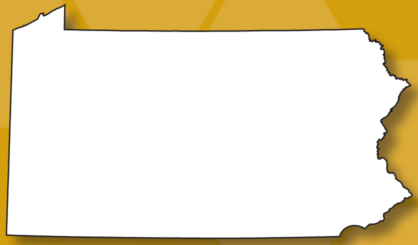
Pennsylvania's Forests 2009



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Abstract

The second full annual inventory of Pennsylvania's forests reports a stable base of 16.7 million acres of forest land. Northern hardwoods and mixed-oak forest-type groups account for 54 and 32 percent of the forest land, respectively. The State's forest land averages about 61 dry tons of wood per acre and almost 6,500 board feet (International ¼-inch rule) per acre on timberland. The ratio of average annual net growth-to-removals for growing-stock trees on timberland was about 2:1. Additional information is presented on forest land use, forest resources, forest sustainability, forest health (including regeneration), and timber products. Detailed information on forest inventory methods and data quality estimates are 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 all the people who collected Forest Inventory and Analysis (FIA) samples and the entire Northern Research Station FIA unit that processed and compiled the information for this report. Without the support of the Pennsylvania Department of Conservation, Bureau of Forestry, this report would not have been possible. We are grateful to Jim Finley (The Pennsylvania State University) and Todd Ristau (U.S. Forest Service, Northern Research Station) for reviews to help ensure that FIA standards provide useful information, particularly in helping policy makers and managers understand prospective management impacts.

Cover: Tree crowns in autumn, Delaware County, Pennsylvania. Photo by Will McWilliams, U.S. Forest Service.

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Foreword

Pennsylvania is the only state in the nation named for its forests. "Pennsylvania" translates from Latin into "Penn's Woods." It was true centuries ago and it is true today, forests are deeply embedded in our state's culture, economy, landscape, and identity. Forests provide clean air and water, recreational opportunities, wood products, energy, aesthetic beauty, plant and wildlife habitat, and a whole host of other uses and values.

The Pennsylvania Department of Conservation and Natural Resources (DCNR), Bureau of Forestry, is responsible for ensuring the long-term health, viability, and productivity of our forests while conserving native, wild plants. A basic requirement for achieving this mission is to understand the status of the forest—its age, composition, growth rate, total acreage, stressors and the myriad factors that affect its health and sustainability. This report, now produced every 5 years, is the result of a partnership between the U.S. Forest Service's Forest Inventory and Analysis program and DCNR Bureau of Forestry. The findings of this report help the Bureau of Forestry and other conservation organizations make informed, science-based decisions about natural resources policy and management.

This report highlights many changes that are occurring in our forests. Some of them are cause for concern, others are more positive. Change has always been constant in our forest ecosystem and our forest will continue to change in the future. Understanding these changes, monitoring them, and understanding how they impact the forest and its uses and values is necessary if we want to keep Penn's Woods healthy and sustainable.

Dan Devlin
State Forester

Department of Conservation and Natural Resources, Bureau of Forestry

Contents

Highlights

On the plus side

- Pennsylvania's forest land area is stable with some parts gaining while other parts are losing forests.
- The State's 16.7 million acres of forest land consist mostly of mixed-oak (54 percent) and northern hardwoods (32 percent) forest-type groups.
- The current distribution of timberland by stand-size class reveals continued build-up of sawtimber-size stands.
- All of the rising trends in wood volume described in the 2004 report have continued during the period from 2004 to 2009, with few exceptions for the major species or species groups.
- The per-acre volume is 2,138 cubic feet for forest land, 2,198 cubic feet for timberland, and 61 dry tons of biomass within the State's forests. The per-acre board-foot (International ¼-inch rule) volume on timberland averaged 6,436.
- The overall net growth-to-removals ratio was 2:1 for both forest land and timberland, indicating the forest is growing twice as much wood than is being harvested. Specifically, the overall growth-to-removals for public and private ownerships were 2.7:1 and 1.8:1, respectively.
- Red maple, black cherry, and northern red oak remained the top three species by volume; sugar maple and chestnut oak are tied at fourth place.

Issues to watch:

- The loss of forest land in Pennsylvania is due primarily to the conversion of forest land to development (67 percent), essentially nonreversible. Forest conversion, fragmentation, and parcelization are separate but highly related phenomena, cumulatively contributing to the process of land being divided into smaller, less contiguous units as forest ownership continues to change hands.
- The State's forests continue to show signs of aging with nearly 40 percent of the forest land being 80 years or older.
- Private landowners control 70 percent of the timberland acreage and consider forest management as a low priority. This aging and diverse ownership group generally lack management planning in caring for their lands. Access to timber will continue to be variable and complicated by owner priorities. Access could be more limited in the future as land changes hands.
- The distribution by stocking class for forest land is as follows: poorly stocked (10 percent), medium stocked (38 percent), fully stocked (48 percent), and overstocked (4 percent).
- Stocking levels on public forests have remained relatively stable since 2004. But stocking conditions on private land continue to show decreases in full and overstocked areas and increases in poor and moderately stocked acreage.
- Gypsy moth along with other pests, native, nonnative, and especially exotic or from foreign lands, have become entrenched. Their cumulative effects coupled with the ability to spread quickly represent an increased risk of future invasion spurned on by the global movement of people and goods. These

1800s wall with phlox, Susquehanna County, Pennsylvania. Photo by Will McWilliams, U.S. Forest Service.

stressors could produce future epidemics resulting in higher levels of tree mortality to an already aging forest resource.

- Regeneration is dependent on favorable light conditions, low levels of competing vegetation, and low deer pressure; and is indicated by advance tree seedling and sapling regeneration (ATSSR) assessments. A general lack of advance regeneration is associated with pressures from white-tailed deer browsing, competing invasive plants, and a significant group of pests affecting hemlock, sugar maple, ash, and American beech.

- Conditions for regenerating the oaks and some associative species are not favorable, requiring very high costs for management activities such as herbicide application and/or deer-exclosure fencing. These same forests are accumulating wood biomass with little advance regeneration of native species, let alone oak species.

- The value of hardwood timber in Pennsylvania was perhaps the highest in the Nation in 2006, prior to the depression of timber prices, employment, production, subsequent multiplier effects. With production, employment, and prices depressed, there is a low demand for wood products, resulting in lower harvest levels and little economic stimulus to the State's economy. Less State revenue translates to lower budgets for programs designed to improve forest conditions and for developing young stands of native high-canopy tree species.

- Timely monitoring and suppression programs are vital to accounting for, and maintaining the positive carbon balance of Pennsylvania's forests.

Background

Reservoir in autumn, Delaware County, Pennsylvania. Photo by Will McWilliams, U.S. Forest Service.

Pennsylvanians are fortunate to live among nearly 17 million acres of forest cover, almost 60 percent of the State. Forests currently provide countless benefits and services to society while supporting habitats for thousands of plants and animals. Assessing forest sustainability is a crucial step for developing programs and policies aimed to ensure their sustainability for future generations. Pennsylvania's forests face many challenges and threats. The results of this report support the finding that Pennsylvania's forests currently provide sustainable products and services, however, overall trends indicate a future trajectory that includes considerable challenges to ensuring desired future conditions.

The over-reaching goal of this report is to inform policy makers dealing with broad-scale forest management decisions in support of fostering future forest sustainability. The information is intended to update a previous 5-year report for 2004 (McWilliams et al. 2007). In addition, it is presented to help ensure that forests are being used wisely by having up-to-date information on the status and trends of this critical resource. Even though criteria and indicators have been addressed by the Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry (PA DCNRBF 2011), this report adds to the scope and depth of that ongoing analysis. In this context, traditional and emerging issues are discussed with salient examples provided.

What is FIA?

The Forest Inventory and Analysis program of the U.S. Department of Agriculture Forest Service, commonly referred to as FIA, is the nation's forest census taker. It was established by the U.S. Congress to "make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirements for the forest and rangelands of the United States" (RPA 1974).

FIA has been collecting, analyzing, and reporting on the nation's forest resources for more than 80 years with the first FIA inventories in the northeastern states occurring in the 1950s. Information is collected on the status and trends of the extent, composition, structure, health, and ownership of the forests. This information is used by policy makers, resource managers, researchers, and the general public to better understand forest resources and to make more informed decisions about its fate. Periodic forest inventories of Pennsylvania were completed in 1955, 1965, 1978, and 1989 (Ferguson 1955, Ferguson 1968, Considine and Powell 1980, and Alerich 1993, respectively, and Widmann 1995). In those earlier inventories, FIA measured trees only on timberland plots and did not report volumes on forest land.

What is this report?

Starting in 2000, Pennsylvania and the Northeastern Research Station commenced the annual inventory system requiring 20 percent of the statewide plots to be surveyed each year. Since the implementation of this annual inventory, FIA has been reporting volume on all forest land, not just timberland. Two annual inventories were completed in 2004 (McWilliams et al. 2007) and 2009 (this report). A third annual inventory (2010-2014) is currently in its fourth year of field collection.

The results of the most recent completed 5-year annual inventory (2009) are reported in chapters that focus on forest features, forest resources, forest sustainability, forest health indicators, and timber products. Details about the data collection and processing, a basic glossary, a complete set of tables for Pennsylvania, and information on statistical reliability, are included in a DVD titled "Statistics, Methods, and Quality Assurance", which is found at the back of this report.

A Beginner's Guide to Forest Inventory

What is a tree?

The Forest Inventory and Analysis program 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 can be very tall, heavily dense, and multi-structured; or short, sparsely populated, and a single layer of trees. FIA defines forest land as land that is at least 10 percent stocked by trees of any size or formally 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.

- Timberland is unreserved forest land that meets the minimum volume productivity requirement of 20 cubic feet per acre per year.
- Reserved forest land is forest withdrawn from timber utilization through legislative regulation.
- Other forest land (unproductive) is commonly found on low-lying sites or high craggy areas with poor soils, where the forest is incapable of producing 20 cubic feet per acre per year.

Most of the trend reporting in this publication is focused on all forest land (including timberland and reserved forest land), except for the area of forest land which was inaccessible for various reasons. Comparing current data to older periodic inventories requires timberland estimates.

How many trees are in Pennsylvania?

Pennsylvania's forest land contains approximately 2.3 billion growing-stock 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 a sample of the total population. The area estimates are calculated from field measurement of 2,945 forested plots classified by ownership. For information on sampling errors see Pennsylvania's Forests 2009: Statistics, Methods, and Quality Assurance found on the DVD in the back of this bulletin.

How do we estimate a tree's volume?

The volume for a specific tree is usually determined by the use of volume equations developed specifically for a given species or a group of species. Volume equations have been developed at the Northern Research Station for application to tree species found within the region. We can produce individual tree volumes based upon species, diameter, and merchantable height. Tree volumes are reported in cubic foot (ft^3) 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, and belowground stump and coarse roots (Jenkins 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 are forest carbon pools estimated?

The FIA program does not directly measure forest carbon stocks. Instead, a combination of empirically derived carbon estimates (e.g., standing live trees) and models (e.g., soil carbon models based on forest type group, latitude, and longitude) are used to estimate forest carbon stocks (Smith et al. 2006).

How do we compare data from different inventories?

Comparing new inventories with older data is done 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. Starting in 2007, 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 merchantable heights and percent cull in order to reduce random variability across datasets.

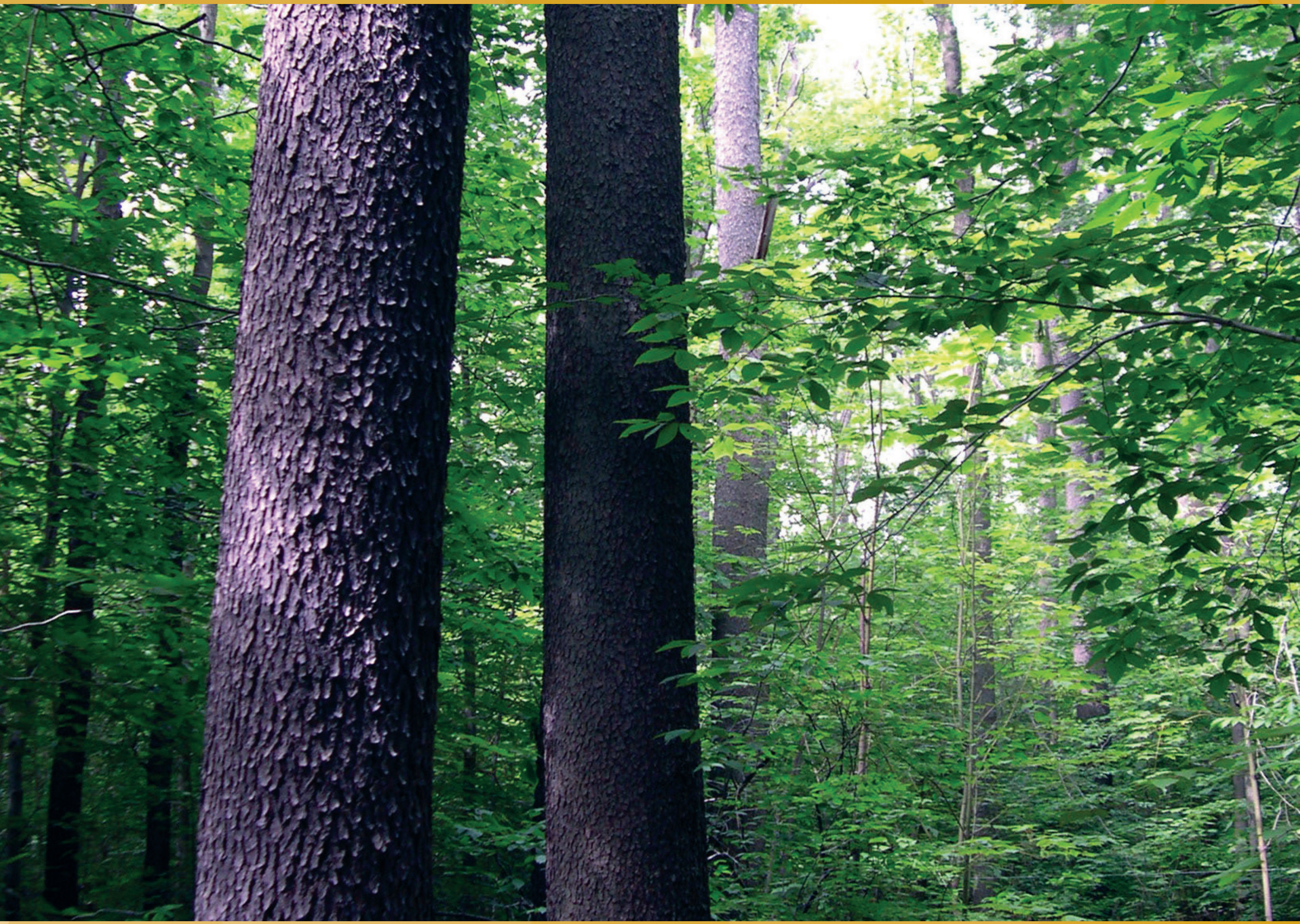
Prior to the implementation of the Component Ratio Method (CRM), volume and biomass were estimated using separate sets of equations (Heath et al. 2009). With the implementation of the CRM, determining the biomass of individual trees and forests has become simply an extension of our FIA volume estimates.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

Differences in methodology for determining growth, mortality, and removals to a specified sample of trees have also been introduced (Westfall et al. 2009). Essentially, the new approach involves growing trees to the midpoint of the inventory cycle (2.5 years for a 5-year cycle) in order to obtain a better estimate for ingrowth (a component of net growth), 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).

Resource Availability

FIA does not attempt to identify which lands are suitable or available for timber harvesting. For example, Butler et al. (2010) estimated that biophysical and social constraints, primarily social constraints, reduced the availability of wood from family forest lands across the northern United States by 62 percent. Availability is dependent upon a complex set of factors including economic/market constraints, accessibility, and ownership objectives; all need to be considered when estimating availability.

