The forest land of Vermont has an estimated 273.3 million dry tons of aboveground tree biomass (an average of 59.6 tons per acre). The distribution of biomass per acre on forest land is displayed in Figure 33. Biomass per acre is highest in southern Vermont and along the Green Mountains in north-central Vermont.

The largest portion of the biomass is in the boles of growing-stock trees (63 percent), but this is also the part of the tree 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. 34).

Total live dry biomass on timberland has increased by 44 percent since 1983 (189.4 to 268.9 million dry tons). This increase is primarily due to the increasing size of sawtimber trees in Vermont. Biomass also increased slightly in the sapling size class. By contrast, biomass decreased in poletimber-sized trees during this period (Fig. 35).

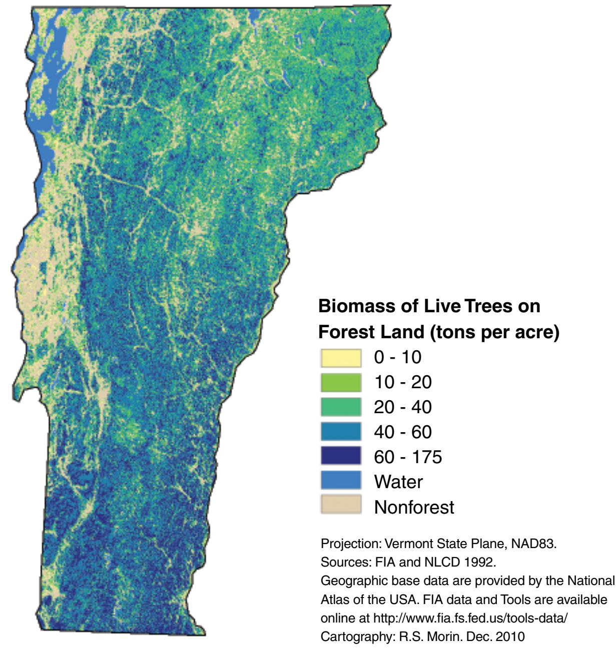


Figure 33.—Live-tree biomass per acre of trees at least 1 inch d.b.h. (dry tons), Vermont, 2006.

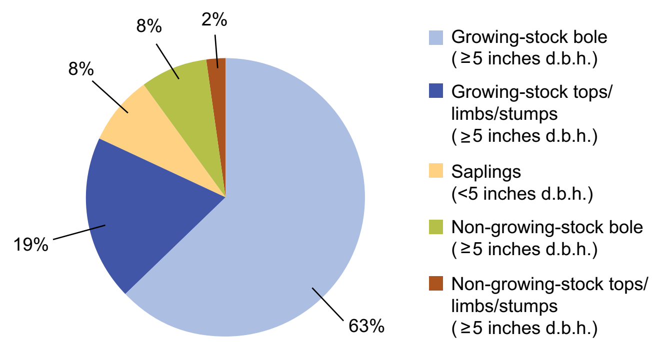


Figure 34.—Percentage of live-tree biomass (trees 1 inch d.b.h. and larger) on forest land by aboveground component, Vermont, 2007.

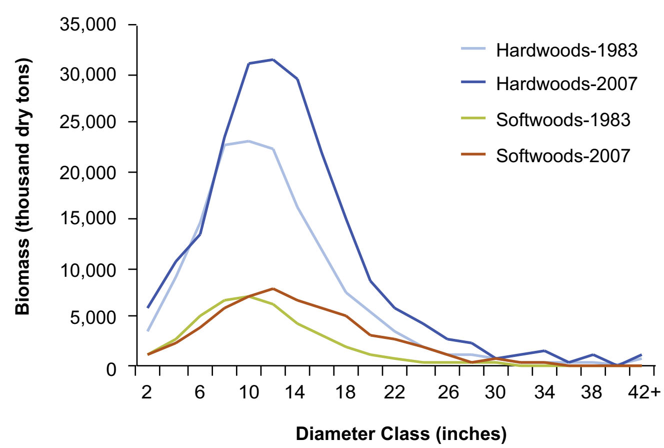


Figure 35.—Distribution of live-tree biomass (trees at least 1 inch d.b.h.) on timberland by species group and 2-inch diameter class, Vermont, 1983 and 2007.

What this means

Vermont's forests are continuing to accumulate biomass as the forests mature. Because most of the biomass is contained in the boles of growing-stock trees, and most of the gains in biomass stocks are found in the high value sawtimber-size trees, only a fraction of the accumulated material is available for use as fuel. If the demand for biomass increases with increases in heating, power production, and (potentially) the production of liquid fuels, the market would become more competitive as the wood products industry looks for more material. This creates an opportunity for enhancing forest management practices to benefit both traditional forest products supplies and those for bioenergy. The Biomass Energy Resource Center produced a detailed report on supply and sustainability of woody biomass (Sherman 2007).

Private forest landowners are the holders of the majority of Vermont's biomass (78 percent). Thus they play an important role in sustaining this resource. Currently, forest landowners are not financially compensated for the carbon sequestration service that is provided by the trees on their land. Markets for forest carbon sequestration are growing so this scenario could change in the future. If carbon trading and biomass production become more common, reliable estimates of biomass and carbon in forests, both in the aboveground biomass and in soils, will become more important. The future of this scenario depends on political decisions and crude oil prices.

Volume of Growing-stock Trees

Background

To assess the amount of wood available for commercial products, the FIA program computes growing-stock volumes for trees meeting requirements for size, straightness, soundness, and species that are growing on timberland and available for harvest. Growing-stock volume includes only trees at least 5 inches d.b.h. and excludes rough, rotten, and dead trees in addition to noncommercial tree species. 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, which is especially important because many past FIA inventories have only growing-stock estimates available.

What we found

The total growing-stock volume of the State has increased steadily since the 1960s as many cleared areas have begun to grow into forests again. The 2007 estimate of 9 billion cubic feet has not changed statistically since the 1997 inventory. The increase in growing-stock volume of about 0.3 percent annually is a reduction compared with the 2- to 5-percent annual increases in previous decades (Fig. 36). Distributions of growing-stock volumes by diameter class from the current and two previous inventories reveal a steady shift in timber volume toward larger diameter trees (Fig. 37). During the most recent inventory period (2003-2007), volume increased in all d.b.h. classes larger than 10 inches, but decreased in the 6-, 8-, and 10-inch diameter classes (Fig. 38).

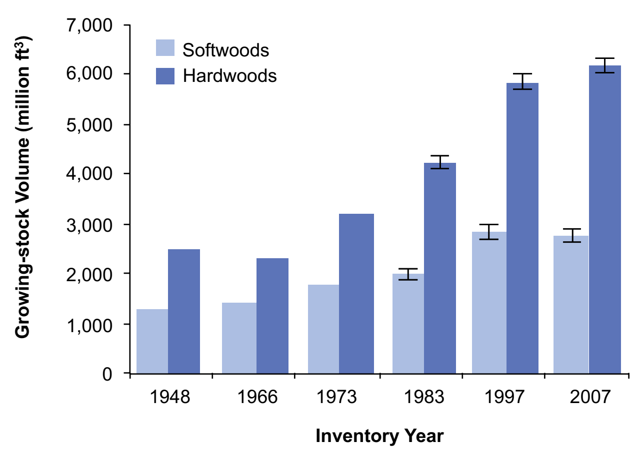


Figure 36.—Growing-stock volume on timberland by species group and inventory year, Vermont, 1948, 1966, 1973, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

The level of growing-stock volume on timberland in Vermont averages almost 2,000 cubic feet per acre. Of this volume, 68 percent is in hardwood species and 32 percent is in softwood species. Sugar maple (25 percent),

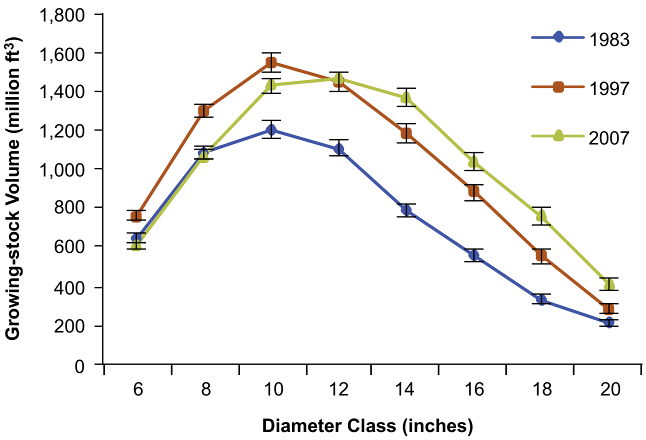


Figure 37.—Growing-stock volume on timberland by diameter class and inventory year, Vermont, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

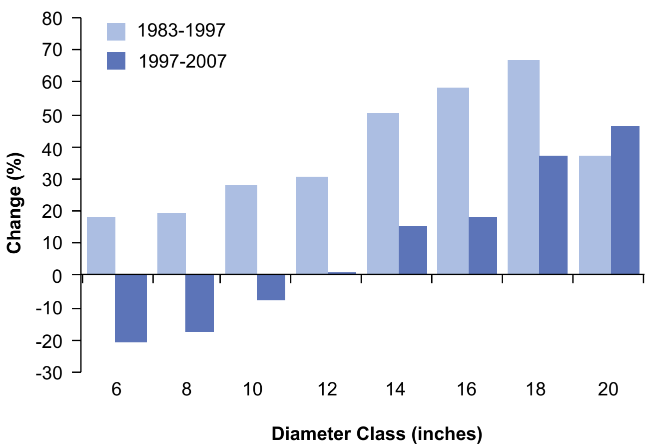


Figure 38.—Percent change in growing-stock volume by diameter class on timberland, Vermont, 1983-1997 and 1997-2007.

American beech (23 percent), red maple (15 percent), and yellow birch (10 percent) make up nearly 75 percent of the hardwood growing-stock volume. Balsam fir (42 percent), red spruce (24 percent), eastern hemlock (18 percent), and eastern white pine (18 percent) account for nearly 93 percent of softwood growing-stock volume.

Sugar maple continues to make up the largest amount of growing-stock volume, followed by red maple, eastern hemlock, and eastern white pine. These species make up 56 percent of the total growing-stock volume in Vermont. The only species that showed significant increases in growing-stock volume were yellow birch and white ash, while the only species to have significant decreases were paper birch and balsam fir (Fig. 39).

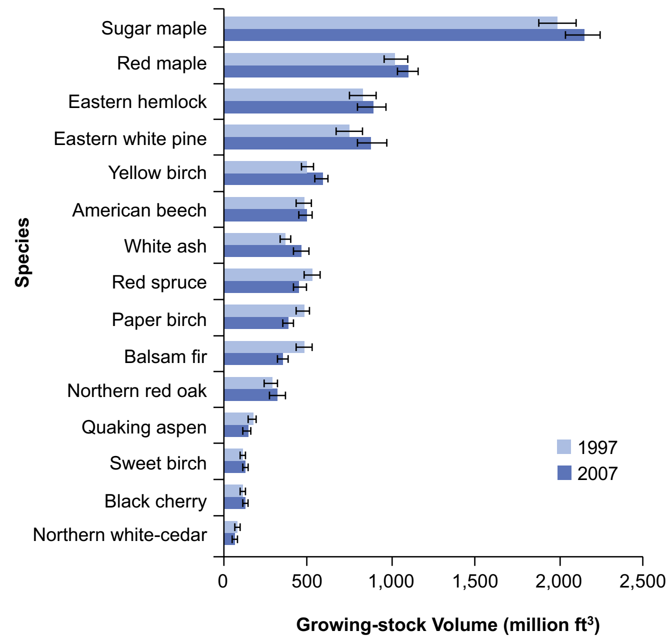


Figure 39.—Growing-stock volume on timberland by species, Vermont, 1997 and 2007. Error bars represent 68% confidence interval around estimate.

When we estimate board-foot volume, the order of the top four species by volume is slightly different from that of growing-stock volume. The increase in total board-foot volume is statistically significant (from 23.1 billion board feet in 1997 to 27.2 in 2007). Sugar maple remains the leading species by a large margin, but eastern white pine replaces red maple as the second highest and red maple drops below both eastern white pine and eastern hemlock. These four species make up 60 percent of the total sawtimber volume in Vermont (Fig. 40). Sugar maple, eastern white pine, and red maple increased significantly in sawtimber volume between the 1997 and 2007 inventories. Sawtimber volume of yellow birch, white ash, and northern red oak (*Quercus rubra*) also increased significantly; no major species decreased.

The distribution of total growing-stock volume and growing-stock volume for the top four species is shown in Figure 41. Total volume is evenly distributed with slightly higher volumes in the southern portion of the State and along the Green Mountains to the north. Volume per acre varies spatially by species. Sugar maple is distributed throughout most of Vermont with higher volumes at higher elevations along ridges. Red maple is also distributed throughout the State; the

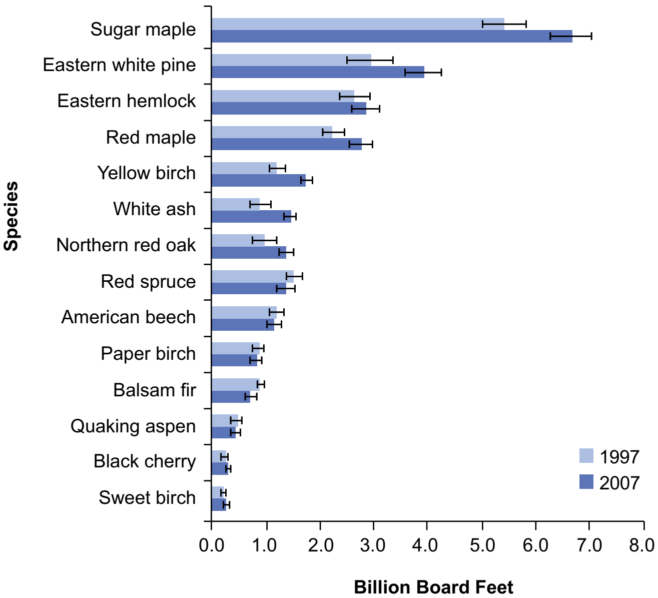


Figure 40.—Board-foot volume on timberland by species, Vermont, 1997 and 2007. Error bars represent 68% confidence interval around estimate.