Forest Features



Kane Experimental Forest with cherry, beech, striped maple, Warren County, Pennsylvania.
Photo by Will McWilliams, U.S. Forest Service.

Forest Area

Background

Perhaps the most important criteria for determining the overall forest health of a state is whether the area of forest land is increasing, staying the same, or being lost through conversion to other uses. In addition, it is important to know where the increases are coming from and where decreases are departing to.

What we found

Pennsylvania contains 16.7 million acres of forests, covering 58 percent of the State's 29.0 million acres of land (Fig. 1). About 97 percent, or 16.2 million acres of forest land, is classified as timberland. The remainder is either reserved forest land or unproductive forest land (Table 1). While the percentage of timberland has decreased slightly since the 1950s, it has remained relatively constant for the past two decades. The decrease is mostly the result of public agencies designating areas off limits to timber harvesting, such as State Forest Wild and Natural Areas and Wilderness and Road-fewer Areas on the Allegheny National Forest.

Table 1.—Area of land by category, Pennsylvania, 2004 and 2009.

Forest land Class	2004	2009
Unreserved Forest land	*thousand acres*	
Timberland	16,038.1	16, 200.3
Unproductive	101.2	80.7
Subtotal	16, 139.3	16, 281.0
Reserved forest land		
Productive	433.6	458.9
Unproductive	--	--
Total forest land	**16, 573.0**	**16, 739.8**

What this means

The results illustrate a pattern of a "stable" forest land base. However, the loss of forest is occurring within localized areas. Although a small net gain has occurred since 2004, it is not certain where those changes have occurred. It is known that abandoned agricultural land (mostly pasture) often reverts to forest, but can reverse direction if trees are cleared for other uses. Even though Pennsylvania is losing about 150 acres of forest per day to development, deforestation, or conversion, reversions are occurring at a faster rate.

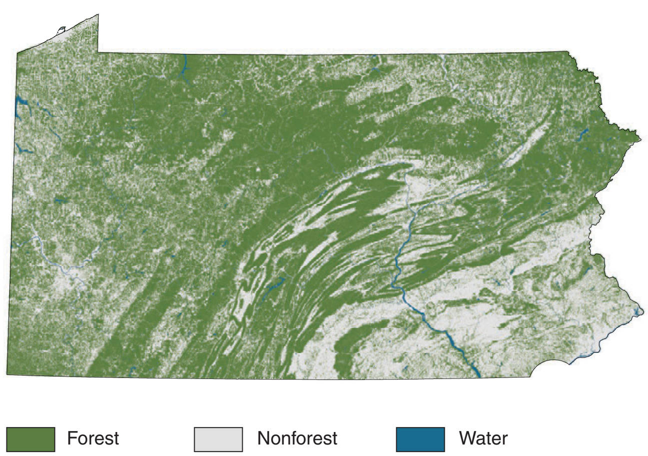


Figure 1.—Distribution of forest land, Pennsylvania, 2001 (National Land Cover Dataset [Homer 2007]).

Reverting field, Susquehanna County. Photo by Will McWilliams, U.S. Forest Service.

Land Use Change

Background

Forest land dynamics is the process by which forest land is gained and lost as a result of converting land to different uses. Forest land dynamics can be measured by comparing estimates of forest land at two or more points in time then quantifying "net change," as a result of additions to and diversions from, forests. The diversion of forest land to development results in a loss of all the benefits the forest normally provides unless the property has an opportunity to revert back to forest conditions. In most cases, this is not likely in cases where the land has been paved for development. Pennsylvania's contemporary landscape provides examples of the gradient; from rural forest, to ex-urban, to suburban, and finally urban forest environments (Fig. 2). Urban development is occurring at a rapid pace and the demand for residential housing is increasing (Claggett et al. 2004). Nowak and Walton (2005) have predicted that the area of U.S. urban land could likely triple from 2000 to 2050.

Figure 2.—Examples of rural-wildland, rural, suburban, and urban forest environments (clockwise from top left), Pennsylvania, 2009. (Photos by Will McWilliams, U.S. Forest Service.)

What we found

The distribution of the remeasured plots illustrates the change in forest land expressed as gain, loss, or remaining as before (Fig. 3). The loss of forest land in the northeast and southeast regions is apparent, but other areas are showing some forest loss as well. Underlying socioeconomic forces of development and their impacts are drivers of forest loss observed in the Philadelphia and Pittsburgh metropolitan areas, and the spread of these forces are currently being felt within the more rural central region of the State. Sixty-seven percent of forest land being lost in Pennsylvania is due to land conversion for development. Forest land lost to other uses was 269,000 acres, with 180,500 acres specifically lost to development. An additional 88,400 acres was converted to agriculture. However, the percentage loss from forest land to urban development only represents 28 percent of the total land conversion, while an additional 49 percent gain to urban land use came from conversion of agricultural lands.

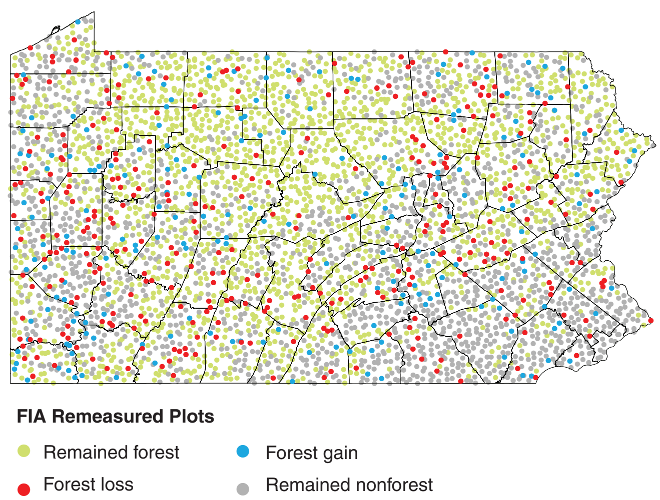


Figure 3.—Change in land use based on remeasured plots, Pennsylvania, 2004 to 2009. Plot locations are approximate.

What this means

Most of the remeasured plots in Pennsylvania have either remained forested or stayed in a nonforest land use (56 percent and 41 percent, respectively). Even though there was a slight net gain in forest land from 2004 to 2009, the State did experience forest loss in certain regions. Pennsylvania lost 2 percent of forest land between 2004 and 2009, according to the FIA remeasurement data, but this loss was offset by some gains from agricultural lands converting to forest. The net result was a forest gain of 1 percent.

What we found

The current forest ownership patterns of the State are summarized by the amount, type, and location of potential management activities. The area north of Interstate 80 contains primarily public forests—mainly the Allegheny National Forest, and forests held by the Pennsylvania Department of Conservation and Natural Resources and the Pennsylvania Game Commission (Fig. 4). Other parts of the State are dominated by either private lands or a mixture of private and State-owned lands (Table 2).

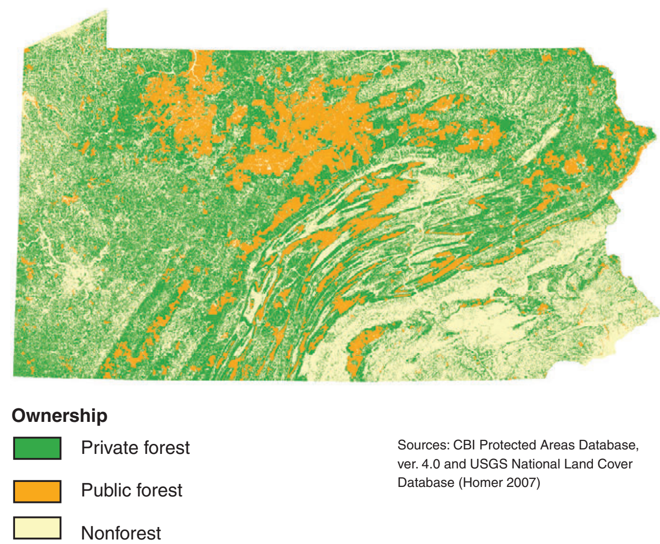


Figure 4.—Location of forest land by ownership, Pennsylvania, 2006.

Family Forest Land Ownership

Background

The owner of any tract of forest land must make decisions about its current and future conditions. The biophysical environment determines short-term productivity, but it is the landowner who prospectively invests in the restoration, conservation, and management of their forests. The National Woodland Owner Survey (NWOS) (Butler et al. 2004, Butler et al. 2008) collects forest landowner characteristics, demographics, management history, and future intentions from private forest owners.

While parcelization, parcels being subdivided and sold, may or may not result in immediate impacts to the forest, the process can have longer-term effects. Whether the new owners choose to develop their newly acquired land or have management objectives that simply differ from their neighbors, the continuity of forest cover could be jeopardized.

Table 2.—Area of forest land by ownership category, 2006.

Ownership category	Area	
	Acres	SE[a]
	Thousands	*Percent*
Private		
Family	8,861	1.6
Other private	2,971	3.8
Total private	11,832	1.1
Public		
Federal	634	8.4
State	3,778	1.4
Local	494	10.6
Total public	4,908	2.8
Total	**16,740**	**0.7**

[a] SE = sampling error

The 2006 NWOS estimate of the number of family and forest owners is about 469,000 ownerships controlling more than 8.9 million acres of forest land. Nearly two-thirds of this forest is held by folks identified as 55 and older, indicating a trend toward retirement-phase owners (Table 3).

Table 3.—Area and number of family forest owners by age of the primary decisionmaker, Pennsylvania, 2006.

Age (years)	Area		Owners	
	Acres	SE[a]	Number	SE[a]
	Thousands	*Percent*	*Thousands*	*Percent*
<35	164	96.8	12	32
35-44	873	21.1	74	22.5
45-54	1,947	10.4	99	15.6
55-64	2,235	9.2	109	17.5
65-74	2,024	10.1	91	16.1
75+	1,293	14.9	58	24.6
No answer	369	46.8	26	54

[a]SE = sampling error

The reasons for ownership of "family" forest land are as diverse as the topography and character of forests in the State (Table 4). An underlying paradigm of ownership is based upon the noneconomic benefits of beauty and nature, as part of a larger property; and the ability to pass this land on to their children or other heirs. This mixture of beliefs and their relative importance over time creates a diversity of management intentions and practices. The challenge for public programs aimed at developing traditional timber resources is to find a cohesive formula for balancing an owner's intentions with the practices needed to maintain a healthy and productive forest.

The distribution of "family" forest owners by the size of holdings highlights the complexity of ownership due to the range of parcel sizes (Table 5).

Finally, the NWOS survey found 90 percent of the family forest owners who controlled 94 percent of the family forest lands had no management plans (Table 6).

Table 4.—Area and number of family forest owners by reason for owning forest land, Pennsylvania, 2006. Numbers include landowners who ranked each objective as very important (1) or important (2) on a seven-point Likert scale.

Reason[a]	Area		Owners	
	Acres	SE[b]	Number	SE[b]
	Thousands	*Percent*	*Thousands*	*Percent*
To enjoy beauty or scenery	6,314	3.1	361	8.3
To protect nature and biologic diversity	4,963	4.1	288	9.7
For land investment	3,608	5.6	127	11.7
Part of home or vacation home	5,491	3.9	349	9.7
Part of farm or ranch	3,064	7	125	13.7
Privacy	5,462	3.7	326	8.9
To pass land on to children or other heirs	4,874	4.2	218	10.4
To cultivate/collect nontimber forest products	751	23.5	27	31.5
For production of firewood or biofuel	1,585	11.9	50	11.8
For production of sawlogs, pulpwood or other timber products	2,210	8.8	43	10.8
Hunting or fishing	4,598	4.5	162	9.1
For recreation other than hunting or fishing	3,600	5.7	161	10.9
No answer	57	253.5	2	47

[a]Categories are not exclusive.
[b]SE = sampling error

Table 5.—Area and number of family forest owners by size of forest landholdings, Pennsylvania, 2006.

Size of forest landholdings	Area		Owners	
	Acres	SE[a]	Number	SE[a]
Acres	*Thousands*	*Percent*	*Thousands*	*Percent*
1-9	885	21.4	301	11.3
10-19	822	22.5	66	9.5
20-49	2,018	10.4	72	6.2
50-99	2,274	10	36	6.1
100-199	1,902	12.1	15	7.4
200-499	1,402	15.8	5	9.3
500-999	611	32.8	1	16.2
1,000-4,999	824	26.7	1	24.9
5,000-9,999	168	99.3	<1	82.1
10,000+	832	24.1	<1	38.6
Total	11,738	1.7	497	6.8

[a]SE = sampling error

Table 6.—Area and number of family forest owners by management plan status, Pennsylvania, 2006.

Management plan	Area		Owners	
	Acres	SE[a]	Number	SE[a]
	Thousands	*Percent*	*Thousands*	*Percent*
Yes	639	27.8	11	24.1
No	7,980	2.3	440	7.7
Do not remember	121	115.4	6	40.6
No answer	166	95.7	12	64.5

[a]SE = sampling error

What this means

The diversity of landowners and their objectives, their age, and the lack of guidance normally provided by management planning will make it a challenge to predict future impacts on the forest land base. The current generation of private owners appears very concerned about the health of their forest and seems to want to improve the conditions of their land. This finding is important, though there remain major challenges due to funding limits for management activities, a general lack of management planning by the owners, and the need for economic recovery in the forest products industry (Strauss et al. 2007).

Urbanization and Fragmentation of Forest Land

Background

The expansion of developed land often results in the "breaking up" or fragmentation of forest land (Wilcox and Murphy 1985). Forest fragmentation and habitat loss threatens not only species requiring interior forest conditions (Donovan and Lamberson 2001), but also species that are slow moving, slow reproducing, and wide ranging (Forman 2000). Forest fragmentation also has a drying effect on micro-climatic environments (Meddens et al. 2008).

Forest fragmentation and increased urbanization can create conduits for the introduction and spread of invasive species. Pennsylvania contains abundant roads and other fragmenting features. The exception occurs in the north-central reaches of the State where large blocks of public forests are common. Marcellus shale gas development is contributing to forest fragmentation and could potentially threaten the interior forest of this region, although relatively little is known of its specific impacts.

Forest fragmentation and increased proximity to human development can lead to a rise in nonnative or exotic invasive plants, as forest patches become smaller, forest edges grow, and human influences increase. The ecosystem services provided by forest land can also be diminished (e.g., clean water, carbon sequestration, aesthetic quality, and nontraditional forest products).

What we found

Forest patch size and housing density are two valuable indicators of the impacts of fragmentation, and they show the location and extent of fragmentation across the State. The forest patch size map (Fig. 5) is calculated from national 30 m land cover data and thus represents an approximation of local forest patch sizes (Riemann et al. 2008). The housing density map (Fig. 6) is derived from U.S. Census Bureau data (U.S. Census Bureau

2002) with forest areas shaded by the housing density of the census block in which they occur (Riemann et al. 2008). White areas in both figures correspond to the population centers within the State: Philadelphia, Pittsburgh, Harrisburg, and Erie. The areas with the highest housing density (bright red in Figure 6) are generally related to the smallest patch sizes (Fig. 5). Although related, each of these factors characterizes a different type of impact on forest land.

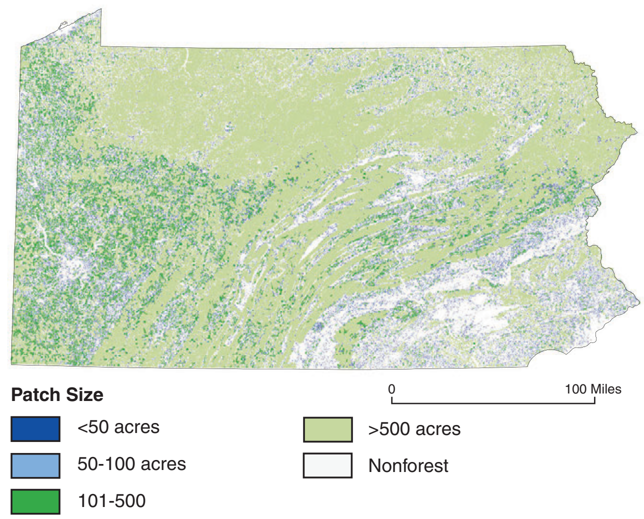


Figure 5.—Distribution of forest land by patch size.

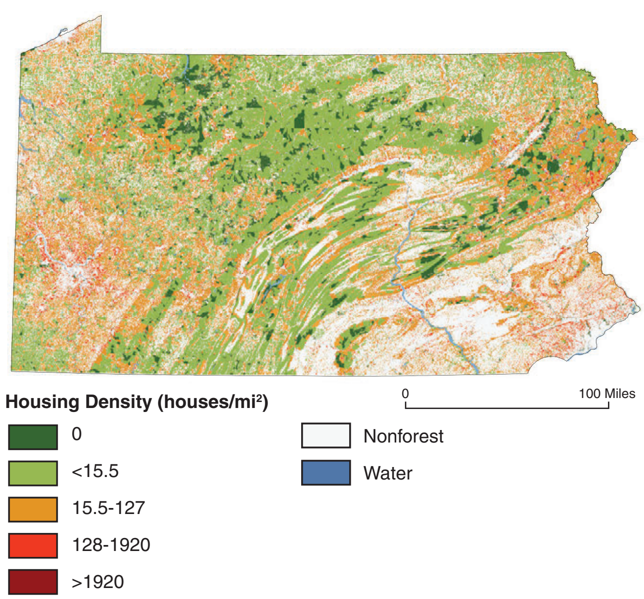


Figure 6.—Housing density in forested areas, Pennsylvania, 2009.

The State's population has increased by only 2 percent since 2004, one of the slowest growth rates (43rd) in the United States and far below the national average of 5.5 percent (PA SDC 2010). This trend is projected to continue through at least 2030 (U.S. Census Bureau 2012).

What this means

Forest urbanization and fragmentation have a cumulative impact on both traditional benefits and ecosystem services provided by forest land. The location, type, and extent of human development is driven by population trends, the pace of the economy, prospective economic development, and continuing cultural trends toward fewer people per house and new residential development in forested and other amenity areas (Radeloff et al. 2005).

Although population growth is expected to continue to be slow, the pace of urbanization and fragmentation of forest land will be affected by housing and industrial development trends such as shale gas development.

Forest Resources

Mixed land use with rural landscape, Susquehanna County. Photo by Will McWilliams, U.S. Forest Service.

Forest Composition

Mixed-oak and northern hardwood forests dominate Pennsylvania's landscapes, each containing unique tree and plant communities while defining the overall character of the State's forests. Mixed-oak forests contain primarily the oaks; including northern red oak, chestnut oak, white oak, scarlet oak; along with the maples, yellow-poplar, ash, hickories, and miscellaneous deciduous species. The understory vegetation is highlighted with mountain laurel and blueberry. Northern hardwood forests contain primarily black cherry, the maples, American beech, the birches; and an understory composition often comprised of ferns, striped maple and beech brush. Hemlock and eastern white pine are common to both forest types and both produce valuable wood products.

To claim a full knowledge of forest "function" solely based upon FIA data concerning forest composition, structure, and health is not possible; however, it is known that Pennsylvania forests offer the full suite of ecosystem services, such as water quality, clean air, beauty, carbon sequestration, and nontraditional forest products, e.g., recreation and natural herbs and food stuffs (DCNRBF 2011). The type and diversity of Pennsylvania's forests have been described through associations by Zimmerman et al. (2012). The analyses for this section uses the most recent inventory dates (2005-2009) and compares them with the results of the 2004 report and the last periodic inventory completed in 1989 (Alerich 1993, McWilliams et al. 2007).

Background

NRS-FIA categorizes forests using a classification of forest land and timberland based on the combination of species that form a plurality of stocking. Individual forest types are aggregated into forest-type groups permitting broad comparisons while illustrating stand composition. The traditional forest-type names and conventions have remained the same over time to allow for consistent trend analysis. Changes in the distribution of forest land by forest-type group depend on natural and anthropogenic impacts to the forest canopy such as insects and diseases, harvesting, a shift in the forest-land base due to land use changes, and succession.

What we found

Forest-type groups are distributed across Pennsylvania's forest land following the contours of the major topographic features such as the Appalachian Mountains (Fig. 7). The State's 16.2 million acres of timberland consists mostly of mixed oak (54 percent of total forest land area) and northern hardwood (32 percent) forest-type groups (Fig. 8). Other forest-type groups with significant area of timberland include white-red-jack pine, elm-ash-cottonwood, and aspen-birch.

What this means

The current maturing forest is mainly composed of mixed oak, northern hardwoods, and a collection of other native tree species. These forests regenerated after logging activities of the 1920s that removed nearly all of the saleable wood for products ranging from lumber to charcoal. Today's vast, relatively even-age forest is trending toward age structures of over 100 years. As a result, this forest is faced with some new, emerging, and existing stressors.

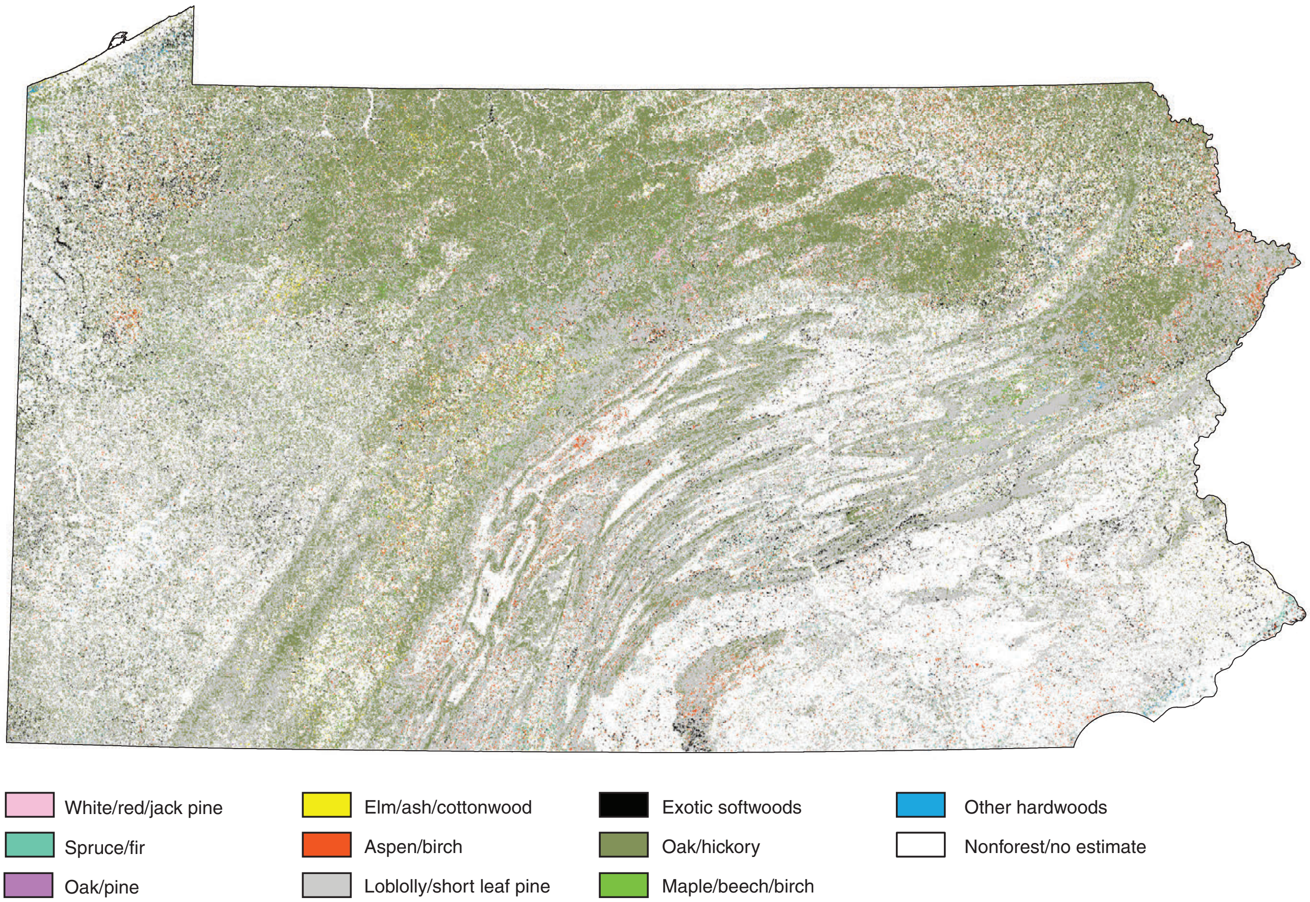


Figure 7.—Distribution of forest land by forest-type group, Pennsylvania, 2007 (National Land Cover Dataset).

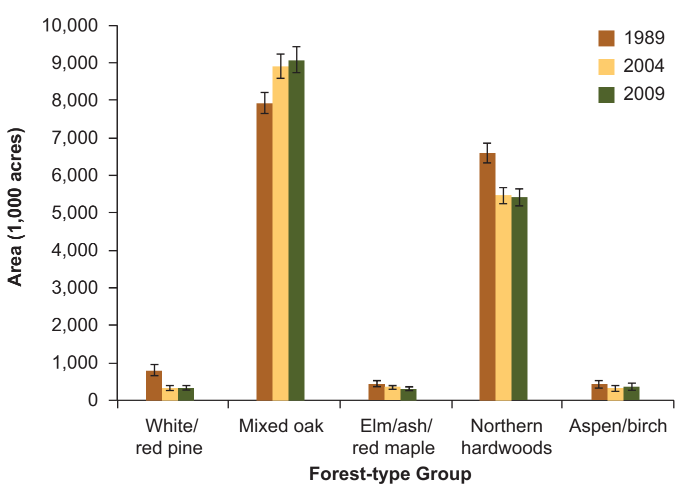


Figure 8.—Area of timberland by forest-type group, Pennsylvania, 1989, 2004, and 2009. Sampling error bars are for 68-percent confidence level.

Stand-size Class

Background

Stand-size class provides a rough indicator for the stage of forest development (e.g., early or late), and is based on standard NRS-FIA tree-size measurements. Sampled forest conditions are assigned to one of three categories, small, medium, and large; based on a range of measurements which accounts for the most stocking of trees per acre. Small stands have a plurality of trees less than 5.0-inches diameter-at-breast height (d.b.h.) (early stage of development). Medium-sized stands are dominated by trees at least 5-inches d.b.h., but less than merchantable size (mid-stage). Large stands are at least 9-inches d.b.h. for softwoods and 11-inches for hardwoods (late stage).

What we found

The distribution of timberland by stand-size class is 65 percent in large, 24 percent in medium, and only 11 percent in the small, early stage class (Fig. 9). Medium-sized forests have been decreasing, while large-sized stands are increasing. Assuming the "desirable" distribution for wood production suggested by Liscinsky (1978), the State now has an overabundance of large stands and an under-abundance of young stands (Fig. 10).

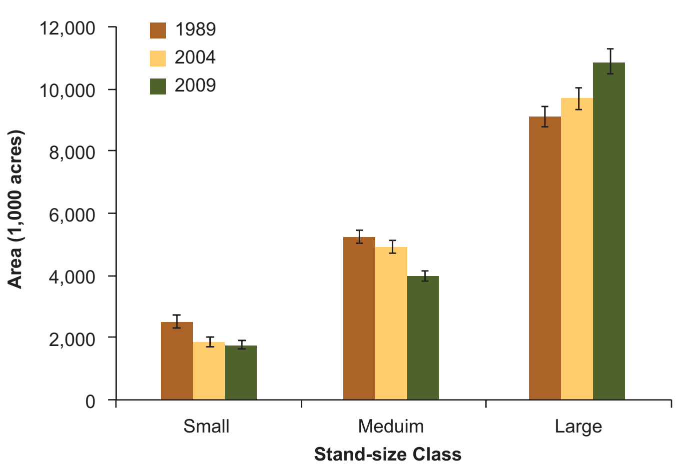


Figure 9.—Area of timberland by stand-size class, Pennsylvania, 1989, 2004, and 2009. Sampling error bars are for 68-percent confidence level.

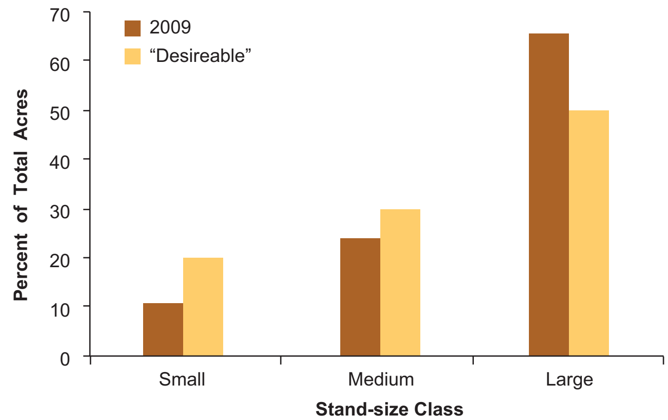


Figure 10.—Area of timberland by stand-size class, Pennsylvania, 2009 and "desirable." (Liscinsky 1978).

Age Class

Background

Age class gives an idea how long a forest has been in place since the last stand replacement event. The classes are the following range of ages: 1 to 20, 21 to 40, 41 to 60, 61 to 80, 81 to 100, and 100+ years. Stand-size classes along with age class help to illustrate forest structure.

What we found

The distribution of timberland by age class substantiates the results by stand-size class, e.g., a maturing forest with little forest land in the earlier stages of stand development (Fig. 11). A slight decrease in the 1 to 20-year age class was concurrent with little change in the area of small-diameter forests. The minor difference is likely due to some medium- or large-sized trees being evaluated in the stand-size computer algorithm, resulting in a young stand being "aged" as older. Currently, one-third of the State's timberland is 80 years and older, with an additional 7 percent over 100 years. Simple extrapolation would suggest that although the 41 to 60 and 61 to 80 year classes decreased lately, these classes will likely continue to add to the older classes. Age classes 80 years and alder are essentially late-succession timberlands based upon economic maturity and when a stand reaches an average of 18 inches d.b.h. (Gansner et al. 1990). Although diameter is not a surrogate for age, stands over 80 years on average sites could easily have grown to this size.

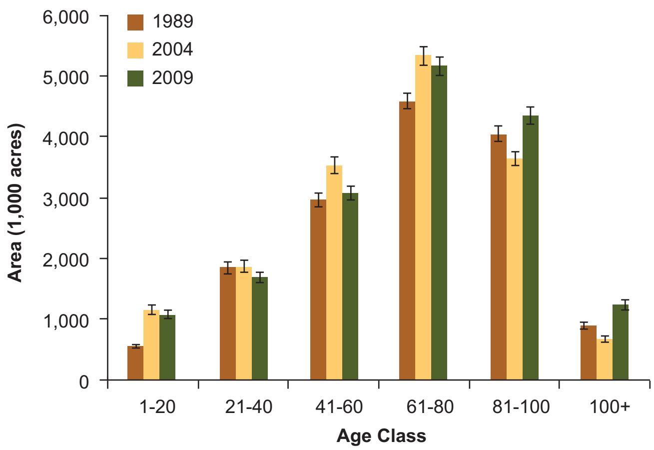


Figure 11.—Area of timberland by age class of dominant trees Pennsylvania, 1989, 2004 and 2009. Sampling error bars are for 68-percent confidence level.