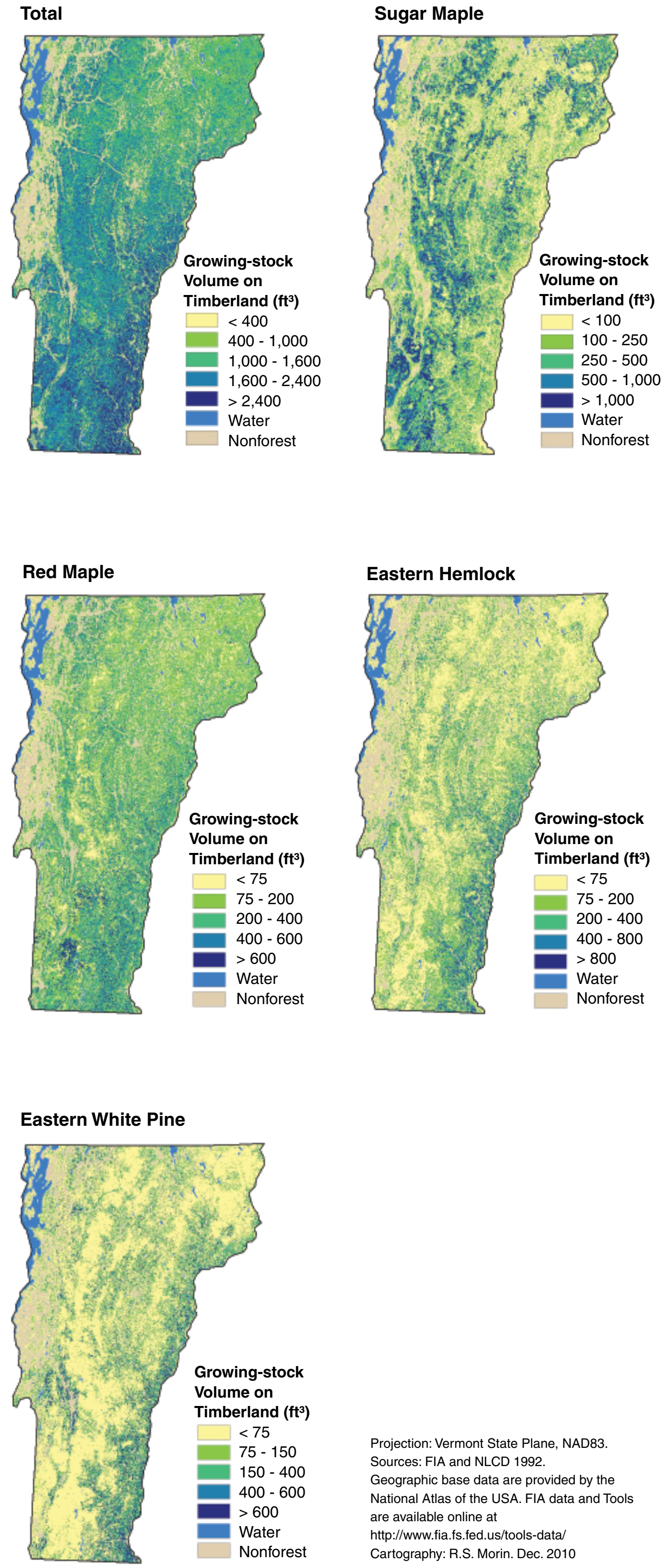


Figure 41.—Growing-stock volume per acre (trees at least 5 inches d.b.h.) on forest land, Vermont, 2006.

highest volumes are generally in the south. Most of the eastern hemlock and eastern white pine volume is in the southern half of Vermont in the Connecticut River Valley along the border with New Hampshire.

What this means

Because of the continuing increases in volume, Vermont's timber resources are at record levels since FIA began doing inventories in 1948. Although growing-stock volumes continue to increase, this increase has slowed and may continue to do so because of the aging forest and reduced growth rates. By contrast, significant increases are concentrated in sawtimber-size trees, as illustrated by the significant increase in sawtimber volume (17 percent). Even though the rate of 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 into the future as the poletimber-size trees replace the sawtimber-size trees.

Changes in volumes by species indicate the changes in species composition that are occurring. Only paper birch and balsam fir have shown significant declines in growing-stock volume since 1997. For both species, this is reflected in loss in growing-stock volume (Fig. 39) and number of growing-stock trees (Fig. 30). These two species may rebound in the future as numbers of sapling-size trees increase (Fig. 31).

Hardwood Sawtimber Quality

Background

Species, size, and quality of a tree determine its value in the forest products market. The highest quality timber, used in the manufacture of cabinets, furniture, flooring, or other millwork, is the most valuable. Lower quality trees are used as pallets, pulpwood, and fuelwood. The quality of an individual tree varies by species as well as diameter, growth rate, and management practice. Hardwood trees must be at least 11 inches d.b.h. to qualify as sawtimber. 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. The grades decrease in quality from grade 1 (high grade lumber) to tie/local use material.

What we found

The proportion of sawtimber volume in tree grades 1 and 2 has remained stable at 40 percent since 1997; however, in absolute terms, the volume in grades 1 and 2 has increased from 5.8 to 7.1 billion board feet. Volume in the lowest grade (tie/local use) increased from 2.8 to 4.3 billion board feet and increased as a proportion of the total from 19 to 24 percent (Fig. 42).

In Vermont, northern red oak and white ash are the only species with more than 50 percent of their sawtimber volume in tree grades 1 and 2. Sugar maple, yellow birch, and sweet birch have at least 35 percent of their sawtimber volume in grades 1 and 2. By contrast, red maple and American beech have less than 25 percent of their sawtimber volume in grades 1 and 2 (Fig. 43). Many beech trees contain large amounts of rotten wood because of beech bark disease. Red maple typically has more defects than other species.

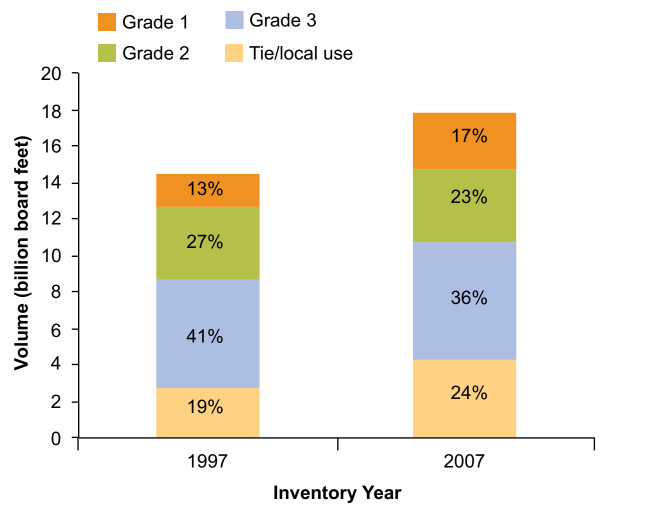


Figure 42.—Hardwood board-foot volume by tree grade, Vermont, 1997 and 2007.

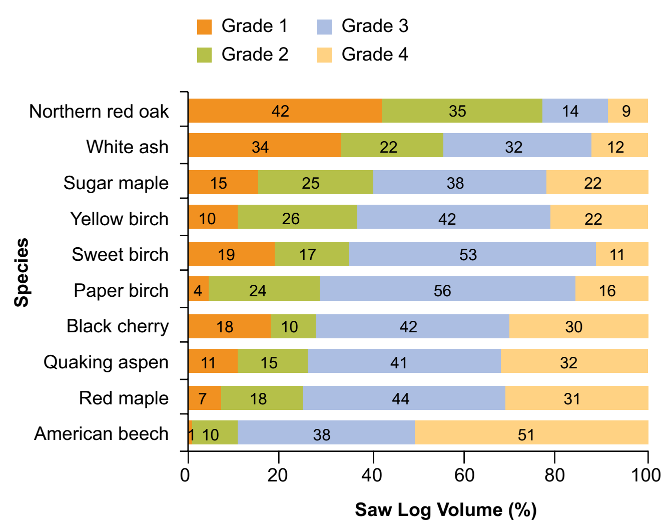


Figure 43.—Percentage of saw log volume on timberland by species and tree grade, Vermont, 2007.

What this means

The quality of saw logs in Vermont has remained stable since the last inventory, but the value of sawtimber has increased based on the increase in available board-foot volume. For example, northern red oak board-foot volume increased significantly between 1997 and 2007

(Fig. 40) and the highest proportion of that volume is in grade 2 or better trees (77 percent). Changes in species composition point toward potential reductions in tree quality into the future. Some of the species with a high proportion of low grade volume, American beech and red maple (Fig. 43), are the same ones that are showing large increases in saplings (Fig. 31).

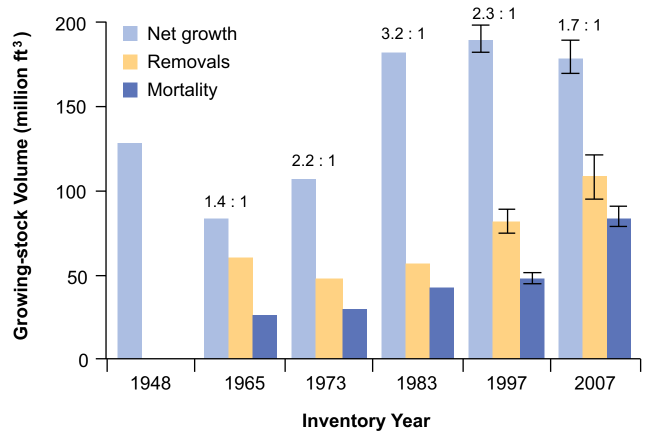


Figure 44.—Net growth, removals, mortality, and growth-to-removal ratio of growing stock on timberland, Vermont, 1948, 1965, 1973, 1983, 1997, and 2007. Error bars represent 68% confidence interval around estimate.

Average Annual Net Growth and Removals

Background

Forests provide a renewable resource if they are well 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 by determining the average annual change over the time period. Net growth is negative when mortality exceeds gross growth. A useful measure to assess growth is the percentage of annual net growth to current inventory volume. Average annual net growth estimates are based on change in volume of growing stock on timberland between the 1997 and 2007 inventories.

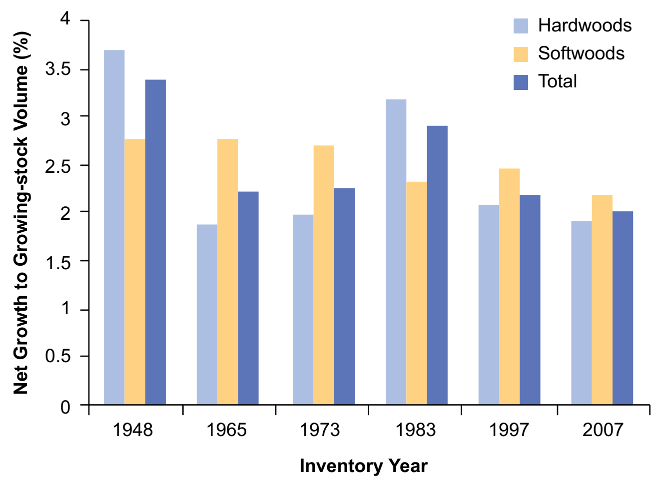


Figure 45.—Net growth of growing stock on timberland as a percent of growing-stock volume on timberland, Vermont, 1948, 1965, 1973, 1983, 1997, and 2007.

What we found

Since 1965, average annual net growth has been steadily increasing (Fig. 44). Net growth averaged 180 million cubic feet annually between 1997 and 2007, about 2 percent of growing-stock volume on timberland. In comparison to previous inventories, this proportion is one of the lowest ever reported (Fig. 45). About 66 percent of net annual growth was in hardwoods and 79 percent was on privately owned land.

The top nine species by growing-stock volume accounted for 91 percent of the average annual net growth of growing stock on timberland from 1997 to 2007. The ratio of growth to removals averaged 1.7:1.0 for 1997 to 2007, but variation between species was considerable. Net growth exceeded removals for all major species. Sugar maple had the highest amount of removals, but its growth still exceeded removals by 1.8:1.0. Eastern white pine and balsam fir ranked second and third in removals, respectively. While eastern white pine growth exceeded removals by 1.5:1.0, balsam fir growth was nearly even with removals at 1.1:1.0. Eastern hemlock, red maple, and northern red oak had the highest growth-to-removals ratios at 3.2:1.0, 2.8:1.0, and 2.8:1.0, respectively (Fig. 46).

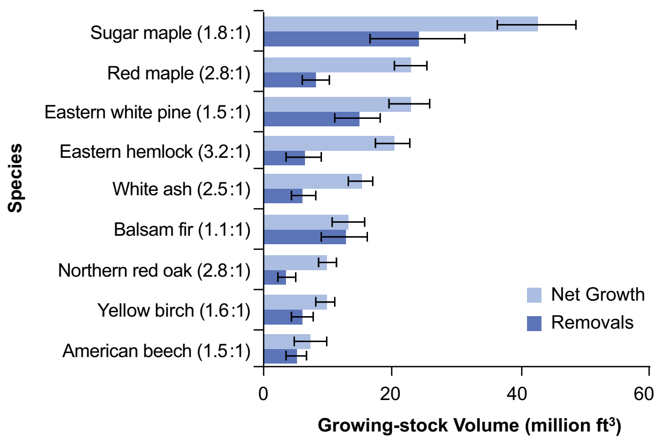


Figure 46.—Average annual net growth, removals, and growth-to-removals (G/R) ratio for major species, Vermont, 2007. Error bars represent 68% confidence interval around estimate; G/R for all species = 1.7:1.

What this means

The well-stocked stands in the current forests of Vermont developed as a result of the growth-to-removal ratios being well above 1.0:1.0 for the last half century, but Vermont's forests have matured and the rate of growth has slowed. In fact, the 1997 to 2007 period is the first time the growth-to-removal ratio has dropped below 2.0:1.0 since the 1960s (Fig. 44). Even with the slower growth rate, the current level of removals appears to be sustainable for the near term barring more increases in mortality. Nunery and Keeton (2010) concluded that unmanaged stands will sequester more carbon than those that are actively managed. Therefore, even with slowing net growth rates, as long as removals are less than net growth, the forests of Vermont should continue to sequester more carbon than they emit. Fortunately, more than 90 percent of the removals are due to harvesting and not land use change. Trees will regenerate because the land remains in timberland.

A comparison of the growth-to-removals ratios of individual species to the average for all species indicates which species may be decreasing or increasing in abundance. Red maple has a higher growth-to-removals ratio than sugar maple, which suggests that it may increase in relative volume. This increase may be due to sugar maple being preferred over red maple as a timber species. The low growth-to-removals ratios of eastern white pine (1.5:1.0) and balsam fir (1.1:1.0) suggest that both of those species may be decreasing in abundance (Fig. 46). This could be true especially for eastern white pine given the lack of eastern white pine saplings present in the State (not in the top 10 species for numbers of saplings – Fig. 31).

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, drought, and many others. Mortality is often initiated by one causal agent (inciting factor), then followed by contributing stress factors making the underlying cause difficult to identify. Although mortality is a natural event in a functional forest ecosystem, dramatic increases in mortality indicate forest health problems. Average annual growing-stock mortality estimates represent the average cubic-foot volume of sound wood that died each year between the 1997 and 2007 inventories. During this interval, Vermont has experienced a range of disturbances that have stressed forests, either as inciting factors or as contributors to the mortality.

What we found

The estimated average annual mortality rate for growing-stock trees in Vermont for 2007 was 85 million cubic feet, which is approximately 0.9 percent of growing-stock volume. This is the highest mortality rate ever reported in an FIA inventory of Vermont. Estimates from earlier inventories ranged from 0.6 to 0.7 percent. From 1997 to 2007, softwoods had a higher mortality rate than hardwoods (Fig. 47). Despite the increase, Vermont's mortality rate is similar to many other states in the region. For example, New Hampshire's rate is 1 percent, Maine's is 1.2 percent, and New York's is 0.9 percent. The rate of mortality is similar across diameter classes, increasing between 1997 and 2007 for nearly all diameter classes. The highest mortality rates are generally found in the smaller diameter trees (Fig. 48).

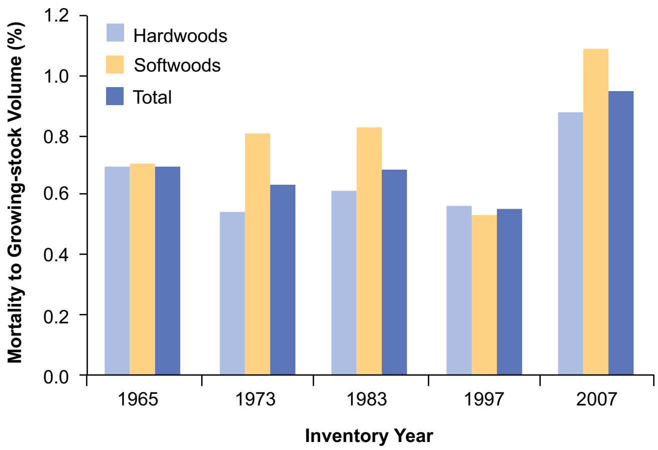


Figure 47.—Mortality of growing stock on timberland as a percent of growing-stock volume on timberland, Vermont, 1965, 1973, 1983, 1997, and 2007.

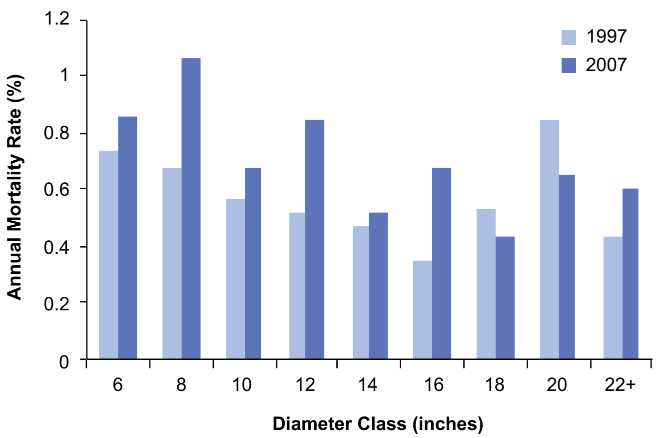


Figure 48.—Average annual mortality rate (in percent) of growing-stock volume on timberland by diameter class, Vermont, 1997 and 2007.

Mortality also increased across nearly all species between 1997 and 2007. Red spruce had the largest increase in mortality rate, but paper birch, balsam fir, red maple, and quaking aspen (*Populus tremuloides*) also increased significantly. The only species for which the mortality rate actually decreased are white ash and northern red oak (Fig. 49). Although mortality rates have generally increased over time, most of the abundant species in Vermont have relatively low mortality rates. The annual average mortality rates of sugar maple, eastern white pine, eastern hemlock, red maple, yellow birch, sweet birch, white ash, and northern red oak are all below the 0.9 percent annual average for tree species combined (Fig. 50). By contrast, quaking aspen, balsam fir, paper birch, red spruce, and American beech all have mortality rates that are nearly double the statewide average.

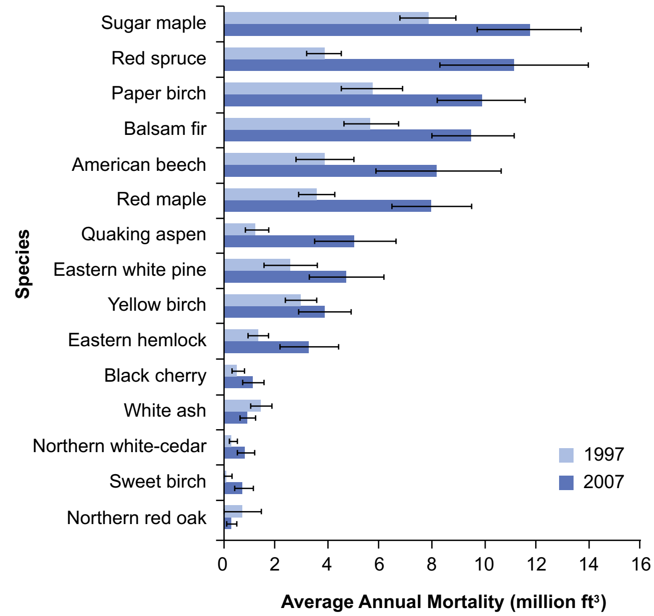


Figure 49.—Average annual mortality of growing stock on timberland for major species, Vermont, 1997 and 2007. Error bars represent 68% confidence interval around estimate.

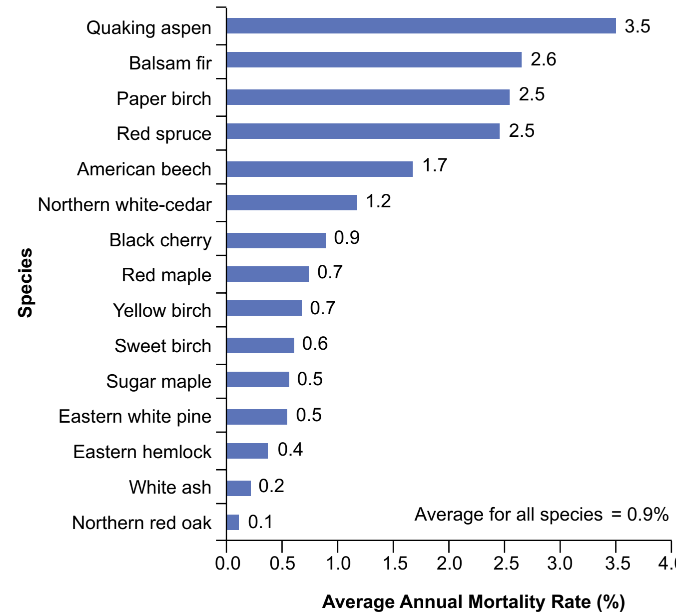


Figure 50.—Average annual mortality rate for major species, Vermont, 2007. Average for all species = 0.9%.

What this means

Tree mortality rates in Vermont have increased over the rates reported in previous inventories, but these rates are comparable to those in surrounding states. Vermont tree health surveys have shown similar trends. Some of the mortality can be explained by stand dynamics (e.g., competition and succession) and the impacts of insects and diseases that affect specific species (e.g., beech bark disease on American beech). In the normal maturation process, some trees lose vigor and eventually die from being outcompeted or they succumb to insect and disease during their weakened state; this is especially apparent in trees 12 inches and smaller d.b.h. (Fig. 48).

Most species in Vermont have low mortality rates, but some have elevated rates. Species such as quaking aspen, balsam fir, paper birch, red spruce, and American beech have increased the overall statewide mortality rate. Quaking aspen and paper birch are both early successional, short-lived species that are intolerant to shade, so as these forests age, high mortality rates are not surprising. American beech has been heavily impacted by beech bark disease for many decades. Weather-related events that significantly affected tree health during this time period include the aftereffects 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 significant 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 defoliation, beech bark disease, spruce winter injury, and balsam woolly adelgid. Recovery following stress events is often dependent on soil fertility; trees growing on calcium rich sites are more likely to recover (Schaberg et al. 1996, Shortle and Smith 1988).

Species Composition

Background

The species composition of a forest is the result of the interaction of climate, soils, disturbance, competition among trees species, and other factors over time. 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 overstory species composition.

What we found

In Vermont, beech is the most numerous sapling (1 to 4.9 inches d.b.h.), accounting for 15 percent of all saplings followed by sugar maple at 13 percent (Fig. 51). Noncommercial tree species (combined) also represent a large portion of saplings, at 19 percent. Striped maple is the most numerous of these noncommercial species followed by eastern hophornbeam and pin cherry. Sugar maple is the dominant species in all diameter classes 5 inches d.b.h. and larger. Eastern white pine is poorly represented in the sapling classes (less than 1 percent),

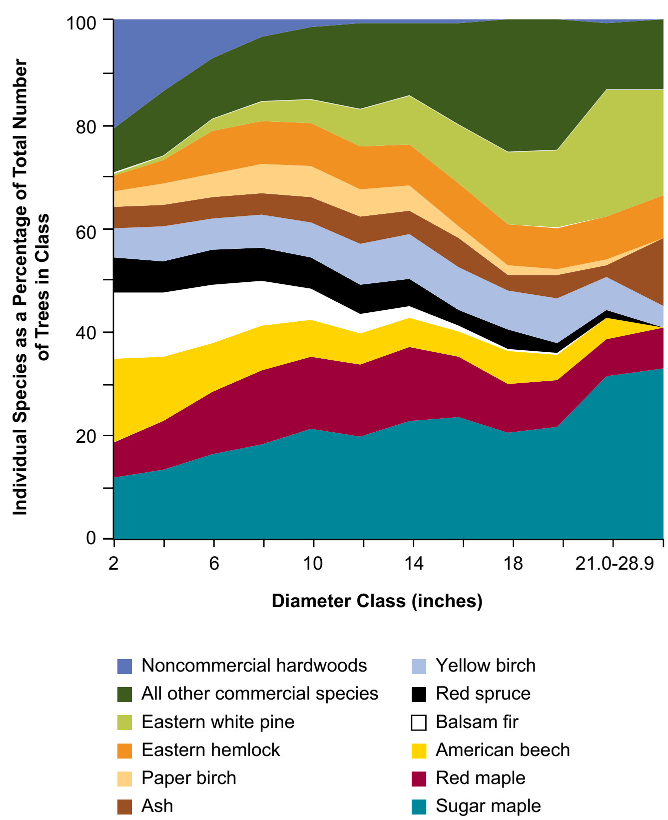


Figure 51.—Species composition by diameter class on forest land, Vermont, 2007. (Noncommerical species includes striped maple, eastern hophornbean, pin cherry, and other species with poor form).

although it makes up a large portion of trees larger than 20 inches d.b.h (Fig. 52). Other species, which have 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 portion of total saplings relative to their share of larger trees. Since the 1966 inventory, sugar maple, red maple, eastern hemlock, eastern white pine, and ash have increased in the proportion of total growing-stock volume they represent (Fig 53). Species that have decreased as a percentage of the total volume include spruce, yellow birch, beech, paper birch, and balsam fir (Fig. 54).