Stocking

Background

Stocking is a measure of the occupancy (density) of land by trees in relationship to the growth potential of the site. The Northern Research Station's FIA stocking classes roughly correspond to traditional stocking guides for the eastern United States (Gingrich 1967, Leak 1981). Poorly stocked (10 to 34 percent), moderately stocked (35 to 59), fully stocked (60 to 100 percent), and overstocked (101+ percent) are classes used to describe the categories for occupancy of forest land. The nonstocked class (0 to 9 percent) is ignored in this analysis because it represents a very small area.

What we found

The display of timberland acreage by stocking class (Table 7) and stand-size class illustrates the maturing of Pennsylvania's timberland (Fig. 12). The tabulation of timberland by stocking and age class shows that the 60 to 80 and 81 to 100 year age classes have an overabundance of acres in medium- and fully-stocked forests (Figure 13). When the timberland base is broken out by stocking level and broad ownership group, change is more apparent under private ownership (Fig. 14). As shown, the current distribution for public owners has been relatively stable since 2004. Conditions on private land continue to show a decrease in full- and overstocked area and increase in the area of poor and medium stocked acreage.

Table 7.—Percent of forest land by stocking class, Pennsylvania, 2009.

Stocking Class	Area of forest land (percent)
Poorly stocked	10
Medium stocking	38
Fully stocked	48
Overstocked	4

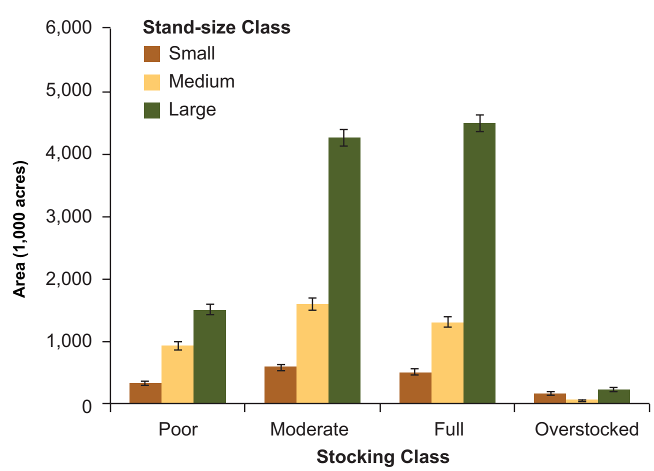


Figure 12.—Area of timberland by stocking- and stand-size class, Pennsylvania, 2009. Sampling error bars are for 68-percent confidence level.

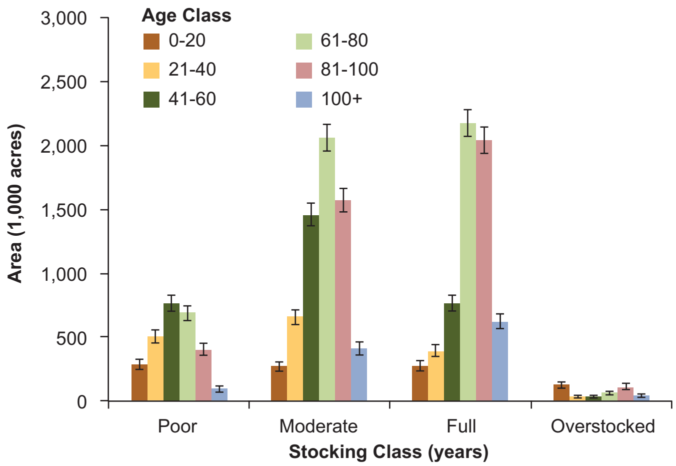


Figure 13.—Area of timberland by stocking- and age-class of dominant trees, Pennsylvania, 2009. Sampling error bars are for 68-percent confidence level.

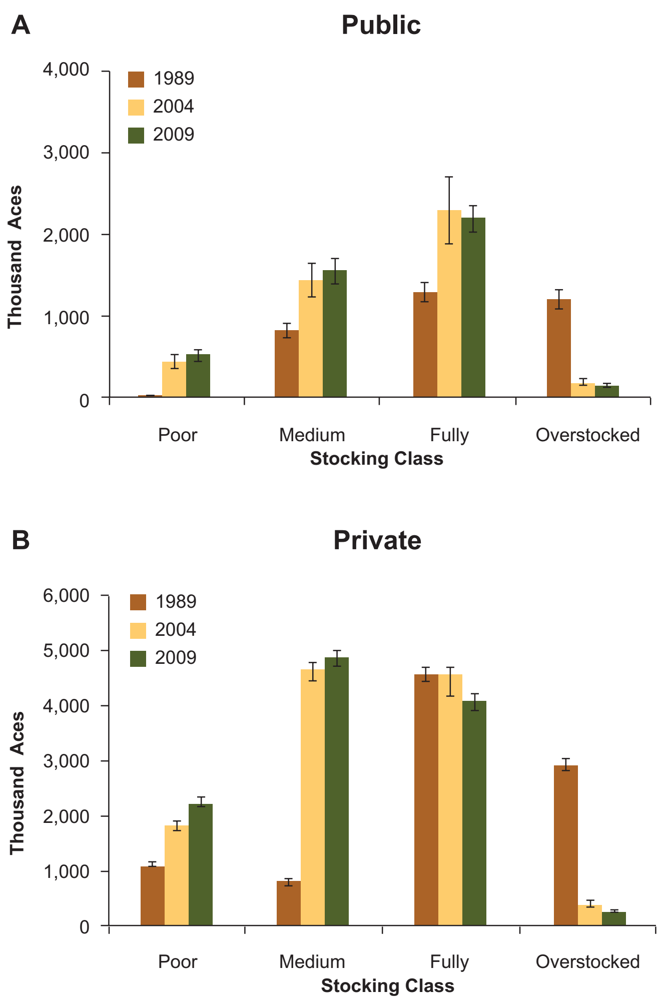


Figure 14.—Area of timberland by stocking class and owner group, Pennsylvania, 1989, 2004, and 2009. Sampling error bars are for 68-percent confidence level.

What this means

Except for areas that have been recently harvested, most of Pennsylvania's forests originated between 90 and 120 years ago, reflecting the widespread clearing and harvesting that occurred to fuel the industrial revolution. As a result, most forest stands are relatively uniform in structure and are dominated by "sawtimber-sized" trees, annually gaining acreage with late-successional characteristics. Many experts agree that Pennsylvania is experiencing both a shortage of early-succession stands and healthy habitat-exhibiting late-succession forests.

Although the trends from the last 5 years mimic the previous survey period, it is abundantly clear that Pennsylvania's forests are stable, but aging. Their rich diversity makes it a challenge to summarize the full dynamics taking place given the many systems and stressors that are working together. It is known that much of the timberland base is of similar age making any decisions regarding this large block of land critical for determining the future trajectory of State's forests. Public forests should be showing more signs of aging such as overstocking, slower growth rates, and the development of late successional conditions; since these lands are not being harvested as heavily as private lands. Private forests continue to be the major source of wood for the forest products industry. At this time, it is apparent private forests are undergoing reductions in stand-level stocking while supplying most of the harvested material.

Number of Trees

Background

The inventory of live trees includes saplings, growing-stock trees, rough cull trees, and rotten cull trees. These tree numbers along with the number of standing dead trees can give a composite view of forest conditions. They have a direct relationship to the quality and volume of wood in our forests.

What we found

Examination of the relative abundance of live trees on forest land by diameter class reveals which species are important during the different stages of forest development (Fig. 15). This importance along with aging makes the lack of young white and chestnut oaks trees readily apparent. Northern red oak exemplifies a species with high abundance in the larger diameter sizes, but a lower occurrence in the smaller diameters. The "invasion" (Abrams 1998) of red maple is illustrated by its high abundance throughout the range of size classes as well as total numbers (Fig. 16). The trends in the number of live trees by diameter class are compared (1954 verses 2009) on timberland as stratified by development stage (Figure 17). The early stage is represented by sapling-size trees (less than 5.0-inches d.b.h., but larger than 1-inch.). The number of sapling-size trees have decreased considerably since 1954. The establishment stage (5- to 11-inches d.b.h.) included the 9-inch class as a "swivel point" where increases since 1954 are occurring in the larger diameter classes. The mid-stage trees (greater than 11.0-inches) increased in numbers since 1954. This small increase in the larger diameter classes translates to significant increases in the volume of these larger trees.

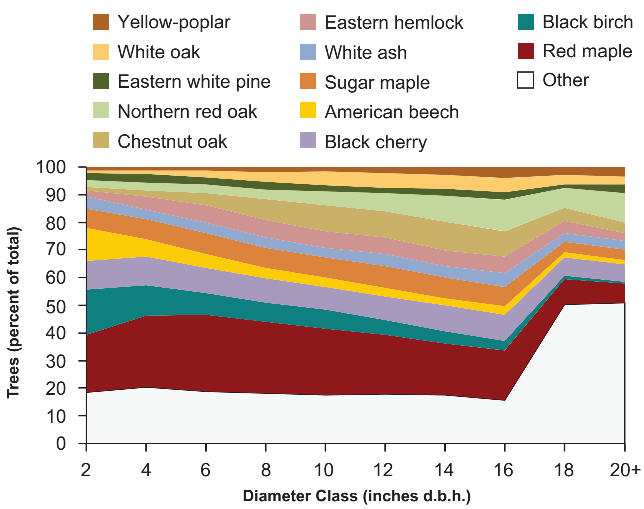


Figure 15.—Number of live trees on forest land for selected species or species groups by diameter class, Pennsylvania, 2009.

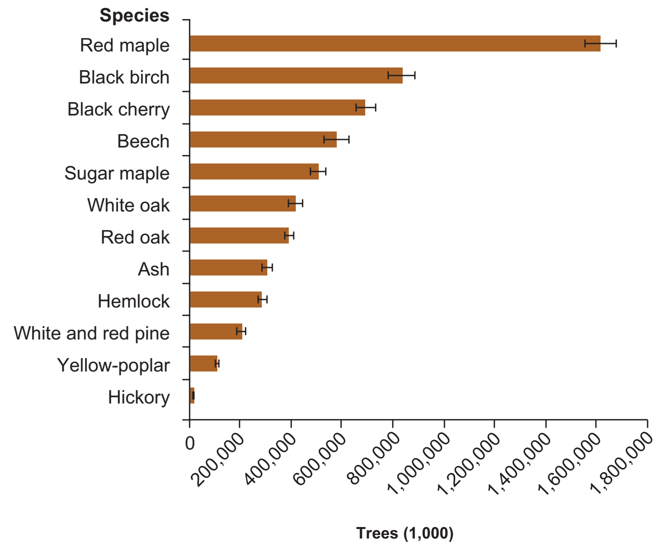


Figure 16.—Number of live trees on forest land for selected species or species groups, Pennsylvania, 2009. Sampling error bars are for 68-percent confidence level.

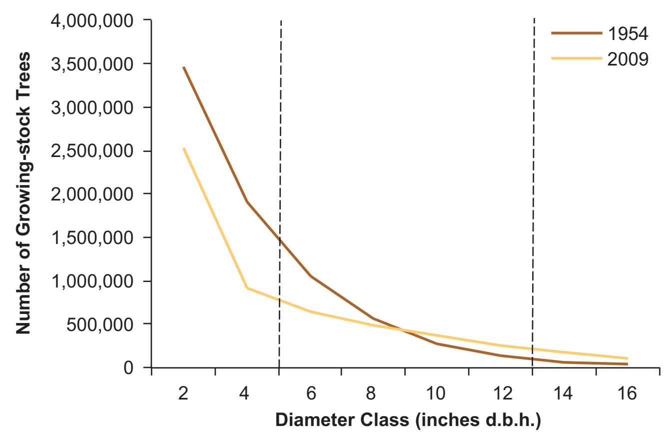


Figure 17.—Number of growing-stock trees on timberland by diameter class and stage of development, Pennsylvania, 1954 and 2009.

Volume

Background

Stand volume is determined by the measurement of all live trees having a d.b.h. greater than or equal to 5.0 inches. Growing-stock volume is the amount of sound wood in live, commercially valuable trees. It excludes all rotten or rough culled trees. This measure has traditionally been used to ascertain wood volume available for commercial use and are important considerations in economic planning and when evaluating forest sustainability.

What we found

The continued increase in the number of large-diameter trees has translated into an average volume of almost 6,500 board feet per acre (International ¼-inch rule). This quantity is equal to a per-acre volume of 2,138 cubic feet on forest land, 2,198 cubic feet on timberland, and an average of 61 dry tons per acre of biomass within the State's forests. Along with record-breaking increases in per-acre volumes, the quality of the inventory is reflected in the shifting of volume from the lower tree grades to higher trees grades for the hardwoods (Fig. 18). The volume of wood classified as tree grade 1 essentially quadrupled since 1989. Tree grades 1 and 2, the grades preferred for timber products such as lumber and veneer, now account for 55 percent of the board-foot inventory. The relative importance of the major commercial species or species groups by board-foot volume (International ¼-inch rule) illustrates the importance of red maple, black cherry, and the oaks (Fig. 19).

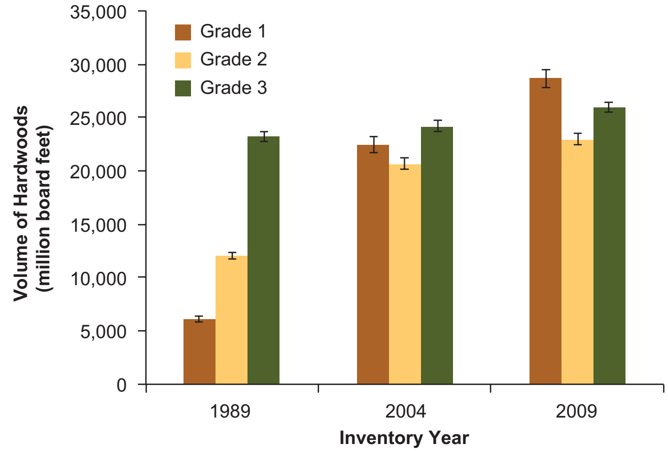


Figure 18.—Volume of hardwoods (International ¼-inch rule) by hardwood tree grades 1 to 3, Pennsylvania, 1989, 2004, and 2009. Sampling error bars are for 68-percent confidence level.

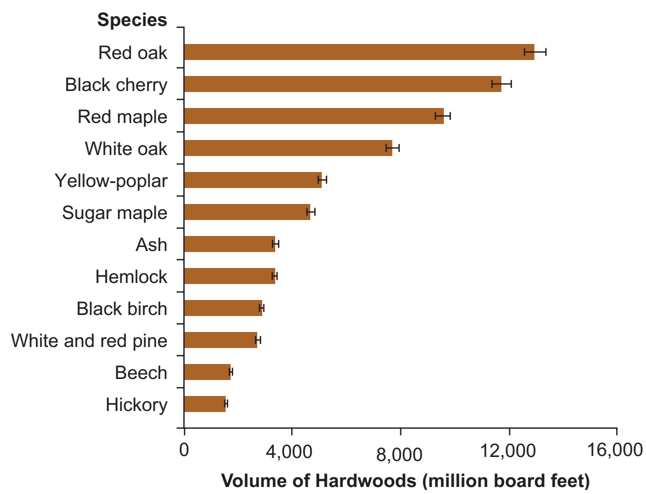


Figure 19.—Volume of hardwoods expressed in millions of board feet (International ¼-inch rule) on timberland for selected species or species group, Pennsylvania, 2009. Sampling error bars are for 68-percent confidence level.

Biomass

Background

Biomass (weight) is based upon the volume of trees and their specific gravities as determined by an individual species. Measurements of biomass provide estimates of the quantity and distribution of forest resources and the availability of these resources for different uses (e.g., carbon sequestration, biofuels, or wildlife habitat.)

What we found

The total aboveground biomass of live trees at least 1-inch (d.b.h.) is approximately one billion dry tons. Ninety-four percent of Pennsylvania's biomass is in hardwood species (Fig. 20). Ranking by species reveals the dominance of red maple, with 18 percent of the total biomass (Fig. 21). Biomass by species group reveals "other hardwoods" group accounts for a third of the total.