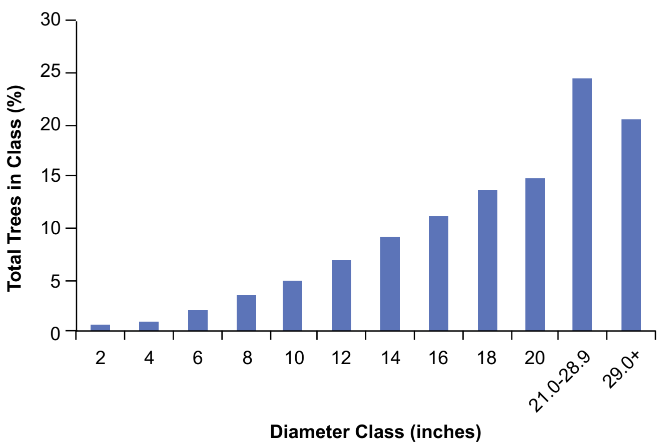


Figure 52.—White pine as a percentage of the total number of trees by diameter class on forest land, Vermont, 2007.

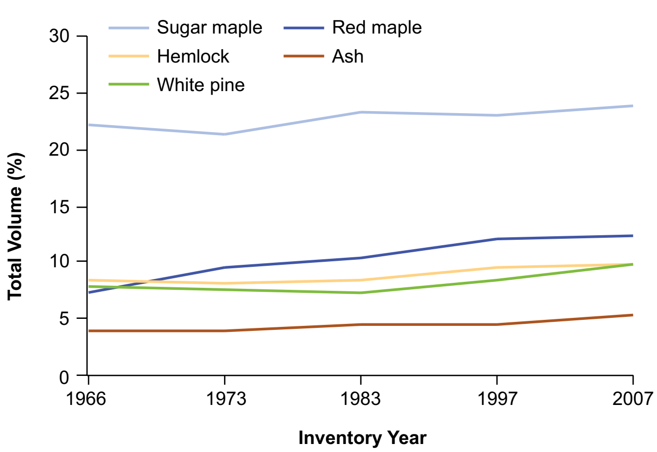


Figure 53.—Species that have increased as a percentage of total growing-stock volume on timberland, Vermont, 1966-2007.

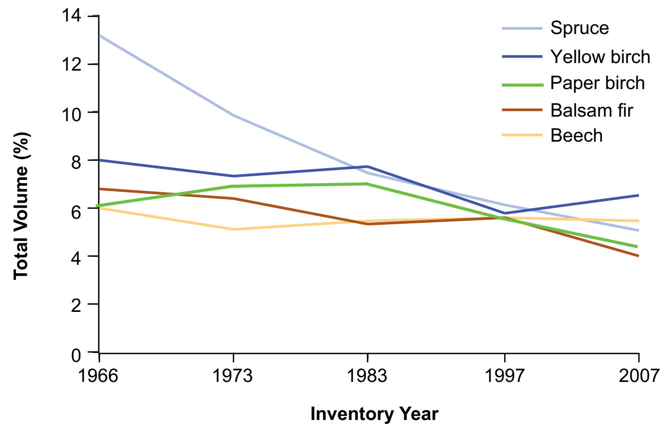


Figure 54.—Species that have decreased as a percentage of total growing-stock volume on timberland, Vermont, 1966-2007.

What this means

Conditions in the understory favor reproduction of shade-tolerant species, as shown by the higher proportion of beech, sugar maple, balsam fir, and red spruce in the sapling diameter classes compared to the larger diameter classes. Besides being shade tolerant, large numbers of sapling-size beech are likely the result of root sprouts following 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 growth of other more valuable species while alive. In contrast, eastern hemlock, another shade-tolerant species, makes up a lower percentage of tree numbers in the sapling diameter classes when compared to the larger diameter trees. This indicates that hemlock is not regenerating as well as expected in the maturing forest of Vermont. Noncommercial species provide habitat diversity in the understory, although they can interfere with the reproduction of commercial species if they become too numerous. Striped maple now makes up 12 percent of trees in the 2-inch diameter class. Land managers should be aware of the potential of this species to cause problems in forest regeneration.

Eastern white pine is well represented in the large diameter classes, and it ranks second statewide in sawtimber volume (Fig. 40). But because it is poorly represented in the small-diameter classes (less than 1 percent of saplings), it will probably be replaced by other species as the larger eastern white pine trees die or are harvested. Sugar maple represents the largest portion of trees in every diameter class 5 inches and larger, which attests to the longevity and size it attains within the forests of Vermont. It will likely be the dominant tree in Vermont's forest for the foreseeable future. Trends in volume show that, since 1966, eastern white pine, eastern hemlock, and red maple have increased in the portion of total volume they represent. Trends in these species will likely slow and reverse because these species 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 spruce and fir trees and fewer white pine and hemlock trees than today. Long-term changes in Vermont's 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 due to the potential impacts of climate change on species.

Forest Products

Vermont sugar maples. Photo by Ronald Kelley.

Timber Products

Background

The harvesting and processing of timber products creates a stream of income shared by timber owners, land managers, marketers, loggers, truckers, and processors. The wood products and paper manufacturing industries in Vermont employed more than 3,000 people, with an average annual payroll of more than $118 million and a total value of shipments of $641 million (U.S. Census Bureau 2007). To better manage the State's forests, it is important to know the tree species, amounts, and locations of timber being harvested.

What we found

Surveys of Vermont's wood-processing mills are conducted periodically to estimate the amount of wood volume that is processed into products. These surveys are supplemented with the most recent surveys conducted in surrounding states that processed wood harvested from Vermont. In 2005, 70 primary wood-processing mills were surveyed to determine what species were processed and where the wood material came from. These mills processed more than 183 million board feet.

A total of 43 million cubic feet of industrial roundwood was harvested from Vermont during 2005. Saw logs accounted for 65 percent of the total industrial roundwood harvested, followed by pulpwood at 24 percent and veneer logs at 11 percent (Fig. 55). All of the timber harvested for pulpwood was shipped to mills in other states. An additional 18 million cubic feet of wood was harvested for fuelwood in Vermont during 2005. Hard maple, at 17 percent, and white pine, at 16 percent, were the two most harvested species groups (Fig. 56). Other important species groups harvested were spruce, hemlock, soft maples, red oaks, and ash.

During the process of harvesting industrial roundwood, 23 million cubic feet of harvest residues were left on the ground (Fig. 57). Approximately 80 percent of the

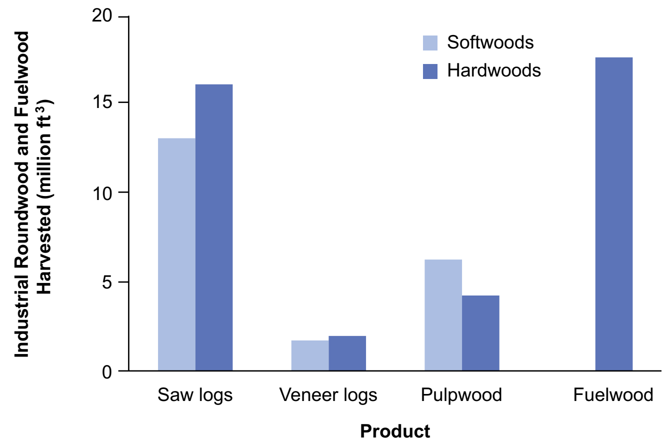


Figure 55.—Roundwood harvested by product, Vermont, 2005.

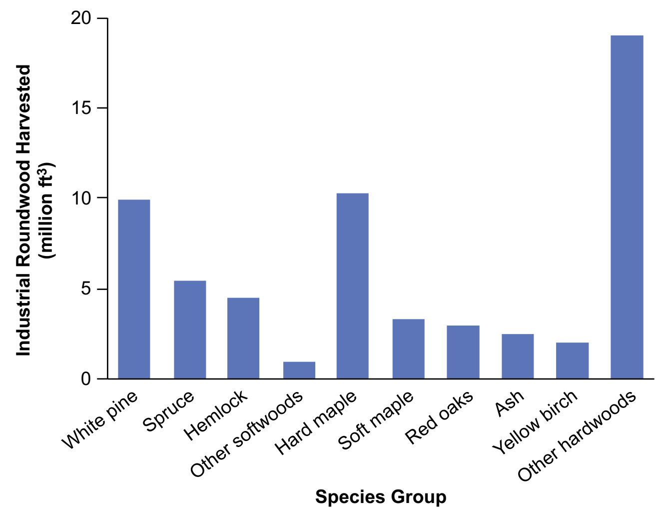


Figure 56.—Roundwood harvested by major species group, Vermont, 2005.

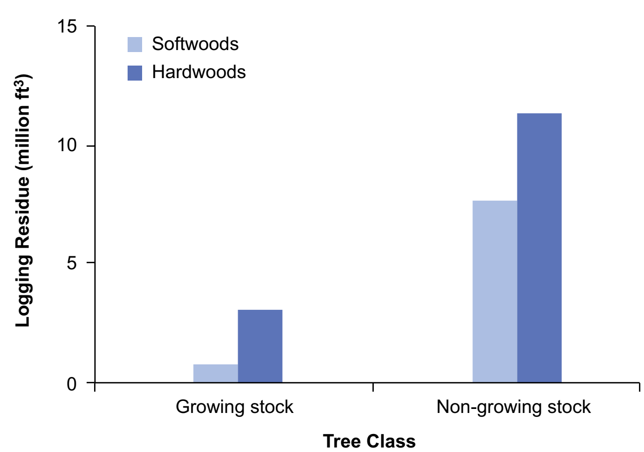


Figure 57.—Logging residue by tree class and species group, Vermont, 2005.

logging residue came from non-growing-stock sources such as crooked or rotten trees, tops and limbs, and noncommercial species. The remaining 20 percent was growing-stock volume left on site. The processing of industrial roundwood in the State's primary wood-using mills generated another 7 million cubic feet of wood and bark residues. Fifty-seven percent of the mill residues were used for pulpwood products and 43 percent were used for industrial and residential fuelwood.

What this means

Most of the wood-processing facilities in Vermont are sawmills processing logs primarily grown in the State. These mills give woodland owners an outlet to sell timber and provide jobs in some of the more rural areas. The demand for wood products is likely to increase, placing a greater demand on the resource. An important consideration for the future of the primary wood-products industry is its ability to retain industrial roundwood processing facilities. The number of wood-processing mills has been steadily declining. The loss of processing facilities makes it harder for landowners to find markets for the timber harvested from their forest land.

Another important issue is the volume of harvest residues generated in Vermont that go unused. Almost 20 percent of the harvest residue is from growing-stock sources that could be used for products. Improved pulpwood markets should lead to better utilization of merchantable trees. The use of logging slash and mill residues for industrial fuelwood at cogeneration facilities and pellet mills should also result in better utilization of the forest resource.

Forest Indicators

Coarse woody debris. Photo by Sandy Wilmot, Vermont Department of Forests, Parks & Recreation.

Tree Crown Conditions

Background

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

Seasonal or prolonged drought periods have long been a significant and historical stressor in Vermont. Since the 1997 FIA inventory, droughts occurred in some regions during 1999 and 2001; alternatively, some of the wettest years on record were 2006 and 2008 (Fig. 58; NCDC 2010). These extreme precipitation events can produce conditions that facilitate insect and/or disease outbreaks and can be even more devastating to trees stressed by pest damage or other agents.

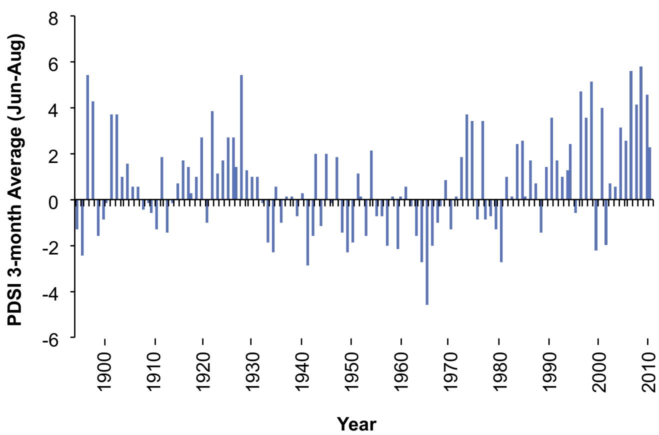


Figure 58.—Palmer Drought Severity Index 3-month average (June-August), Vermont, 1895-2010.

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, Vermont's forests 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. A more recent invader in Vermont is hemlock woolly adelgid (*Adelges tsugae*), and potential future invaders include emerald ash borer (*Agrilus planipennis*) and Asian longhorned beetle (*Anoplophora glabripennis*).

Tree-level crown measurements are collected on FIA P3 plots, including vigor class, crown ratio, light exposure, crown position, crown density, crown dieback, and foliage transparency. Three factors were used to determine the condition of tree crowns: crown dieback, crown density, and foliage transparency. Crown dieback is defined as recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. Secondly, crown density is defined as the percent of crown branches, foliage, and reproductive structures that block light visibility through the crown and can serve as an indicator of expected growth in the near future. Finally, foliage transparency is the amount of skylight visible through the live, normally foliated portion of the crown. Changes in foliage transparency can also occur because of defoliation or reduced foliage resulting from stresses during preceding years. A crown was labeled as "poor" if crown dieback was greater than 20 percent, crown density was less than 35 percent, or foliage transparency was greater than 35 percent. These three thresholds were based on preliminary findings by Steinman (2000) that associated crown ratings with tree mortality.

What we found

The incidence of poor crown condition is evenly distributed across Vermont (Fig. 59). The species with the highest proportion of live basal area containing poor crowns is eastern hemlock at nearly 33 percent. For white ash and American beech, 25 and 20 percent of the basal area, respectively, had poor crowns. Conversely, the occurrence of poor crowns in yellow birch, red maple, and eastern white pine was very low (Table 2).

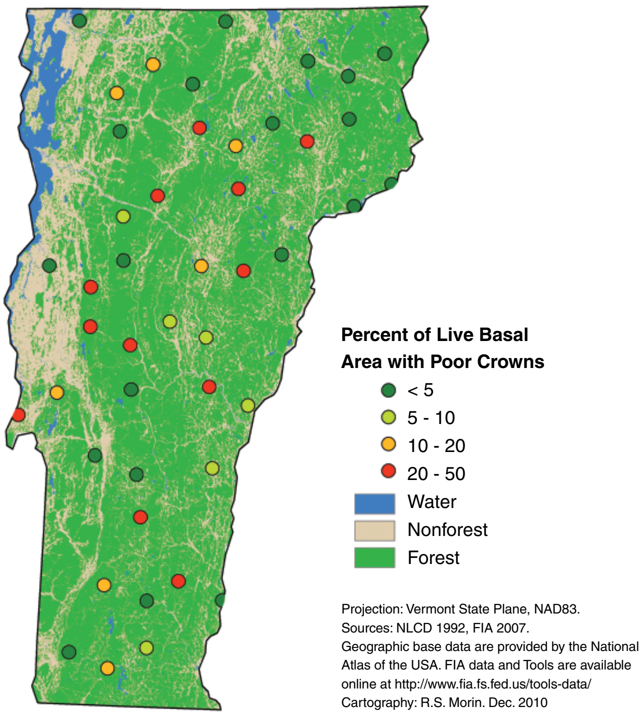


Figure 59.—Percent of live basal area with poor crowns, Vermont, 2007.

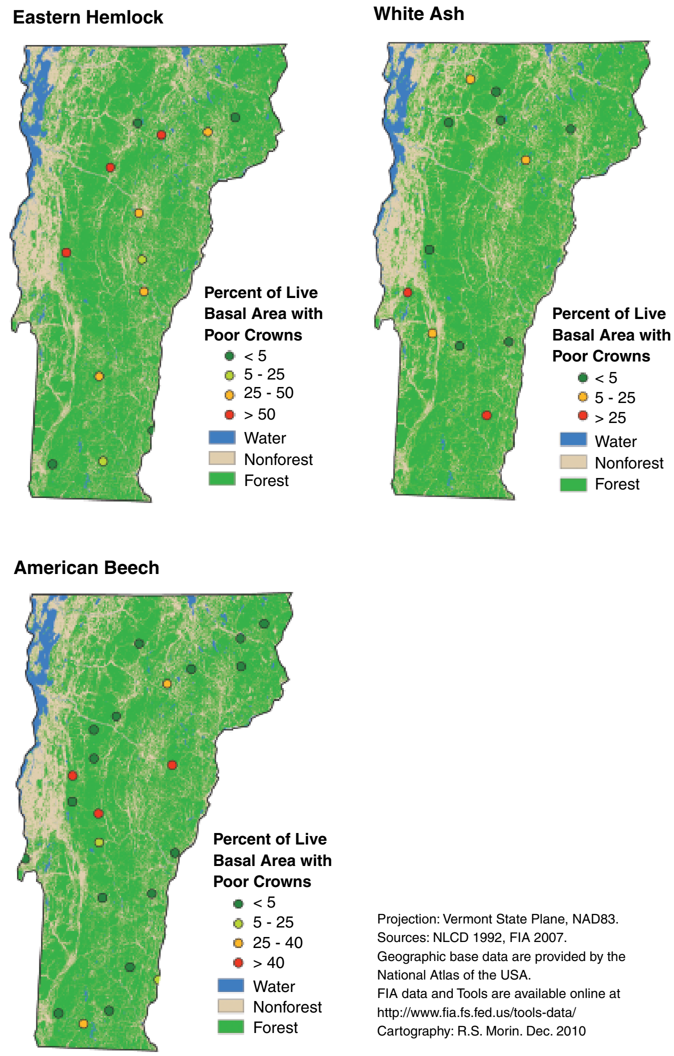


Figure 60.—Percent of live basal area with poor crowns by species, Vermont, 2007.

Table 2.—Percent of live basal area with poor crowns, Vermont, 2007

Species	Percent of Basal Area with Poor Crowns
Eastern hemlock	33
White ash	25
American beech	20
Red spruce	13
Balsam fir	11
Paper birch	10
Sugar maple	10
Eastern white pine	7
Red maple	6
Yellow birch	2

The highest proportion of eastern hemlock and American beech basal area containing poor crowns was found in the northern half of Vermont. By contrast, poor crowns were more prevalent in white ash in the southern part of the State (Fig. 60).

What this means

Some of the highest levels of eastern hemlock density across its range are located in the eastern portions of Vermont. Eastern hemlock is an important species in Vermont due to its high value as timber and wildlife habitat, the unique niche it fills in riparian areas, and its value as an ornamental tree. Levels of eastern hemlock mortality have increased since the 1997 inventory (Fig. 49). Many eastern hemlocks were classified as having poor crowns due to high foliage transparency ratings, but they typically have higher foliage transparency ratings than many other species given their unique needle morphology. Hemlock woolly adelgid (HWA) can cause thinning foliage, widespread defoliation, and sometimes mortality of eastern hemlock (McClure et al. 2001, Orwig et al. 2002). Although HWA was discovered in Vermont, in Windham County, in 2008, the poor crown condition of many hemlock trees is unlikely to be associated with it because HWA has not been discovered in the areas where poor crowns were sampled.

American beech is also a major component of the forests in Vermont. It is an important forest tree that is a source of wood products including pulpwood, firewood, and chips as well as a vital source of mast for wildlife. The poor crown condition in beech is likely to be related to the impacts of beech bark disease (BBD). BBD is an insect-fungus complex involving the beech scale insect (*Cryptococcus fagisuga* Lind.) and the exotic canker fungus *Neonectria coccinea* (Pers.:Fr.) var. *faginata* Lohm. or the native *Neonectria galligena* Bres. that kills or injures American beech. Three phases of BBD infestations are generally recognized: (1) the “advancing front,” areas recently invaded by scale populations; (2) the “killing front,” areas where fungal invasion has occurred (typically 3 to 5 years after the scale insects appear, but sometimes as long as 20 years) and tree mortality begins; (3) the “aftermath forest,” areas where the disease is endemic (Houston 1994, Shigo 1972). The BBD killing front moved through Vermont decades ago and, therefore, the State is now aftermath forest.

Lichen Communities

Background

Lichens are symbiotic, composite organisms made up of members from as many as three kingdoms. The dominant partner is a fungus. Fungi are incapable of producing their own food, so they typically feed as parasites or decomposers. The lichen fungi (kingdom Fungi) cultivate partners that manufacture food by photosynthesis. Sometimes the partners are algae (kingdom Protista), other times cyanobacteria (kingdom Monera), formerly called blue-green algae. Some enterprising fungi associate with both at once (Brodo et al. 2001).

Lichen community monitoring is included in the FIA P3 inventory to address key assessment issues such as the impact of air pollution on forest resources or spatial and temporal trends in biodiversity. This long-term lichen monitoring program in the U.S. dates back to 1994. The objectives of the lichen indicator are to address key assessment issues such as the impact of air pollution on forest resources, spatial and temporal trends in biodiversity, and the sustainability of timber harvesting. Lichens occur on many different substrates (e.g., rocks), but FIA sampling is restricted to standing trees or branches/twigs that have recently fallen to the ground. Samples are sent to lichen experts for species identification.

A close relationship exists between lichen communities and air pollution, especially acidifying or fertilizing nitrogen- and sulfur-based pollutants. A major reason lichens are so sensitive to air quality is their total reliance on atmospheric sources of nutrition. By contrast, it is difficult to separate tree-growth responses specific to air pollution (McCune 2000).

What we found

A total of 73 lichen species (gamma diversity) were sampled on the lichen plots in Vermont (Table 3). The most common lichen genera, *Phaeophyscia*, were present on 12 percent of the plots (Table 4). The genus with the highest number of species sampled was *Cladonia* (7 species).

The easiest way to measure species diversity is to count the number of species at a site; this measure is termed species richness. However, species richness does not provide a complete picture of diversity in an ecosystem because abundance is excluded. Richness values fell into the medium and high categories across Vermont (Table 3). The spatial distribution of lichen species richness scores is shown in Figure 61. In general, species richness scores increased with increasing latitude. The lichen

Table 3.—Lichen communities summary table, Vermont, 1994-2003

Parameter	Vermont, 1994-2003
Number of plots surveyed	24
Number of plots by species richness category	
0-6 species (low)	0
7-15 species (medium)	19
16-25 species (high)	5
Median	12.5
Range of species richness score per plot (low-high)	7-22
Average species richness score per plot (alpha diversity)	12.6
Standard deviation of species richness score per plot	3.9
Species turnover rate (beta diversity)[1]	5.8
Total number of species per area (gamma diversity)	73

[1]Beta diversity is calculated as gamma diversity divided by alpha diversity.

species richness and diversity scores reported here will serve as baseline estimates for future monitoring at the state and regional level.

What this means

Due to the sensitivity of many lichen species to airborne pollution, it is useful to look at acid deposition levels. Showman and Long (1992) reported that mean lichen species richness was significantly lower in areas of high sulfate deposition than in low deposition areas. Sulfate deposition levels have been relatively homogeneous across Vermont and are relatively low compared to other areas in the northeastern United States (Fig. 62). A general pattern of lower lichen species richness scores is evident in high deposition areas and vice versa (Fig. 63). But other factors may affect the distribution of lichen species including intrinsic forest characteristics and long-term changes in climate.

Table 4.—Percentage of specimens and number of species for lichen genera sampled, Vermont, 1994-2003

Genus	All Specimens	All Species
Phaeophyscia	11.6	5
Melanelia	8.3	5
Physcia	8.1	4
Parmelia	7.6	3
Flavoparmelia	7.2	2
Cladonia	6.0	7
Punctelia	5.7	3
Hypogymnia	5.3	2
Usnea	5.0	5
Evernia	4.8	1
Candelaria	4.7	1
Physconia	4.7	3
Cetraria	4.5	6
Myelochroa	3.3	2
Bryoria	1.2	1
Platismatia	0.9	2
Cetrelia	0.7	1
Lobaria	0.7	2
Parmeliopsis	0.7	3
Ramalina	0.5	2
Anaptychia	0.3	1
Flavopunctelia	0.3	1
Imshaugia	0.3	1
Peltigera	0.3	2
Pseudevernia	0.3	2
Pyxine	0.3	1
Leptogium	0.2	1
Menegazzia	0.2	1
Parmotrema	0.2	1
Physciella	0.2	1
Xanthoria	0.2	1
Total	100	73

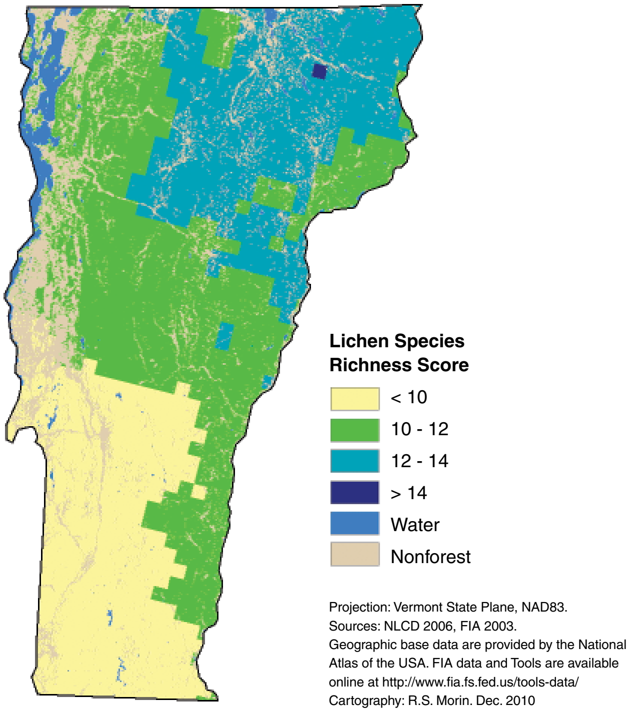


Figure 61.—Estimated lichen species richness, Vermont, 2000-2003.

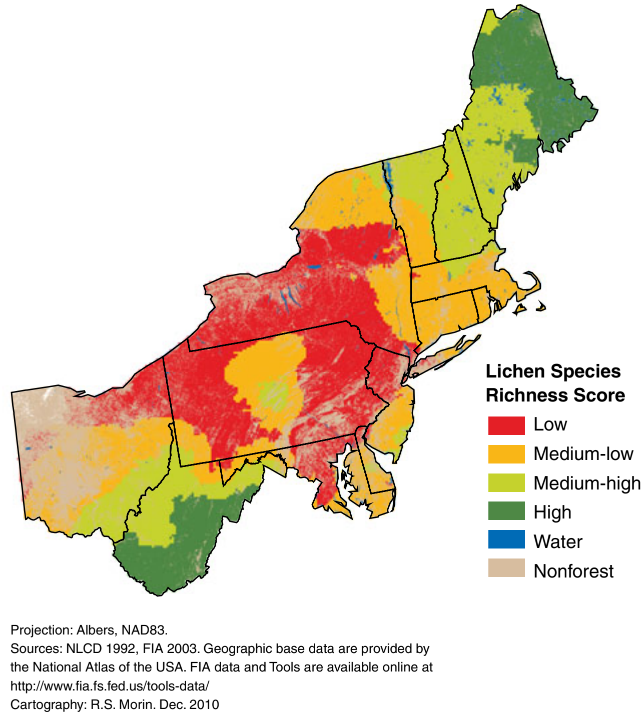


Figure 63.—Estimated lichen species richness, Northeastern U.S., 2000-2003.