What this means

Number of trees, timberland volumes, and live biomass on forest land all point to the fact that Pennsylvania's forest are getting older. This is happening at the cost of younger-age stands which would normally provide both the seed and sprouts for the next generation.

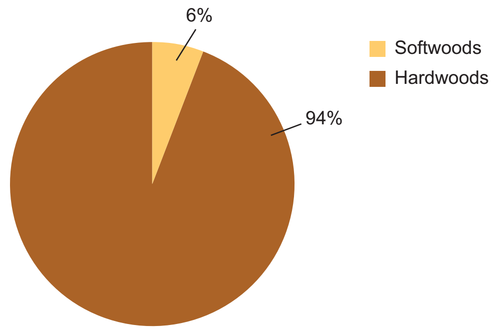


Figure 20.—Distribution of tree biomass (dry weight) on forest land by broad species group, Pennsylvania, 2009.

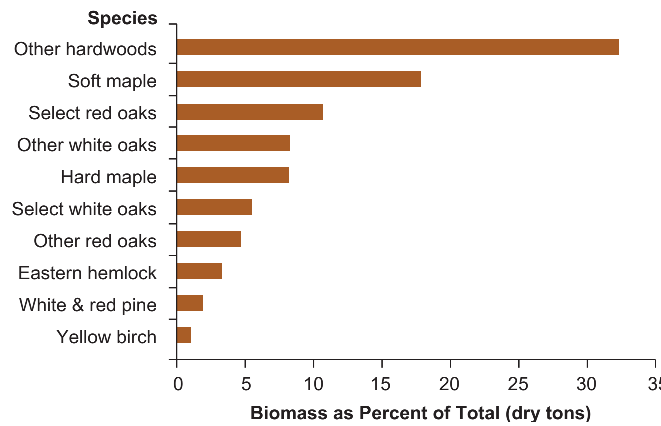


Figure 21.—Distribution of tree biomass (dry weight) on forest land by species or species group, Pennsylvania, 2009.

Forest Sustainability

Late succession forest, Alan Seager Natural Area, Centre County. Photo by Will McWilliams, U.S. Forest Service.

Growth, Removals, and Mortality

Background

Forests normally change very slowly, but during disturbance they can quickly and dramatically change structure and composition. The FIA change components (growth, removals, and mortality) are indicators of the overall productivity and sustainability of the existing forest land, whether expressed as a volumetric attribute such as cubic-foot volume or as biomass or carbon stock over time. A basic measure of forest sustainability is the comparison of the volume of wood removed versus the volume accumulated through net tree growth. If net growth exceeds the amount of wood removed, then theoretically, the timber supply is sustainable. However the consideration of other factors is necessary to truly evaluate forest sustainability, including species composition, tree quality, and the regenerative capacity of the forest.

The "gross" growth of trees on forest land is as close an estimate of net primary productivity (NPP) as FIA provides. Others have tried to model nontree attributes to develop NPP estimates for carbon studies (Pan et al. 2011). Net growth is the difference between gross growth and mortality, providing the best context for Pennsylvania's "working forest" since timberland excludes public unproductive and public reserved forest land. Comparisons of net growth and removals provide an indicator of sustainability, using the ratio of average annual net growth to removals (G:R). A G:R ratio of 1:1 is a useful benchmark for evaluating whether there is a drain on forest land. The "removals" portion of the ratio includes harvest removals, and removals due to administrative withdrawals, land conversion for development, or deforestation.

What we found

All of the basic trends in volume and biomass described in the 2004 report (McWilliams et al. 2007) have continued to increase over this 5-year reporting period (2005 to 2009) with few exceptions for the major species or species groups. The change components further demonstrate these positive trends for both live trees on forest land and growing-stock trees on timberland (Table 8). Total gross growth of live trees on forest land was about 1.2 billion cubic feet per year and net growth was 886 million cubic feet. The overall net G:R ratio was 2:1, indicating the forest is growing twice as much wood on live trees as is being harvested, including land which has shifted to other land uses. The information for growing-stock trees on timberland also reveals the overall G:R ratio was 2:1, however public and private ownerships were 2.7:1 and 1.8:1, respectively. These results for the average annual change components are the first to be produced for Pennsylvania under the annual inventory system and are based on the complete remeasurement of the full grid of plots. All of the major species and species groups had ratios greater than 1:1, with white-red pine, hemlock, red oak, hickory spp., soft maple (essentially red maple), yellow-poplar, and miscellaneous hard hardwoods having ratios above 2:1 (Fig. 22).

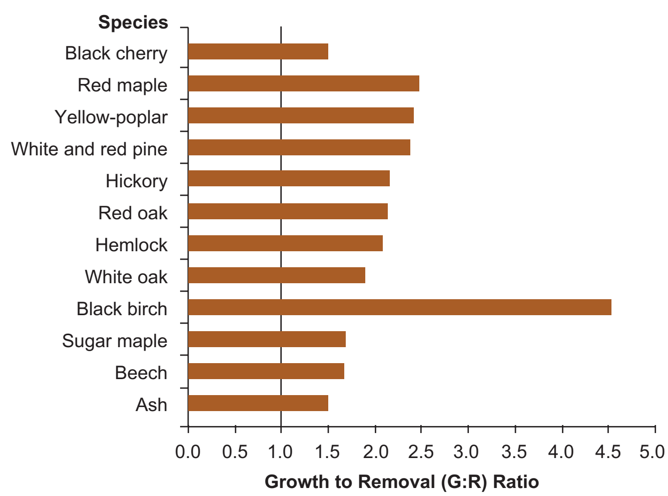


Figure 22.—Average annual net growth-to-removals ratio for selected species or species groups, Pennsylvania, 2004 to 2009.

Table 8.—Average annual growth, mortality, and removals of live trees on forest land, growing-stock trees on timberland, in million cubic feet, and net growth-to-removals ratio, Pennsylvania, 2009.

	Live Trees	Growing-stock Trees
	million cubic feet	
Public		
Gross growth	280.9	243.4
Mortality	101.3	66.7
Net growth	179.6	176.7
Removals	44.1	65.3
Net growth-to-removals ratio	4.1:1	2.7:1
Private		
Gross growth	905.6	757.1
Mortality	219.8	166.2
Net growth	686.6	590.9
Removals	380.8	326.1
Net growth-to-removals ratio	1.8:1	1.8:1
All owners		
Gross growth	1,187.4	1,000.3
Mortality	321.2	166.2
Net growth	866.2	767.7
Removals	424.9	391.5
Net growth-to-removals ratio	2:1	2:1

Average annual mortality rates can be used to elucidate the overall health of the forest and major species or species groups. Mortality rates are calculated as mortality volume for growing-stock trees on timberland divided by the total growing-stock inventory volume. The overall statewide rate was 0.75 percent while most major species and species groups were less than this (Fig. 23). American beech, black birch, black cherry, ash, and the pines had rates higher than average.

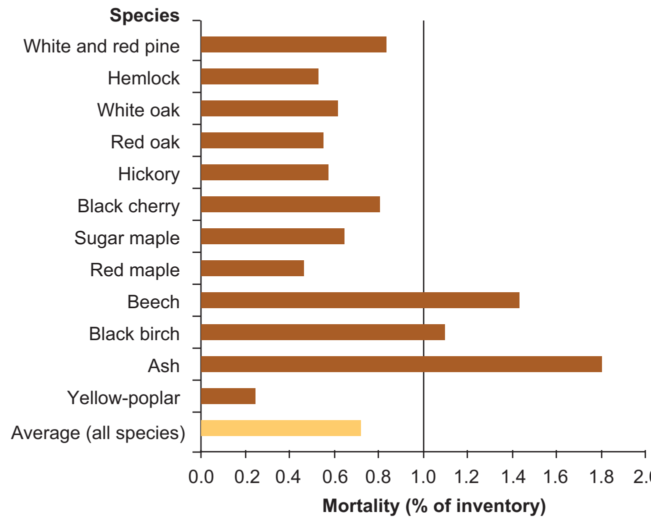


Figure 23.—Average annual mortality of growing-stock trees on timberland expressed as a percent of inventory volume for selected species or species groups, Pennsylvania, 2004 to 2009. Average mortality is 1 percent for northeastern states.

What this means

Based on the ratio of growth to removals, Pennsylvania's forests appear sustainable for the near-term. But considering the holistic suite of variables and characteristics of the forest (especially conditions for regeneration), future timber sustainability is a cause for concern.

The findings show continued positive trends in overall productivity of Pennsylvania's forests. The difficulty for managers and policy makers is to stimulate "active management" of private forest for a sustainable future during times of depressed timber economy and strong risk from biological stressors.

Carbon Stocks

Background

Worldwide, promoting sustainable forests has been recognized as a key strategy for mitigating potential impacts of a changing climate. Sustainably managed forests can store carbon for decades, while also providing co-benefits such as improved water quality, plant and animal habitat, wood products, and recreation opportunities. Durable wood products generated from harvested timber are an important and recognizable long-term carbon sink, with a smaller carbon footprint compared to other, more energy intensive building materials, such as concrete and steel.

Pennsylvania's forests sequester substantial amounts of carbon annually, with carbon flowing in and out of identified carbon pools for a number of reasons; all related to disturbance events such as insect and disease mortality, wildfires, storms, and harvesting. Overall, Pennsylvania's forests sequester carbon as trees add volume. These forests clearly provide a critical ecosystem service each year by absorbing and retaining about 5 percent of the State's greenhouse gas (GHG) emissions (PA DCNRBF 2011).

Collectively, forest ecosystems represent the largest living terrestrial carbon sink on earth. The accumulation of carbon in forests through sequestration helps to mitigate carbon dioxide emissions from sources such as forest fires and fossil fuel burning. The FIA program does not directly measure forest carbon stocks in Pennsylvania. Instead, estimates of forest carbon are obtained from field measurements (e.g., standing live and dead trees) and models (e.g., soil organic carbon and litter) based on stand age, forest type, and geographic area, among other tree- and site-level attributes. Estimation procedures are detailed in Smith et al. (2006), Woodall et al. (2011), and Domke et al. 2011. Note that estimates of tree biomass (e.g., live and standing dead trees and downed woody materials) are converted to carbon using a carbon concentration constant of 0.50.

What we found

Pennsylvania's forests currently contain more than 1.2 billion tons of carbon. Live trees and saplings represent the largest forest ecosystem carbon stock in the State with more than 612 million tons, followed by soil organic matter (SOM) with more than 461 million tons (Fig. 24).

Within the live-tree and sapling pool, merchantable boles contain the bulk of the carbon (~372 million tons), followed by coarse roots (~100 million tons), and tops and limbs (~91 million tons). The majority of Pennsylvania's forest carbon stock is found in 61- to 100-year-old forests (Fig. 25).

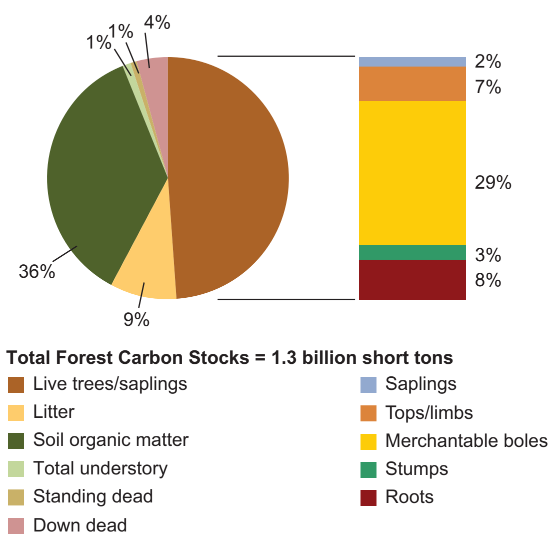


Figure 24.—Estimated total carbon stocks on forest land by forest ecosystem component, Pennsylvania, 2009.

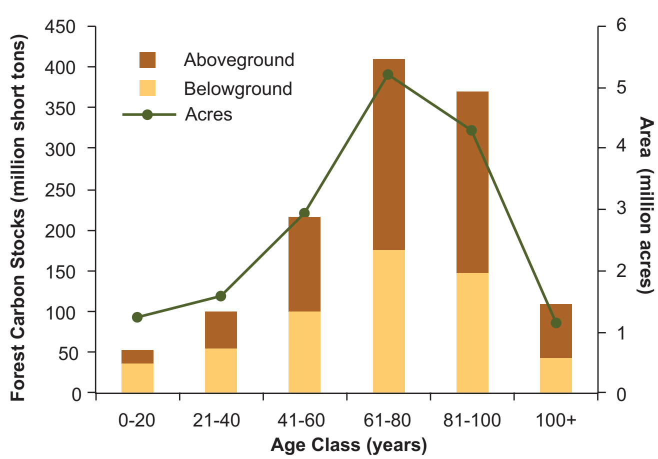


Figure 25.—Estimated above and belowground carbon stocks on forest land by stand age class, Pennsylvania, 2009.

Early in stand development, most of the forest ecosystem carbon is in the SOM and belowground tree components. As forest stands mature, the ratio of above- to belowground carbon shifts and by age 41-60 years, the aboveground component represents the majority of ecosystem carbon. This trend continues well into stand development as carbon accumulates in live and dead aboveground components.

A look at carbon by forest-type group on a per-unit-area basis found that six of the nine groups held between 70-88 tons of carbon per acre (Fig. 26). Despite the similarity in per-acre estimates, the distribution of forest carbon stocks by forest-type group is quite variable. In the mixed-oak group, for example, 55 percent (~39 tons) of the forest carbon is in live biomass, whereas in the aspen-birch group, only 27 percent is in live biomass.

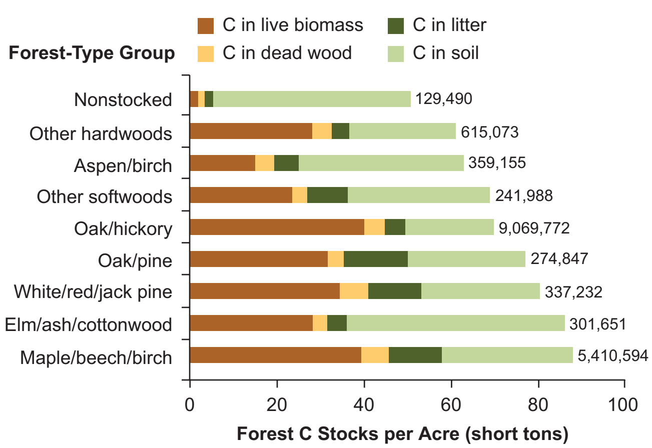


Figure 26.—Estimated carbon stocks on forest land by forest type group and carbon pool per acre, Pennsylvania, 2009. Note: Other softwoods forest type includes spruce, fir, loblolly and shortleaf pine, other exotic softwoods, Douglas-fir, and exotic softwoods; and Other hardwoods includes oak, gum, cypress, and exotic hardwoods forest types.

What this means

Carbon stocks in Pennsylvania's forests have increased substantially over the last several decades. The majority of forest carbon in the State is found in stands dominated by relatively long-lived species. This suggests that Pennsylvania's forest carbon will continue to increase as stands mature and accumulate carbon in above and belowground structures. Given the age class structure and species composition, there may be some opportunities to increase forest carbon stocks. That said, managing for carbon in combination with other land management objectives will require careful planning and creative silviculture.

Forest Health Indicators

Invasive ericaceous shrub, Clearfield County, Pennsylvania. Photo by Will McWilliams, U.S. Forest Service.