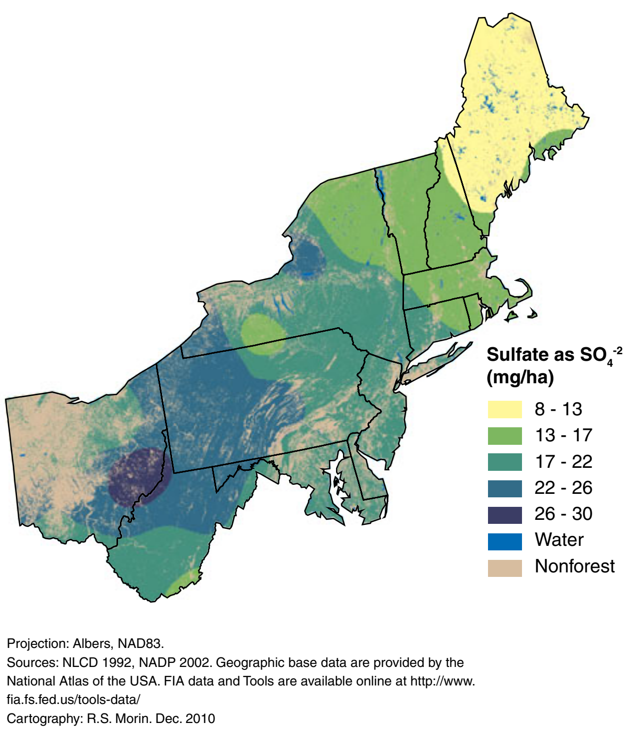


Figure 62.—Mean sulfate wet deposition, Northeastern U.S., 1994-2002. Data source: National Atmospheric Deposition Program.

Forest Soils

Background

The soils that sustain forests are influenced by several factors including climate; the trees, shrubs, herbs, and animals living there; landscape position; elevation; and the passage of time.

Forest carbon sequestration is a topic of public concern. Carbon stocks in soils are important long-term stores of carbon accumulated from woody biomass and foliage. The accumulation and subsequent decay of leaf litter adds carbon to forest soils. Tree roots—and translocation from the forest floor—add carbon to the mineral soil. Measurements of current carbon stocks help managers understand the importance of different forest types and landscapes in the carbon cycle.

Atmospheric pollution is one significant way that humans influence the character and quality of the soil and indirectly affect the forest. For example, industrial emissions of sulfur and nitrogen oxides lead to “acid rain.” The deposition of acids strips the soil of important nutrients, notably calcium and magnesium. The loss of calcium and magnesium results in a shifting balance of soil elements toward aluminum, which is toxic to plants in high concentrations. We can use the ratio of aluminum to calcium as a measure of the impact of acid deposition on forest soils; high ratios suggest a shift toward more aluminum.

What we found

Forest floor carbon in Vermont’s forests is strongly influenced by two factors: forest-type group and ecological section – a type of semi-homogeneous landscape unit (Table 5). Maple/beech/basswood forests tend to store the largest amounts of carbon in their forest floor.

Table 5.—Predicted forest floor carbon (Mg ha-1) in Vermont

	Ecological Section		
Forest type	**M211B**	**M211C**	**Other**
Conifer	2.66	2.12	3.2
Other Hardwoods	3.44	1.17	1.96
Maple/beech/basswood	3.47	3.54	4.01

In contrast, carbon in the mineral soil under Vermont’s forests is strongly correlated to forest-type group in combination with the latitudinal and longitudinal location (Fig. 64). Maximum soil carbon under maple/beech/birch forests is found in the southern part of the State while conifer soil carbon peaks in the northeast. Mineral soil carbon under other types of hardwood forests grade from low to high, moving in a westerly direction. Of the three forest-type groups, conifers tend to store the most mineral soil carbon. We can use this information to build spatial predictions of carbon content in the top 20 cm of mineral soil.

By focusing on tree species data, it is possible to evaluate tree:soil interactions with some statistical rigor. For example, the aluminum:calcium ratio in the soil is an important predictor of several measures of crown vigor in Vermont, and the effect varies across tree species.

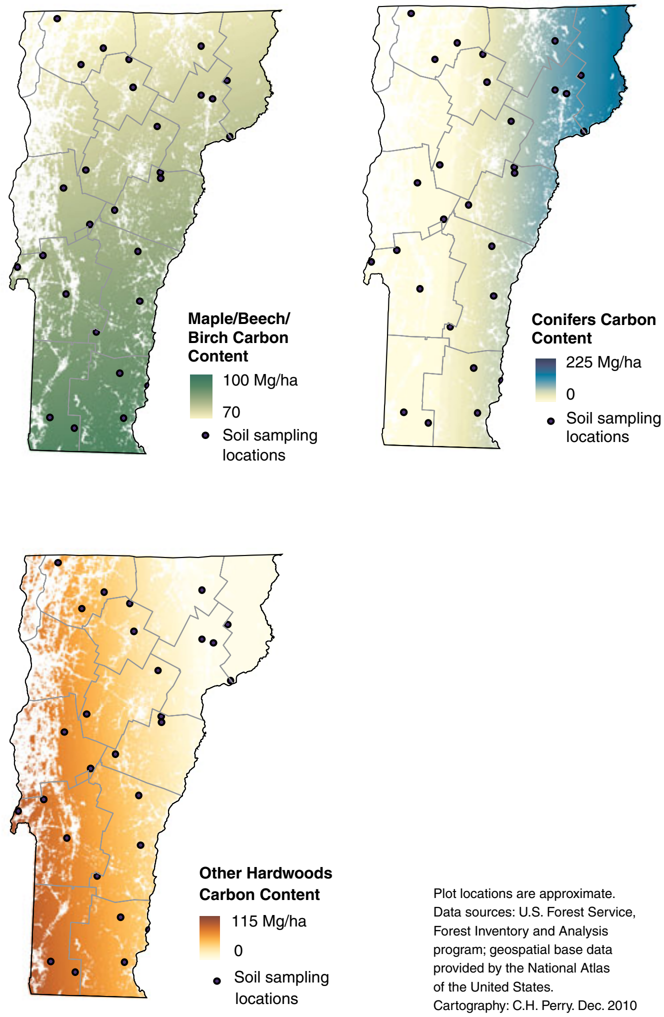


Figure 64.—Total carbon content in the mineral soil (0-20 cm) by forest type and location. Note the varying range of values within each forest type.

The uncompacted live crown ratio is determined by dividing the live crown length by the actual tree length. Larger values are associated with healthier trees; low values can be related to self pruning and shading from other tree crowns, but other reasons include defoliation due to dieback, and loss of branches due to breakage or mortality. The aluminum:calcium ratio is a significant predictor of the uncompacted live crown ratio (Fig. 65). The lowest crown ratios are associated with low levels of aluminum, but this effect varies across tree species. The live crown ratios of black cherry and red maple steadily decline with increases in aluminum values (increasing aluminum:calcium ratio) (Fig. 66). This observation is consistent with intensive site studies conducted in New England (Schaberg et al. 1996, Shortle and Smith 1988).

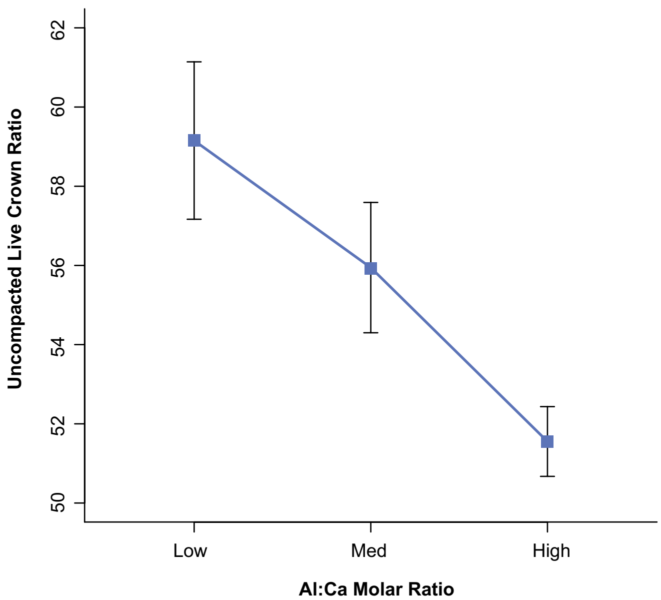


Figure 65.—Uncompacted live crown ratio by aluminum to calcium ratio in the soil. Error bars represent one sampling error (68%).

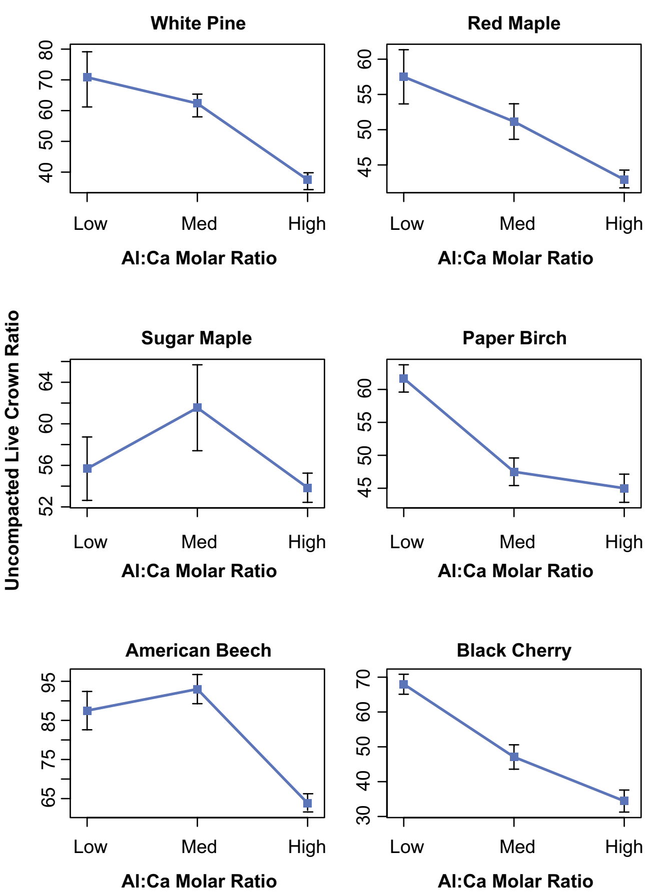


Figure 66.—Uncompacted live crown ratio by aluminum to calcium ratio in the soil by species. Error bars represent one sampling error (68%).

What this means

Tree species occupy different niches in the landscape, which provides a competitive advantage for colonization, growth, and reproduction. Atmospheric deposition of different compounds changes the soil substrate through additions and removals of nutrients and pollutants. These changes in the soil chemistry influence the ability of existing trees to thrive and reproduce in their current locations, as well as the ability of other trees to colonize new landscapes. It is important to document and understand natural and anthropogenic processes in the soil because they profoundly influence the current health of forests and the success of future forest management plans.

Down Woody Materials

Background

Down woody materials, in the form of fallen trees and branches, fill a critical ecological niche in Vermont's forests. Down woody materials both provide valuable wildlife habitat in the form of coarse woody debris and contribute toward forest fire hazards via surface woody fuels. Pieces of wood are selected in the coarse woody debris sample if they are at least 3 inches in diameter and intersect one of three transects emanating from the center of each FIA plot (Woodall and Monleon 2008).

What we found

The fuel loadings of down woody materials (time-lag fuel classes) are not very high in Vermont (Fig. 67). When compared to the neighboring states of New Hampshire and Maine, Vermont's fuel loadings of all time-lag fuel classes are not substantially different (for time-lag definitions, see Woodall and Monleon 2008). The size-class distribution of coarse woody debris appears to be heavily skewed (77 percent) toward pieces less than 8 inches in diameter (Fig. 68A). In the decay class distribution of coarse woody debris, there appears to be a fairly uniform distribution of stages of coarse woody

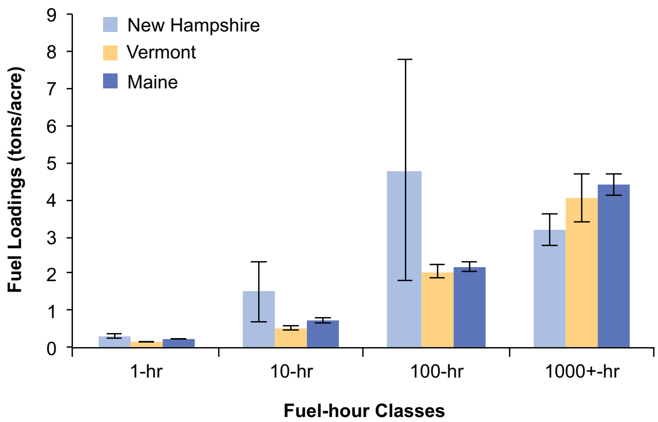


Figure 67.—Means and associated standard errors of fuel loadings (tons/acre, time-lag fuel classes) on forest land in Vermont and neighboring states, 2004-2008. Error bars represent 68% confidence interval around estimate.