Insects and Disease

Background

Many insects and diseases put Pennsylvania forests at risk. The European gypsy moth (*Lymantria dispar*) has remained the most pervasive and harmful pest since it arrived in Pennsylvania in the 1930s (Hajek and Tobin 2009). The interactions among multiple factors, such as climate, insects, diseases, competition, and regeneration, can become "complexes," the most famous of which is oak decline. Other well-known exotic and invasive agents are Dutch elm disease, chestnut blight (*Cryphonectria parasitica*), beech bark disease, and hemlock woolly adelgid (*Adelges tsugae*). More recent invasions include the emerald ash borer (*Agrilus planipennis*), Asian longhorned beetle (*Anoplophora glabripennis*), and Sirex wood wasp (*Sirex noctilio*). This report will focus on the European gypsy moth and the emerald ash borer.

The diversity and abundance of insects and diseases in Pennsylvania is high, and can be quite devastating, particularly when acting in combination with other stressors on our forests. To exemplify the issue, the tree-mortality risk map for Pennsylvania (2006-2020) predicts the location of forests with the highest risk for tree mortality based upon the combination of damage-causing agents (Fig. 27). The map depicts the most pressing threats prioritized by a given tree species susceptibility to damage and its vulnerability to mortality. This map can be an important tool for determining the implications of different management schemes on the landscape (PA DCNRBF 2011).

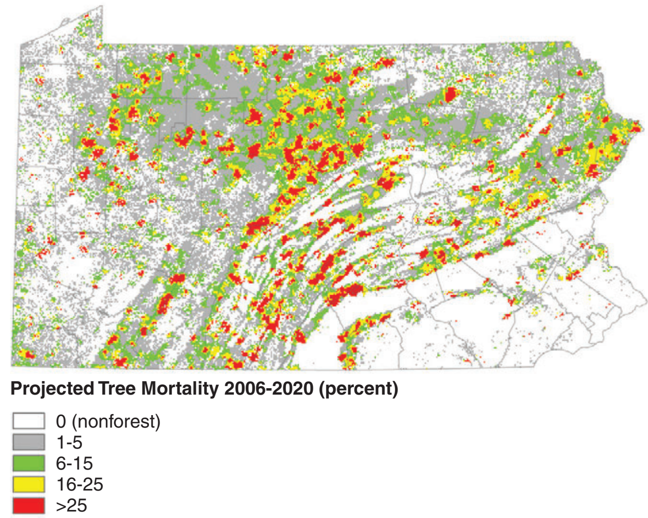


Figure 27.—Projected tree mortality, Pennsylvania, 2006-2020 (PA DCNRBF 2011).

European gypsy moth activity, Susquehenna County. Photo by Will McWilliams, U.S. Forest Service.

European gypsy moth

Background

The European gypsy moth makes a good case study of insect invasion as it lies somewhere between relatively senescent invasions (e.g., American chestnut blight and Dutch elm disease) and the very recent intrusion by the emerald ash borer. There are four issues to address concerning the European gypsy moth: 1) the insect is ubiquitous and persistent, 2) it is difficult to track location and spread, 3) infestations are back with an intense attack, and 4) the insect negatively affects oak forests.

What we found

The European gypsy moth can be found peppered throughout the mixed-oak forest, occurring on individual trees or in small patches. This is different than some earlier infestations when typically large swaths of contiguous forest were damaged for literally miles along oak-dominated ridges (Fig. 28). The numbers of standing dead oak trees are more than twice as high in defoliated stands than in uninfected areas, resulting in the volume of oak mortality to be four to five times higher.

What this means

European gypsy moth serves as an example of other pests, both native and exotic, which have become entrenched, working together and spreading quickly; producing an increased risk of future invasion directed by the global movement of people and goods. All insects and diseases can increase the risk of forest health epidemics and tree loss. As the State's forests continue to age, pest damage combined with other stressors (e.g., weather events and climate change) accent the importance of healthy oak regeneration as a major role in future forest development.

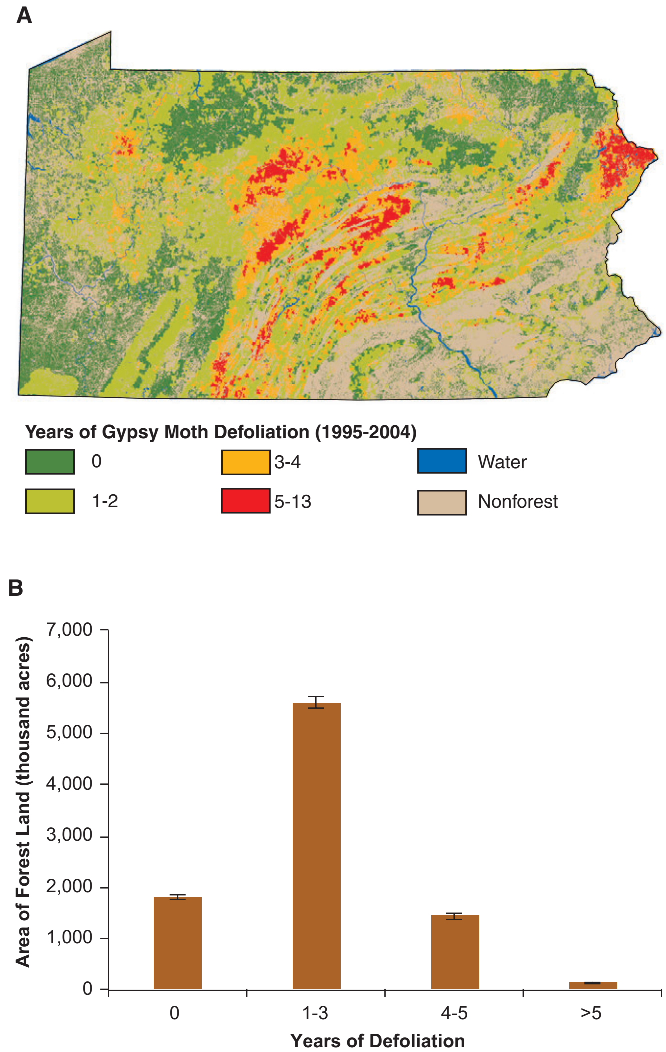


Figure 28.—A) Years of gypsy moth defoliation, Pennsylvania, 1975-2004, and B) acres of forest land in mixed-oak forest-type group by years of gypsy moth defoliation from 1975 to 2004, Pennsylvania..

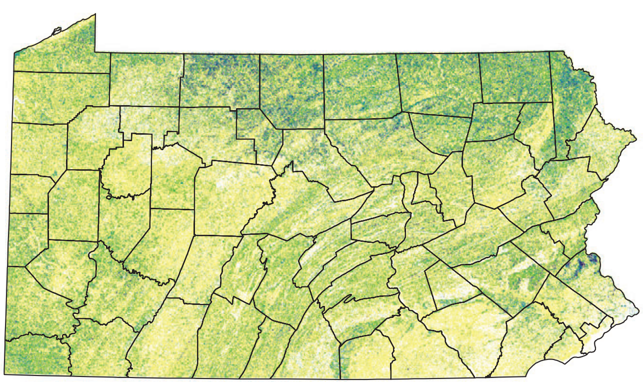
Emerald ash borer

Background

Emerald ash borer (*Agrilus planipennis*; EAB) offers the opportunity to understand the compelling story of a very recent invasion by a devastating insect. EAB is a wood-boring beetle native to Asia. In North America, EAB is a known pest to all native ash species (Poland and McCullough 2006). Trees and branches as small as 1 inch in diameter have been attacked, and while stressed trees may be initially preferred, healthy trees are also susceptible (Cappaert et al. 2005). In areas with a high density of EAB, tree mortality generally occurs 1 to 2 years after infestation for small trees, and 3 to 4 years after infestation for larger trees (Poland and McCullough 2006). Spread of EAB has been facilitated by human transportation of infested material, particularly firewood. EAB was discovered in western Pennsylvania in 2007, but is believed to have been present in the State for approximately 7 or 8 years prior to detection.

What we found

The number of counties with EAB continues to increase and as of 2011, the entire State is under Federal quarantine. Pennsylvania's forest land contains an estimated 305 million ash trees (greater than 1 inch d.b.h.) which account for 1.7 billion cubic feet of wood. Ash is found throughout the State, but is concentrated in the northern portions of Pennsylvania (Fig. 29). Ash is present on 5.3 million acres, or 32 percent of forest land, but it is rarely the most abundant species in a stand. Instead, ash generally makes up less than 25 percent of total live-tree basal area.



Ash Basal Area (ft^2/acre)

18-60
9-17
3-8
Less than 3

Processing note: This map was produced by linking plot data to MODIS satellite pixels (250 m) using gradient nearest neighbor techniques.

Figure 29.—Ash density on forest land, Pennsylvania, 2009.

What this means

Since EAB has caused an extensive decline in ash trees throughout the north-central United States it represents a significant threat to the forested and urban ash resources of Pennsylvania. In addition to economic losses, ash mortality in forested ecosystems will affect species composition and alter community dynamics. Continued monitoring of ash will help to identify the long-term impacts of EAB in forested settings. Efforts to slow the spread of EAB will be enhanced by discontinuing the transportation of firewood.

Oriental bittersweet and knotweed, Delaware County. Photo by Will McWilliams, U.S. Forest Service.

Vegetation Diversity and Invasive Plants

Pennsylvania contains a diverse assemblage of plants and animals including 3,000 species of plants, 400 species of birds, 200 species of fish, 75 species of reptiles and amphibians, and 70 species of mammals. All told there are more than 25,000 species documented to be within the state, more than half of which are either a species of fungi or invertebrate (e.g., insects, crustaceans, and worms); all dependent upon the forests for their habitats. The diversity of plant life is an essential foundation for the productivity of terrestrial forest ecosystems. Because plants are able to convert the sun's energy through photosynthesis, most animals (including humans) are directly or indirectly dependent on plants. Some fauna are species-specific and require the presence of a certain species or group of species to survive (e.g., various butterflies or moths). Plants can also help filter pollutants, stabilize soil, and increase nitrogen availability. The survey of the composition of plant communities can provide information about disturbance, soil moisture, and nutrient availability.

In Pennsylvania, understory vegetation data have been collected on approximately 6 percent of all field plots since 2007, resulting in a complete vegetation survey on a total of 115 plots. FIA uses the USDA Natural Resources Conservation Service's PLANTS database (NRCS 2012) as the basis for scientific terminology and determination of whether a plant is invasive.

What we found

Pennsylvania's forests support many plant species. Five-hundred and nineteen identifiable species were found on the 115 plots measured from 2007 through 2009. Of the species recorded, the largest percentage (39 percent) was classified as forbs or herbs (Fig. 30). Trees also comprised a significant proportion (15 percent) of the total species on these plots. Of the species recorded, 63 percent were native to the United States, while 16 percent were introduced (Fig. 31). On these plots, the number of species and genera tallied ranged from 13 to 125 per plot with an average of 51. The 18 most frequently encountered species are dominated by woody species and include one invasive plant, multiflora rose (*Rosa multiflora*).

From 2007 through 2009, invasive plant data were collected on 337 forested plots (approximately 20 percent of the Phase 2 field plots). The most frequently observed invasive plant species was multiflora rose (primarily from planting during the 1950s for habitat, cover, and food for wildlife), which was present on 154 plots (Figure 32). Garlic mustard (*Alliaria petiolata*) was detected on 76 of the plots while Japanese barberry (*Berberis thunbergii*) (spread mostly from planting in urban settings as an ornamental) occurred on 75 plots (Fig. 33).

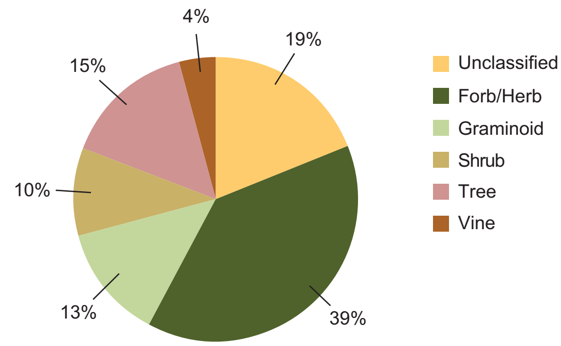


Figure 30.—Percentage of species by growth habit category, Pennsylvania, 2007-2009.

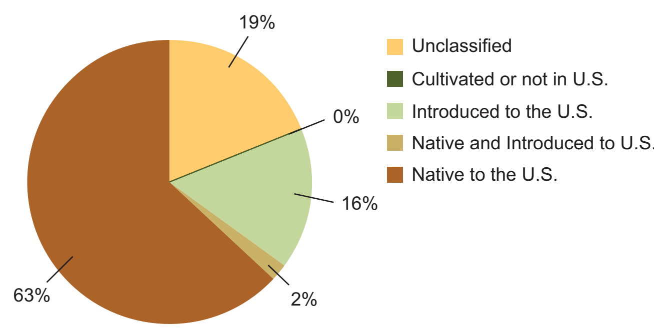
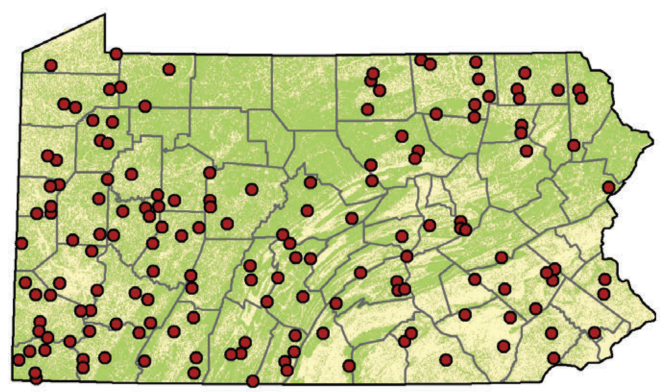


Figure 31.—Percentage of species by domestic or foreign origin, Pennsylvania, 2007-2009.



Plot data: USDA Forest Service Forest Inventory and Analysis Program 2007-2009 Phase 2 Invasive data. State and County layers: ESRI Data and Maps 2005. Forest layer: USGS National Land Cover Dataset, 2006. Depicted plot locations are approximate. Cartographer: C. Kurtz.

Figure 32.—Distribution of multiflora rose, Pennsylvania, 2007 to 2009. Plot locations are approximate.

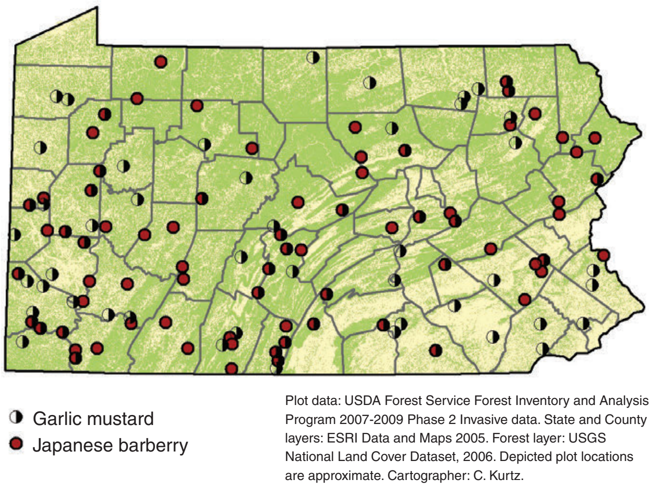


Figure 33.—Distribution of garlic mustard and Japanese barberry, Pennsylvania, 2007 to 2009. Plot locations are approximate.

What this means

The presence of invasive plant species in the forest community is a reason for concern among landowners and managers. Invasive species have the potential to rapidly expand across sites, and in the process, take resources from native plants while degrading habitats. Their competitive advantage over native plants includes early emergence and leaf out, and in many cases, a lack of natural controlling agents (e.g., insects and disease) that would normally keep populations in check.

The FIA survey in Pennsylvania identified 519 plant species. Both native and nonnative species were found. The presence of nonnative and invasive plants within the forest community is problematic as they have the potential to displace the native plants upon which fauna depend. The invasive plants are a particular concern since they have characteristics, such as high seed production and rapid growth, which allow them to quickly spread through the forest understory.

Data on the vegetation communities provides key information on site quality and species distribution. Future survey data on the presence and abundance of nonnative and invasive plant species will provide knowledge of spread and facilitate management decisions. Such data will provide information on how plant community's change under the influence of an evolving plant community comprised of shifting species composition, both native and nonnative.

Tree-of-heaven under northern red oak, Delaware County. Photo by Will McWilliams, U.S. Forest Service.

Tree-of-heaven

Background

Tree-of-heaven (*Ailanthus alitissima*) provides an example of an exotic-invasive tree which has become naturalized in some areas. Unfortunately, little is known about the ecology, silvics, or longevity of this new component of forest structure. Tree-of-heaven and other tree species are the only life forms measured consistently over time by FIA; shrubs, vines, and other life forms are still in their first cycle of baseline measurement.

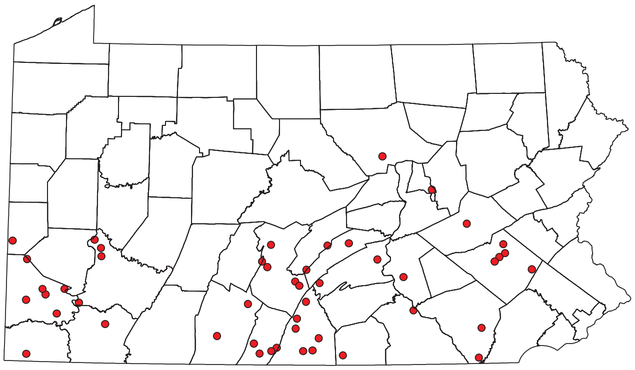
What we found

The invasion of the tree-of-heaven started around population centers (south of Interstate 76 and the eastern and western edges of the State). While existing patches have expanded, the tree has now spread to smaller patches in more rural areas (Fig. 34).

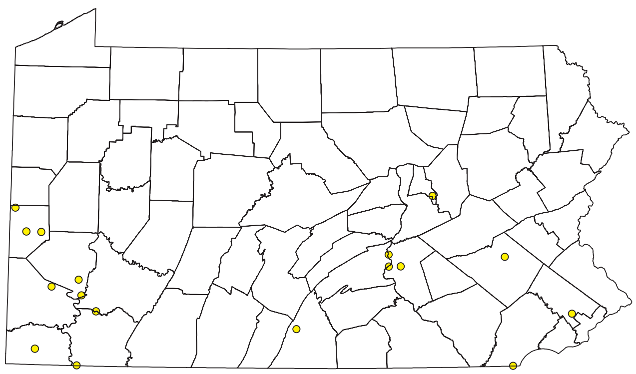
What this means

The results for tree-of-heaven support the need for new science in all aspects of forest ecology. Invasive plant species alter nutrient cycling, hydrology, fire

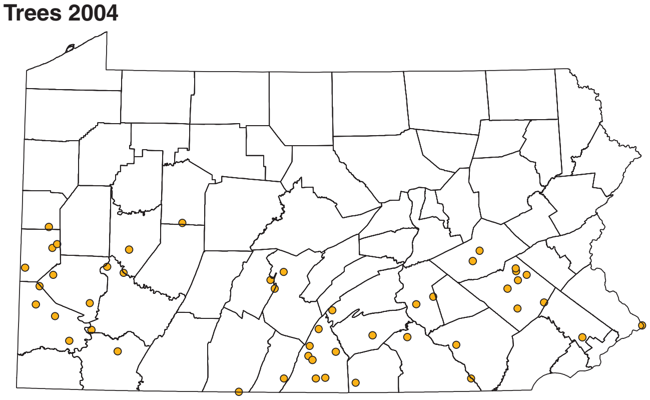
Seedlings and saplings 2009



Trees 1989



Trees 2004



Trees 2009

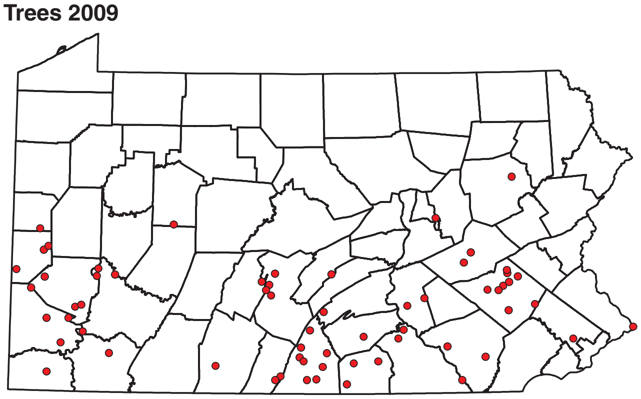


Figure 34.—Distribution tree-of-heaven (5 inches or larger d.b.h.), 1989, 2004, and 2009; and seedlings and sampling only, 2009. Plot locations are approximate.

regimes, light penetration, native species regeneration, and habitat structure. Clearly, their expansion threatens healthy forest ecosystems (PA DCNRBF 2011). The complexity of prospective future forests comprised of mixtures of native and exotic life forms provides a challenge to today's scientific community.

Tree Crown Conditions

Background

Tree-level crown measurements include vigor class, crown ratio, light exposure, crown position, crown density, crown dieback, and foliage transparency. Crown dieback, crown density, and foliage transparency were used to determine the condition of tree crowns. Crown dieback is defined as recent mortality of branches with fine twigs and reflects the severity of recent stresses on a tree. Crown density is defined as the amount 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. 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 from 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 three species with the highest proportion of live basal area with poor crowns are red maple, northern red oak, and sugar maple at 23, 17, and 13 percent, respectively (Table 9). Conversely, the occurrence of poor crowns in white oak, sweet birch, and yellow-poplar was very low. The highest proportion of northern red oak basal area containing poor crowns was found in the central portion of Pennsylvania, while the highest portion of maples with poor crowns was in the northeastern portion of the State (Fig. 35).

Table 9.—Percent of live basal area with poor crowns by species, Pennsylvania, 2009.

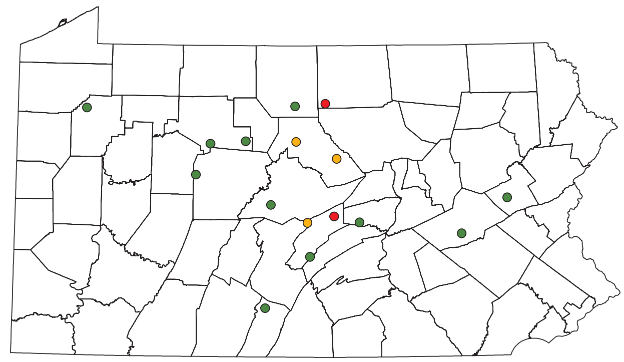
Species	Percent of Basal Area with Poor Crowns
Red maple	23
Northern red oak	17
Sugar maple	13
Black cherry	11
Chestnut oak	10
White ash	10
Eastern hemlock	9
White oak	4
Sweet birch	3
Yellow-poplar	trace

What this means

Red maple is the most numerous tree species in Pennsylvania and contains the greatest volume of wood. It is a very important species due to its value as a timber and pulpwood producer, and is very popular for its attractive fall foliage. There is a concern since 23 percent of the basal area for red maple is contained in trees with poor crowns.

Northern red oak is the ninth most numerous tree species in the State and contains the third highest volume of wood. It is an important species due to its value for timber products while also being preferred by many wildlife species. The levels of northern red oak mortality have decreased slightly since the 1989 periodic inventory. The incidence of poor crowns in northern red oak appears to coincide with areas where the European gypsy moth has been very active.

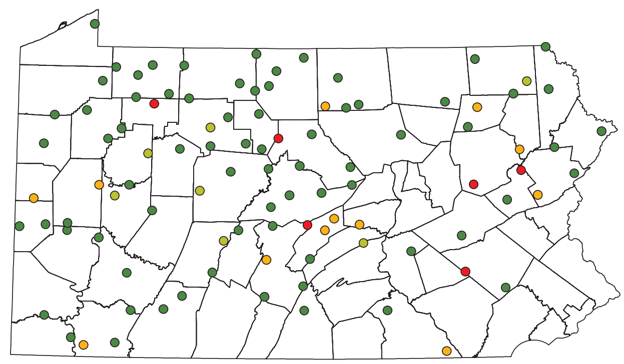
Northern red oak



Percent of Live Basal Area with Poor Crowns

- 0
- 1-5
- 6-20
- >20

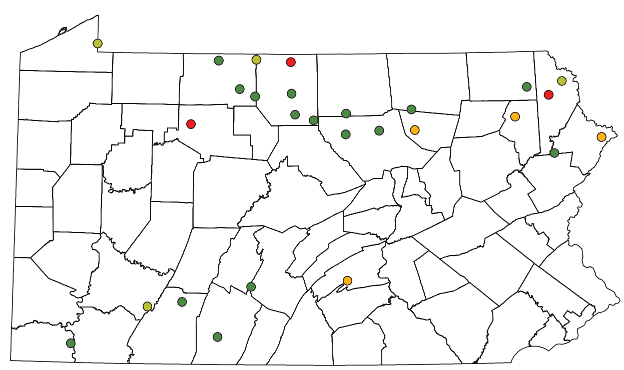
Red maple



Percent of Live Basal Area with Poor Crowns

- <3
- 3-10
- 11-25
- >25

Sugar maple



Percent of Live Basal Area with Poor Crowns

- 0
- 1-5
- 6-15
- >15

Figure 35.—Crown conditions for red maple, northern red oak, and sugar maple, Pennsylvania, 2007.

Oak seedlings under shelterwood, Bradford County. Photo by Will McWilliams, U.S. Forest Service.

Lack of Forest Regeneration

Background

Pennsylvania's forests are a keystone example of deciduous ecosystems of the mid-Atlantic region. There has been a long and well-known history of controversy over management of the deer herd (Frye 2007). Evaluating advance tree seedling and sapling regeneration (ATSSR) is one approach for assessing the effectiveness of large-scale management and wildlife policy decisions on forest properties, and is based upon the SILVAH Oak and Allegheny Hardwoods computer program (Brose et al. 2008). The importance of regeneration is exemplified by deer habitat assessments conducted by the Pennsylvania Game Commission and used for planning deer harvest levels (Pennsylvania Game Commission 2012). ATSSR is considered the primary component of "healthy" deer habitat in these assessments and are are related to the amount of competing vegetation, ungulate pressure, and the light levels reaching the forest understory. The status of these variables form the basis for conducting informed forest vegetation management decisions aimed at maintaining native flora (Jackson and Finley 2005).

Pennsylvania's forest understory contains a layer of vegetation below the dominant forest canopy consisting of shrubs, grasses, sedges, wildflowers, other herbs, low-canopy trees, saplings, seedlings, fungi, mosses, and lichens (Latham et al. 2005, PA DCNR 2012). The presence of advance regeneration made up of tree seedlings and saplings that are in a position to replace high canopy trees frequently determines the capacity of the forest to re-establish following disturbance (Brose et al. 2018, Marquis 1994).

The issue becomes complex because in the understory, native, and exotic plants occur in all life forms (e.g., herbs, grasses, vines, shrubs, and trees). In addition, all three can be further classified as invasive or noninvasive. As such, this system can be conceptualized as a three-by-two identity matrix: native non-invasive (e.g., azalea, *Rhododendron* spp.); native invasive (hay-scented fern, *Dennstaedtia punctilobula;* mountain laurel, *Kalmia latifolia;* grape vine, *Vitis vinifera*); exotic non-invasive (dandelion, *Taraxacum officinale*); and exotic invasive (garlic mustard, *Alliaria officialis*; Japanese stiltgrass, *Micriostegium vimineum;* oriental bittersweet, *Celastrus orbiculatus;* and tree-of-heaven, *Ailanthus altissima*). For an excellent synthesis of invasive plants in Pennsylvania, see PA DCNRBF (2000).

The State's wildlife depend heavily on forest habitat for their existence, i.e., food, shelter, and space. Forest interior species (wood thrush, *Hylocichla mustelina;* prothonotary warbler, *Protonotaria citrea*; great-horned owl, *Bubo virginianus*), along with edge specialists (turkey, *Melagris gallopavo*), and generalists (white-tailed deer, *Odecoleus virginianus*) require forest habitat. The more and larger the habitat is, the better for existing wildlife populations.

The history of mast production is important in Pennsylvania as evidenced by the native range of the American chestnut prior to devastation by the chestnut blight in the 1930s and oak mast production (Fig. 36). Oaks along with other species eventually replaced chestnut-dominated forest. Oak is the major food for 120 species, many of which rely very heavily on oak mast, such as small mammals. It is clear that losing oak forests would be devastating to mast-dependent wildlife (McShea and Healy 2002).

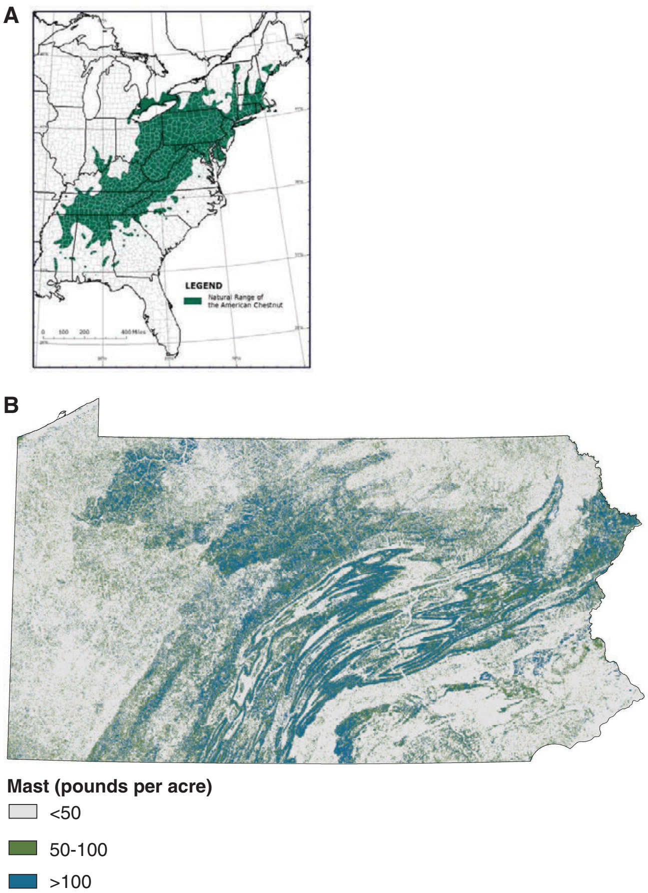


Figure 36.—A) American chestnut natural range (American Chestnut Foundation), and B) oak mast, Pennsylvania, 2009.

ATSSR methodology

The Pennsylvania Regeneration Study (PRS) began in 2000 and is funded by the Pennsylvania DCNR, Bureau of Forestry, in partnership with the U.S. Forest Service Northern Research Station (McWilliams et al. 1995). It is the only study in the country that includes measurements of tree seedlings by height class, ungulate pressure, competing vegetation, and exotic/invasive plants at the landscape level (McWilliams et al. 2001).

PRS measurements are conducted on FIA sample plots during the leaf-on season. PRS measurements include a detailed tally of all tree seedlings down to a height of 2 inches tall and a survey of percent cover for all nontree life forms (McWilliams et al. 2004). Results are analyzed using silvicultural guidelines for Pennsylvania (Brose et al. 2008, Marquis 1994). Sample plots are evaluated to gauge the capacity of ATSSR to renew the stand using thresholds and a weighting scheme for the numbers of seedlings and saplings as adapted from Brose et al. (2008). Measurements of associated understory vegetation provide information on understory character and health. For details on the methods used for this study, see Statistics, Methods, and Quality Assurance on the DVD included with this publication.