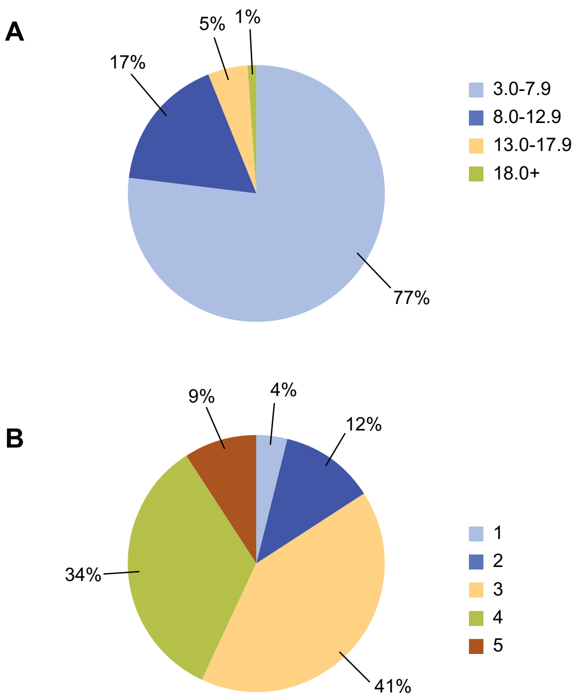


Figure 68.—Mean proportions of coarse woody debris total pieces per acre by transect diameter (inches; A) and decay classes (B) on forest land in Vermont, 2004-2008.

decay across the State, except for decay class three and four logs (75 percent) (Fig. 68B). Coarse woody debris in decay class three and four are typified by moderate to heavily decayed logs that are sometimes structurally sound but missing most/all of their bark with extensive sapwood decay. There is no strong trend in coarse woody debris volumes/acre among classes of live-tree density (basal area/acre). Stands with the highest volumes of coarse woody debris were found more often in stands with moderate amounts of standing live-tree density (Fig. 69).

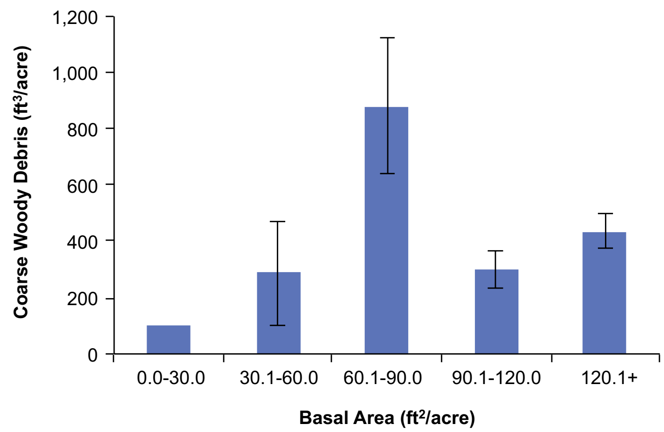


Figure 69.—Means and associated standard errors of coarse woody debris volumes (cubic feet/acre) on forest land in Vermont, 2004-2008. Error bars represent 68% confidence interval around estimate.

What this means

The down woody fuel loadings in Vermont's forests are not very different from those found in neighboring states. Therefore, only in times of extreme drought would these low amounts of fuels pose a hazard across the State. Of all down woody components, coarse woody debris (i.e., 1,000+-hr fuels) made up the largest amounts, but coarse woody debris volumes were still relatively low and were represented by small, moderately decayed pieces. The scarcity of large coarse woody debris resources may also indicate lower quality habitat for some wildlife species. Overall, because fuel loadings are not very high across Vermont, associated fire dangers are outweighed by the benefits of down woody material for producing wildlife habitat and carbon sinks.

Vegetation Diversity and Invasives

Background

Ground flora play many important roles in the forests of northern New England. Vegetation helps curtail erosion and runoff, regulate soil temperature, sequester carbon, and provide food and cover for forest animals. In addition, plants have the ability to filter pollutants and influence nutrient availability. Data on species composition help resource managers determine site quality, which serves as a guide for developing management goals. In New Hampshire and Vermont, plant species data were collected on the P2 Invasive plots and P3 plots. Due to the small number of plots, the data from the two states were analyzed together. For 2007-2008, there were 125 P2 Invasive plots (63 in Vermont and 62 in New Hampshire) and 36 P3 plots (17 in Vermont and 19 in New Hampshire).

What we found

All species

On the P3 plots, 343 species were found; the greatest quantity of classified species (140) occurred in the forb/herb category based on classification by the USDA Natural Resources Conservation Service's PLANTS Database (Table 6). Forty-four plants were classified as graminoids (grass or grass-like plants). Beyond these categories, there were 62 trees, 48 shrubs, and 10 vines. For the P3 plots, 274 (80 percent) of the 343 plant species were native to the U.S. and 25 species (7 percent) were introduced (Table 7). Canada mayflower (*Maianthemum canadense*), the most commonly observed understory species, occurred on 92 percent (33 plots) of all P3 plots in New Hampshire and Vermont (Table 8). The most commonly observed tree species was American beech, which was found on 29 plots or 81 percent of all P3 plots. Of the 20 most commonly observed species, 12 were of woody growth form.

Table 6.—Number of species on New Hampshire and Vermont P3 plots by growth habit (per PLANTS Database, USDA Natural Resources Conservation Service), 2007-2008

Growth habit	Number of species or undifferentiated genuses
Forb/herb	140
Graminoid	44
Shrub	25
Shrub, subshrub, vine	2
Subshrub, forb/herb	2
Subshrub, shrub	13
Subshrub, shrub, forb/herb	6
Tree	33
Tree, shrub	27
Tree, shrub, subshrub	2
Vine	3
Vine, forb/herb	3
Vine, shrub	1
Vine, subshrub	1
Vine, subshrub, forb/herb	2
Unclassified	39
Total	343

Table 7.—Number of species on New Hampshire and Vermont P3 plots by domestic or foreign origin (per PLANTS Database, USDA Natural Resources Conservation Service), 2007-2008

Origin	Number of species or undifferentiated genuses	Percentage
Introduced to the U.S.	25	7.3
Native and introduced to the U.S.	5	1.4
Native to the U.S.	274	79.9
Unclassified	39	11.4
Total	343	100

Nonnative invasive species

None of the 43 invasive plant species FIA monitors on P2 Invasive plots (Table 9) were among the top 20 species on P3 plots. On the P3 plots, broadleaf helleborine (*Epipactis helleborine*) was the most commonly observed nonnative plant species (8 plots; 22 percent of P3 plots); common dandelion (*Taraxacum officinale*) was the second most common nonnative plant species (6 plots; Table 10).

Table 8.—The top 20 plant species or undifferentiated genera or categories on New Hampshire and Vermont P3 plots, the number of plots on which the species were found (in parentheses), and the mean number of tree saplings and seedlings per acre on the plots, 2007-2008

Species	Tree saplings per acre	Tree seedlings per acre
Canada mayflower (33)	705	2,483
American beech (29)	622	2,453
Sugar maple (28)	714	2,775
Red maple (26)	659	1,949
Eastern hayscented fern (25)	741	2,400
Sedge (25)	616	2,579
Striped maple (25)	685	2,848
Wild sarsaparilla (25)	688	2,644
Starflower (23)	748	2,760
Eastern white pine (20)	632	2,260
Sensitive fern (20)	772	3,069
Yellow birch (20)	658	2,732
American red raspberry (18)	483	2,977
Paper birch (17)	813	2,515
Common ladyfern (16)	595	2,600
Eastern hemlock (16)	555	2,222
Northern red oak (16)	481	2,014
Red spruce (16)	597	2,883
Sessileleaf bellwort (16)	618	2,563
White ash (16)	661	3,130

On the P2 Invasive plots, common barberry was the most frequently occurring invasive plant species (4 plots; Table 11), followed by glossy buckthorn (*Rhamnus frangula*), common buckthorn (*Rhamnus cathartica*), and multiflora rose (3 plots). All of the invasive species found on New Hampshire and Vermont P2 Invasive plots were woody species, except for bull thistle (1 plot). The high number of woody plants observed reflects the high number selected for monitoring on the P2 Invasive plots.

Invasive plants were widely distributed throughout New Hampshire and Vermont. Common barberry was found on plots only in Vermont (Fig. 70) even though, according to the NRCS PLANTS database, it is known to occur in New Hampshire. Another trend observed was that common buckthorn was found only in the southern

Table 9.—Invasive plant species target list for Northern Research Station FIA P2 Invasive plots, 2007 to present

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

part of New Hampshire and Vermont (the southernmost plot in Vermont, which shows multiflora rose present, also had common buckthorn present), and glossy buckthorn and multiflora rose were observed on plots only in the central portion of each of these states.

Table 10.—Nonnative plant species found on New Hampshire and Vermont P3 plots, the number of plots (in parentheses), and the mean number of tree saplings and seedlings per acre on the plots. Some plots may have multiple non-native plant species and thus may be counted more than once in the table

Species	Tree saplings per acre	Tree seedlings per acre
Broadleaf helleborine (8)	562	2,141
Common dandelion (6)	587	2,479
Claspleaf twistedstalk (4)	600	3,017
Common yarrow (4)	600	1,151
Bird vetch (3)	526	2,158
Common buckthorn (2)	114	2,187
Common St. Johnswort (2)	487	2,699
Meadow hawkweed (2)	225	2,661
Broadleaf Solomon's seal (1)	1,199	1,649
Bull thistle (1)	225	3,598
Climbing nightshade (1)	750	1,799
Coltsfoot (1)	225	3,598
Common barberry (1)	1,199	375
Common mallow (1)	1,574	5,098
Common mullein (1)	300	6,597
Dovefoot geranium (1)	1,199	375
European black currant (1)	750	1,799
European columbine (1)	77	3,324
European cranberrybush (1)	77	3,324
Glossy buckthorn (1)	750	1,349
Hedge false bindweed (1)	260	1,822
Japanese barberry (1)	450	1,499
Multiflora rose (1)	750	1,349
Narrowleaf cattail (1)	675	150
Orange hawkweed (1)	1,199	375
Oxeye daisy (1)	225	3,598
Redtop (1)	1,349	1,424
Scots pine (1)	675	3,224
Smooth crabgrass (1)	750	1,349
Threadstalk speedwell (1)	1,574	1,499

Table 11.—Invasive plant species found on New Hampshire and Vermont P2 Invasive plots, the number of plots (in parentheses), and the mean number of tree saplings and seedlings per acre on the plots, 2007-2008

Species	Tree saplings per acre	Tree seedlings per acre
Common barberry (4)	918	656
Glossy buckthorn (3)	500	4,798
Common buckthorn (3)	126	4,332
Multiflora rose (3)	423	4,436
Japanese barberry (2)	1,050	1,649
European cranberrybush (1)	77	3,324
Autumn olive (1)	371	3,338
Oriental bittersweet (1)	150	1,874
Bull thistle (1)	225	3,598
Black locust (1)	750	1,799

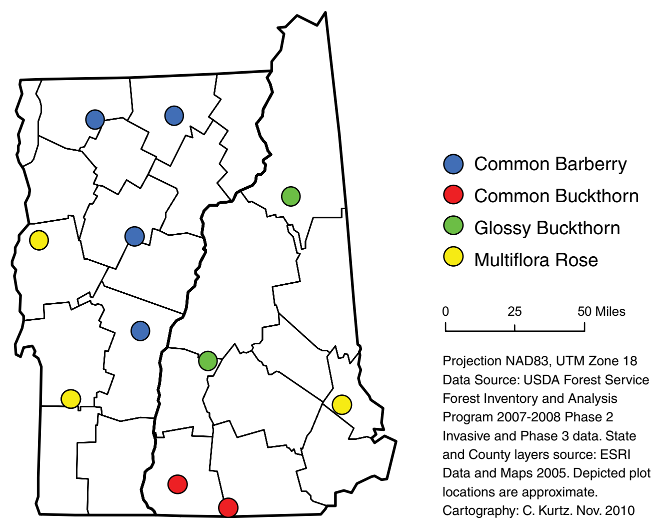


Figure 70.—Distribution of the four most frequently occurring invasive species (common barberry, common buckthorn, glossy buckthorn, and multiflora rose) observed on 2007-2008 FIA P2 Invasive and P3 plots in New Hampshire and Vermont; approximate plot locations depicted. Note that common and glossy buckthorn each appeared on three plots; however, these species co-occurred on plots with multiflora rose so their presence is not indicated on those plots.

What this means

The forests of New Hampshire and Vermont support a variety of species distributed across five growth habits (forb/herb, graminoid, shrub, tree, and vine). The presence of nonnative invasive plants in these states poses risk to the forests because these plants can inhibit regeneration of native species and change the overall forest structure. Additionally, these species can change resource availability and the habitat quality for flora and fauna.

In New Hampshire and Vermont, the presence of the 43 monitored invasive plant species is relatively low (13 percent) compared to neighboring New England states, Maine (14 percent) (McCaskill et al. 2011.) and Massachusetts (45 percent) (Butler et al. in press). Even though the occurrence of invasive plant species is low, the presence of these particular species causes concern because vigorous individuals have the potential to rapidly increase in cover and extent and impact co-occurring native species. Currently, in New Hampshire and Vermont, the data suggest the presence of invasive plants may cause a reduction in seedling cover. This conclusion is supported by comparing Table 8, which shows the top 20 plant species found on P3 plots (none of which are invasives) with Figure 71, which shows the nonnative species found on P3 plots. Table 8 shows only one species (red maple) with an average number of tree seedlings fewer than 2,000 per acre, while Figure 71 shows 15 of the 30 species have covers of fewer than 2,000 tree seedlings per acre.[1] Furthermore, plotting the percent cover of invasive plant species against the number of seedlings and saplings per acre (Fig. 72) suggests that, as invasive cover increases, the number of seedlings decreases. Although the sample size is small and only 2 percent of the 161 plots have invasive cover of 6 percent or more, this analysis raises concerns because it suggests those sites that do have invasives might fail to regenerate, eventually reducing future forest density.

The measurement of additional P2 Invasive and P3 plots will provide a better understanding of invasive plant distribution and facilitate analyses of the impact and spread of these species. Such knowledge can help forest managers understand where invasive species might be successful in establishing themselves and allow managers to craft strategies of treatment and mitigation, where necessary.

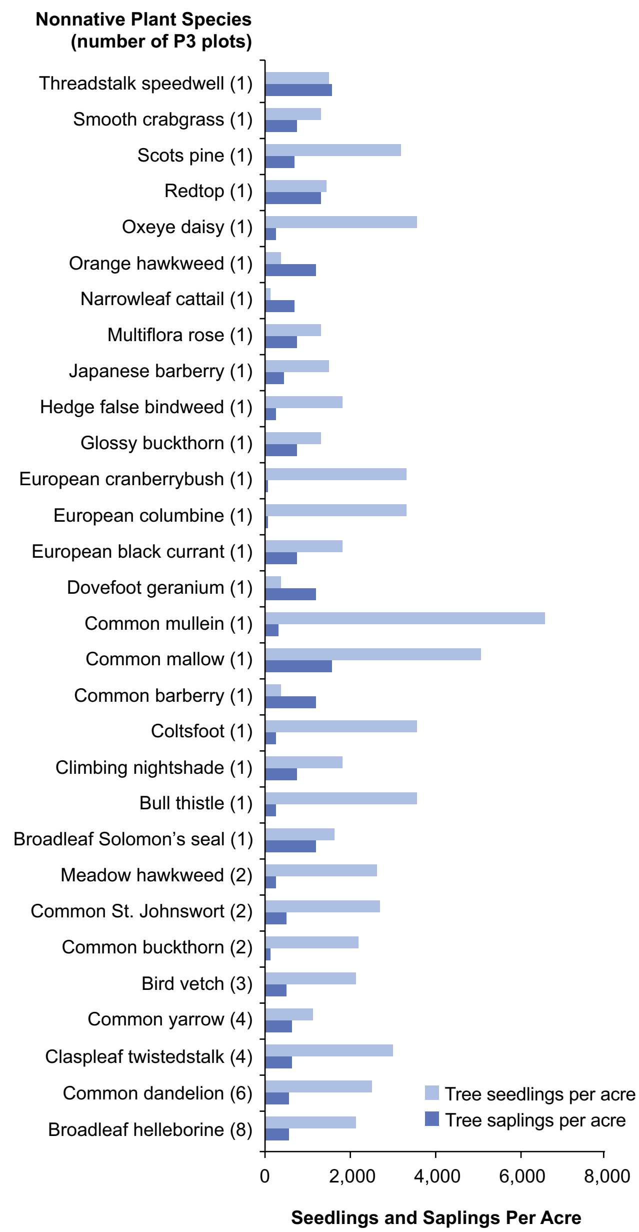


Figure 71.—Nonnative species on New Hampshire and Vermont P3 plots, the number of plots (in parentheses), and the mean number of tree seedlings and saplings per acre on the plots, 2007-2008.

[1] Caution must be used when analyzing these data due to the low overall number of plots.

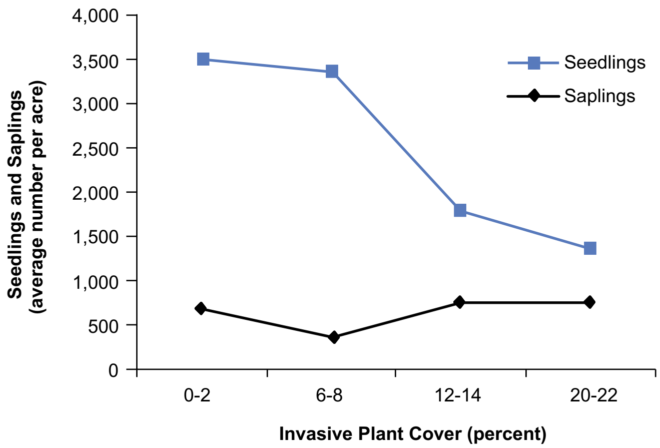


Figure 72.—Average number of seedlings and saplings per acre by invasive plant cover class for invaded P2 Invasive and P3 FIA plots in New Hampshire and Vermont, 2007-2008.

Ozone Bioindicator Plants

Background

Ozone, a byproduct of industrial development, is found in the lower atmosphere. Ozone forms when nitrogen oxides and volatile organic compounds go through chemical transformation in the presence of sunlight (Brace et al. 1999). Ground-level ozone is known to have detrimental effects upon forest ecosystems. Certain plant species exhibit visible, easily diagnosed foliar symptoms to ozone exposure. Ozone stress in a forest environment can be detected and monitored by using these plants as indicators. The FIA program uses these indicator plants to monitor changes in air quality across a region and to evaluate the relationship between ozone air quality and the indicators of forest condition.

The ozone-induced foliar injury on indicator plants is used to describe the risk of impact in the forest environment, using a national system of sites (Smith et al. 2003, 2007). These sites are not co-located with FIA samples. Ozone plots are chosen for ease of access and optimal size, species, and plant counts. As such, the ozone plots do not have set boundaries and vary in size. At each plot, between 10 and 30 individual plants of three or more indicator species are evaluated for ozone injury. Each plant is rated for the proportion of leaves with ozone injury and the mean severity of symptoms, using break points that correspond to the human eye's ability to distinguish differences. A biosite index is calculated based on amount and severity ratings where the average score (amount * severity) for each species is averaged across all species at each site and multiplied by 1,000 to allow risk to be defined by integers (Smith et al. 2007).

What we found

The majority of the plants sampled were milkweed (*Asclepias* spp.) or blackberry (*Rubus* spp.) (Table 12). The findings for Vermont indicate that risk of foliar injury due to ozone has been trending downward since the mid-1990s (Table 13 and Fig. 73) as have ozone exposure levels (Fig. 74).

Table 12.—Distribution of plants sampled for ozone injury by species, Vermont, 1994-2007

Species	Number	Percent
Milkweed	5,933	32.9
Blackberry	4,420	24.5
Black cherry	3,137	17.4
White ash	2,138	11.9
Spreading dogbane	1,934	10.7
Pin cherry	458	2.5

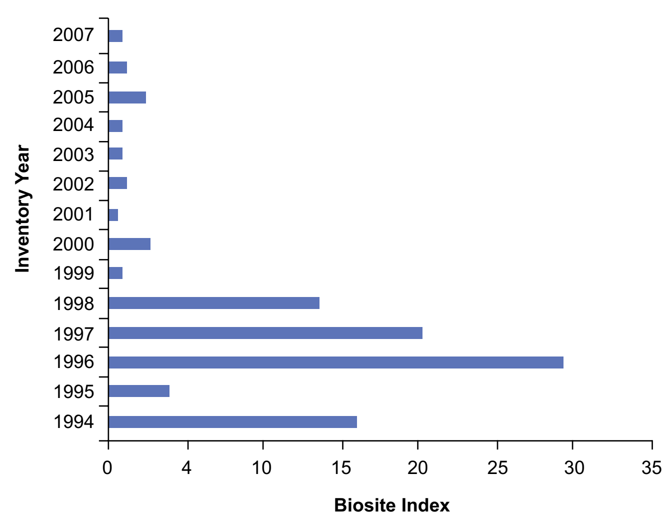


Figure 73.—Biosite index, Vermont, 1994-2007.

Table 13.—State-level summary statistics for ozone bioindicator program, Vermont, 1994-2007

Parameter	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number of biosites evaluated	14	18	16	17	17	21	22	18	15	16	17	14	12	11
Number of biosites with injury	12	5	13	9	9	7	6	4	5	5	4	4	5	1
Average biosite index score	16.01	3.84	29.4	20.28	13.46	0.86	2.73	0.6	1.24	0.89	0.82	2.39	1.2	0.99
Number of plants evaluated	858	1,169	1,049	1,092	946	1,382	1,544	1,335	1,409	1,639	1,752	1,435	1,235	1,186
Number of plants injured	195	22	200	139	98	40	74	29	23	25	18	8	13	15
Maximum SUM06 value (ppm-hr)[2]	15.54	14	10.44	13.11	9.33	16.92	5.46	13.57	17.23	11.59	7.58	9.59	7.45	9.12

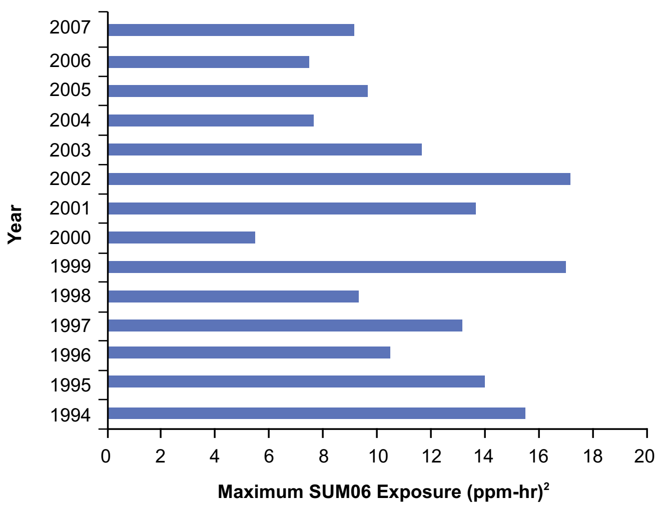


Figure 74.—Maximum SUM06 exposure levels (ppm-hr)[2], Vermont, 1994-2007.

What this means

Ozone exposure rates have been decreasing with corresponding decreases in foliar injury. This finding contrasts with evidence of medium and high risk in portions of the Mid-Atlantic region (Coulston et al. 2003).

A typical summer ozone exposure pattern for Region 9 (the Eastern Region of the U.S. Forest Service) is shown in Figure 75 (USDA For. Serv. 2002). The term SUM06 is defined as the sum of all valid hourly ozone concentrations that equal or exceed 0.06 ppm. Controlled studies have found that high ozone levels (shown in orange and red) can lead to measurable growth suppression in sensitive tree species (Chappelka and Samuelson 1998). Smith et al. (2003) reported that even when ambient ozone exposures are high, the percentage of injured plants can be lower in dry years.

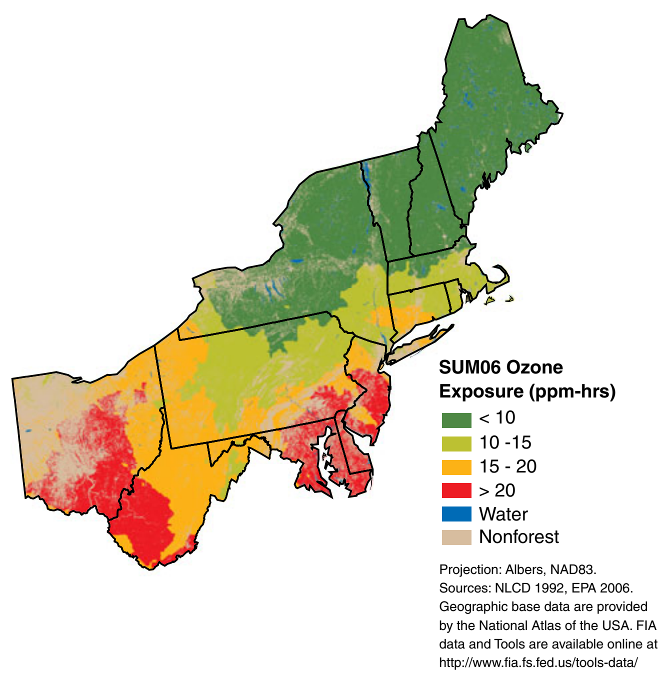


Figure 75.—Typical ozone exposure rates in Region 9.

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DVD Contents

Vermont's Forests 2007 (PDF)

Vermont's Forests: Statistics and Quality Assurance (PDF)

Vermont's Inventory Database (CSV file folder)

Vermont's Inventory Database (Access file)

Field guides that describe inventory procedures (PDF)

Database User Guides (PDF)

Morin, Randall S.; Barnett, Chuck J.; Brand, Gary J.; Butler, Brett J.; De Geus, Robert; Hansen, Mark H.; Hatfield, Mark A.; Kurtz, Cassandra M.; Moser, W. Keith; Perry, Charles H.; Piva, Ron; Riemann, Rachel; Widmann, Richard; Wilmot, Sandy; Woodall, Chris W. 2011. **Vermont's Forests 2007.** Resour. Bull. NRS-51. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 56 p. [DVD included].

The first full annual inventory of Vermont's forests reports more than 4.5 million acres of forest land with an average volume of more than 2,200 cubic feet per acre. Forest land is dominated by the maple/beech/birch forest-type group, which occupies 70 percent of total forest land area. Sixty-three percent of forest land consists of large-diameter trees, 27 percent contains medium-diameter trees, and 9 percent contains small-diameter trees. The volume of growing stock on timberland has been rising since the 1980s and currently totals nearly 9 billion cubic feet. The average annual net growth of growing stock on timberland from 1997 to 2007 is approximately 180 million cubic feet per year. Additional information is presented on forest attributes, land use change, carbon, timber products, and forest health. Detailed information on forest inventory methods and data quality estimates is included in a DVD at the back of the report. Tables of population estimates and a glossary are also included.

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

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