What we found

Regeneration of commercial species

When all commercial species are examined (commercially desirable and all commercial), results show no improvement in regeneration between 2004 and 2009. Forty-six percent of the sample plots have adequate advance regeneration in 2009 with no significant change since 2004. The confidence interval was approximately ±4 percent at the State level for a 95 percent confidence level, or ±2 percent for a 68-percent level (Fig. 37). When only the most desirable commercial timber species (commercially desirable group) are considered, only about 34 percent of the plots had adequate advance regeneration in 2004 and 2009. Results for the most desirable commercial timber species show the percentage of sample plots with adequate advance regeneration ranged from a low of 26 percent in the north-central region to 43 percent in the south-central region (Fig. 38). Conditions for the all-commercial group show slight improvement in the southwestern and south-central regions. But, the regenerative capacity is less in the northeastern and southeastern regions.

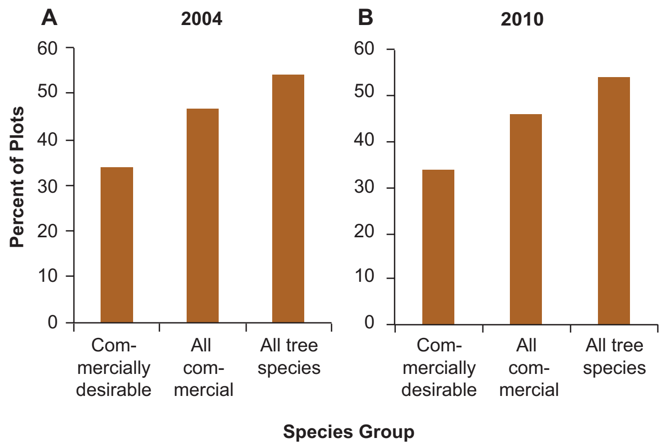


Figure 37.—A) Percent of plots adequately stocked with advance tree seedling and sapling regeneration (ATSSR) for commercial species and plots 40 to 75 percent stocked, by species group, Pennsylvania, 2001 to 2004. B) Percent of plots adequately stocked with advance tree seedling and sapling regeneration (ATSSR) for commercial species and plots 40 to 75 percent stocked, by species group, Pennsylvania, 2006 to 2010.

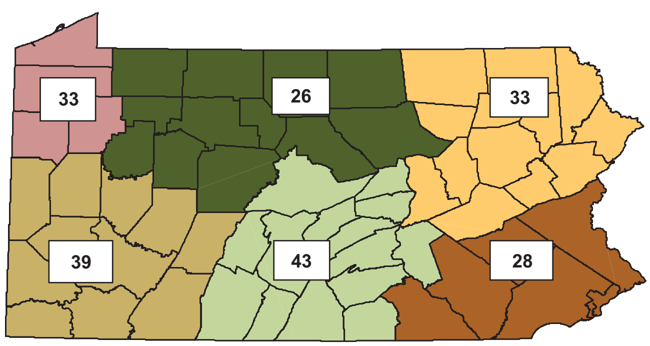


Figure 38.—Percent of plots adequately stocked with advance tree seedling and sapling regeneration (ATSSR) for commercial species and plots 40 to 75 percent stocked, by eco-political region, Pennsylvania, 2006 to 2010.

Canopy replacement

Species capable of producing a high-canopy forest provide a broad measure of the forest's ability to reproduce the native tree canopy. Forty-eight percent of the sample plots contained adequate advance regeneration of these species in 2004 and 2010 (Fig. 39). This means that only about half of the State's forests would regenerate to high-canopy status following significant overstory disturbance, a condition that has not changed in roughly a decade. For high-canopy species, the percentage of sample plots with adequate advance regeneration ranged from 35 percent in the southeastern region to 50 percent in the northeastern region (Fig. 40). Notable are the suggestions of improvement in the north-central region. Conditions appear to have worsened in the southwestern and south central regions.

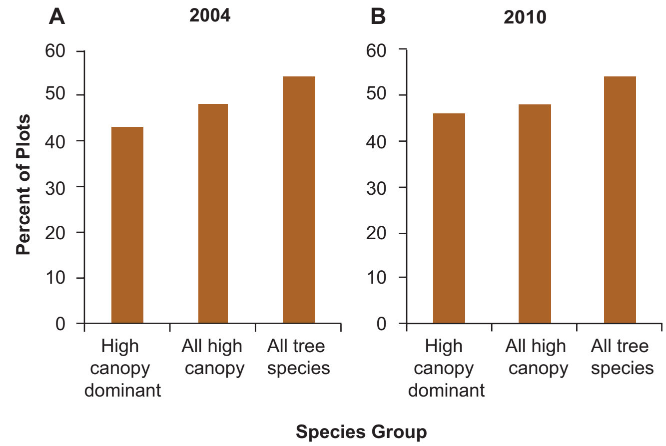


Figure 39.—A) Percent of plots adequately stocked with advance tree seedling and sapling regeneration (ATSSR) for canopy replacement species and plots 40 to 75 percent stocked, by species group, Pennsylvania, 2001 to 2004. B) Percent of plots adequately stocked with advance tree seedling and sapling regeneration (ATSSR) for canopy replacement species and plots 40 to 75 percent stocked with trees, by species group, Pennsylvania, 2006 to 2010.

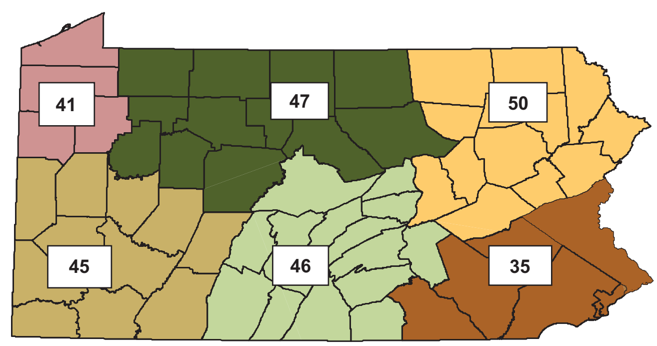


Figure 40.—Percent of plots adequately stocked with advance tree seedling and sapling regeneration (ATSSR) for canopy replacement species and plots 40 to 75 percent stocked with trees, by eco-political region, Pennsylvania, 2006 to 2010.

Deer fence with Japanese stiltgrass, Valley Forge National Historic Park, Delaware County. Photo by Will McWilliams, U.S. Forest Service.

Herbicide treatment of fern and beech brush, Clearfield County. Photo by Will McWilliams, U.S. Forest Service.

What this means

Regeneration

Regeneration difficulties are related to white-tailed deer browsing, competing native and exotic invasive plants, and significant pests and pathogens attacking the major species or species groups such as hemlock, sugar maple, ash, and American beech. There is a concern for both early- and late-successional habitats, but the primary importance is the development of new stands to replace older forests. Overall, the potential changes to tree species diversity, structural components of the forest, and the distribution of succession stages across the landscape, suggest that Pennsylvania's forests are moving toward an unsustainable condition. Many factors including harvest practices, insects and disease outbreaks, and the uncertainty of future weather events, are causing tree mortality, threatening regeneration, and reducing diversity, all of which reduce the health and resiliency of the forest.

Oaks

There are major challenges with oak regeneration across Pennsylvania's forested landscape. Oak regeneration has emerged as a major issue, even though there are excellent guides for regenerating oak in Pennsylvania (Brose et al. 2008, Marquis 1994). The heart of the issue is this: the conditions for regenerating oaks and many other species are not favorable, forcing very high costs for management activities such as herbicide applications and fencing. At the landscape level, management history has included uninformed cutting practices that decimate oak and other native seed sources. Combine this with the impact of past pest outbreaks and opportunities for management become even more challenging, particularly for Pennsylvania's diverse mix of private owners.

The connections between humans, wildlife, forest health, and forest regeneration are the basis for sound forest management and policy formulation. The lack of advanced regeneration on almost half of the State's forest land makes future work costly. Cumulative effects of these and other forces make for complicated policy and management decisions. Plans for maintaining the oak component are needed to slow the prospective loss of oak trees over the next 100 years (McShea and Healy 2002). Few statistical summaries of oak regeneration are available at this broad scale, but Rose (2009) cited the loss of oak regeneration as a major issue in a recent report for Virginia, as did Widmann et al. (2012) for West Virginia.

Recommendations

Background

The picture for the future will be unsustainable without a considerable amount of work to improve forest regeneration particularly native oak forests. There is a wealth of information for managing mid-Atlantic forest systems. For the basic philosophy and approach for tending the region's forests, Nyland (2007) covers important topics needed to operate within the forest. In Pennsylvania, work emphasizing the control of competing vegetation, deer, and light levels can create a healthy environment for producing abundant regeneration in the native forest of the State (Jackson and Finley 2005). The greatest difficulties are the costs and associated risks of implementing the management guidelines.

What is clear from the results is that a "better" distribution of forest land by age classes is needed, along with a mosaic of dominant and codominant canopy trees to insure Pennsylvania's forest systems will be resilient against existing and future stressors. For example, a more balanced age structure within mixed-oak forests would improve its resiliency against gypsy moth.

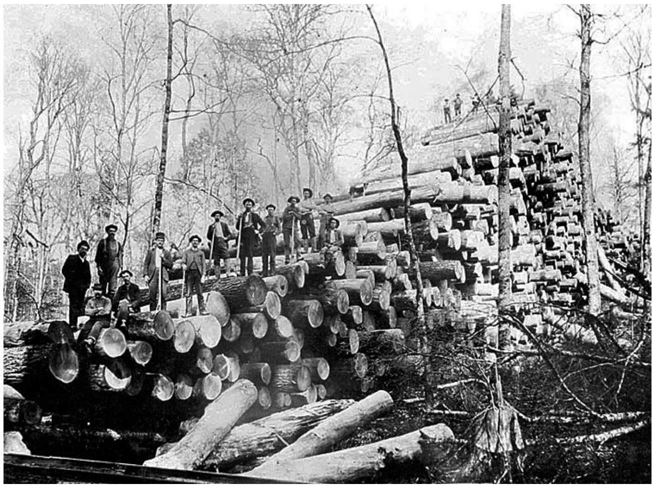
The following recommendations are general in nature but can help guide more specific processes, policies, management guidelines, and planning to foster the health of native Pennsylvania forests into the future. The following synthesis is adapted for Pennsylvania's unique mixed oak and northern hardwood forests:

Native rosy azalea, Wayne County.

- *Late Sapling Forest* (stands averaging 1 to 4.9 inches diameter): Stand tending, weeding, and cleaning
- *Established Forest* (stand averaging 5 to 10.9 inches diameter): Manage composition and stocking
- *Mid-stage Forest* (stands averaging 11 to 16.9 inches diameter): Intermediate stand management (Improvement cutting, thinning)
- *Mature Forest* (stand averaging 17 inches and larger in diameter): Begin regeneration process (shelterwood cutting, herbicide, and fence)
- *Regeneration Stage* (seedling dominated stands, ATSSR): continue regeneration management by controlling competing vegetation, deer, and available light

Timber Products

Timber stack near Picture Rocks, Pennsylvania. Photo by Jared Bronayur, via Wiki Commons.



Turn-of-the-century loggers at railhead, Tioga County. Photo by Lycoming Co. Historical Society, used with permission.

Background

Pennsylvania produces more hardwood lumber than any other state while contributing significantly to local and state economies. Some of the finest hardwoods in the world are grown within the State including cherry, oak, maple, and ash. Finished products include high-end furniture and cabinets, hardwood flooring, handles and baseball bats, pallets, and railroad ties. In 2007, harvest levels were estimated at 1.6 billion board feet with annual sales of $16 billion and a total economic impact of $27 billion (PA DCNRBF 2011). It is well documented that Pennsylvania has a great treasure in its forests, at least in terms of timber value prior to the recent economic downturn. As such, the timber products output situation is critical to forest and human health (Murphy 2006).

Wood-for-energy has emerged as a priority issue in Pennsylvania. The term "sustainability" can be ambiguous when addressing wood-for-energy because of dual definitions (PA DCNR 2011). Energy entrepreneurs refer to the need for a sustainable source of cellulosic material to fuel bioenergy production operations. The forestry community desires the capacity to regenerate a healthy future forest of native species that fills all the functions currently supplied, and to ensure existing and new benefits from the forest are preserved (see PA DCNRBF 2008).

What we found

In 2007, the forest products industry began a downturn as housing prices fell. Exasperated by the financial markets crash of 2008, these events were especially hard felt in Pennsylvania (Smith and Guldin 2012). Changes in market conditions along with a lack of new survey information on timber products for roundwood products (pulp, paper, lumber, and other), the number of mills, and residue use left a void when information was needed. A summary of findings based upon reports, articles, and experts is presented (Table 10). Sawmills responded to the downturn by substantially reducing lumber production levels and working off existing inventories. Most mills operated with limited hours during 2009 while reducing their workforces; other mills closed permanently. Some estimates place Pennsylvania's 2009 hardwood lumber production at about half of its normal volume, or the lowest level since the Great Depression. By early 2010, the price for most hardwood lumber products improved as supply and demand fell into balance. With a slow recovery, the demand for hardwood lumber remained well below pre-recession levels. The initial recovery was stronger in some export markets than in domestic economy (Pennsylvania Hardwood Development Council 2010). While still impacted by the economic downturn, Pennsylvania's paper producers fared better than their sawmill counterparts. Recovery for higher-end lumber species such as black cherry has lagged behind the more economical species and lower-grade woods used for the production of pallets, ties, and industrial products. There is also anecdotal evidence that certified wood products have moved from being a niche product to a relevant part of the overall wood demand.

The recent economic recession affected the forest products industry similarly to other manufacturing sectors. Total employment in the forest product industry of Pennsylvania is down (Pennsylvania Hardwood Development Council 2008). The sustainable production of high quality forest products is critical to both Pennsylvania's economy and the landscape of the working forest.

Table 10.—Impact on the forest products industry, Pennsylvania, 2002-2009.

Type of Impact	Degree of Impact	Citation
Hardwood lumber production[a]	Reduced production: 1250 mmbf (2002) 1150 MM bf (2006) 680 mmbf (2009)	Smith and Guldin 2012
Sawmills	Limited hours Reduced workforce Mill closures	Pennsylvania Hardwood Development Council 2010
Forest industry employment	Decreased employment: 85,000 (2002) 81,000 (2006) 62,000 (2009).	Smith and Guldin 2012
Finished hardwood product prices	Price decreases from 30 to 50 percent	Smith and Guldin 2012
Bioenergy	Complicated and competitive supply constraints Not sustainable for large regional-level plants	Pennsylvania Hardwood Development Council 2008

[a]mmbf = million board feet

What this means

Pennsylvania's forests supply raw materials to the global industry, producing a wide range of products from paper to hardwood flooring to high-end furniture and cabinetry—with black cherry, oak, and sugar (hard) maple currently being most desired. The forest products industry is an important component of many rural economies and timber provides an important economic value to forest land that is increasingly competing with the value of other land uses like housing and commercial development.

The value of hardwood timber in Pennsylvania was perhaps the highest in the Nation prior to the depression of timber prices, employment, production, and multiplier effects on the economy.

The timber economy included secondary manufacturing (such as furniture), quality sawtimber, wood-fiber use, exports, and in general, a vibrant market for wood. With production, employment, and prices depressed, there is little positive to report. The lack of demand means a lack of harvests, resulting in a reduced economic stimulus to the state economy, and therefore, reduced funding for the management of Pennsylvania's forests.

The future of the Pennsylvania's wood and lumber production industry will depend on demand for hardwood products both domestically and globally. Demand will be influenced by the health of the U.S. and international economies, housing markets, consumer preferences, and the success of competitors who produce nonwood substitutes. Pennsylvania producers will be successful at meeting the growing demand for wood as this recovery progresses by having the management skills and production efficiencies to address the challenges imposed by limited timber access, logger shortages, restricted access to financing, and regulatory burdens in such a way that allows them produce a reliable flow of wood to the highly dynamic global marketplace (Strauss et al. 2007).

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DVD Contents

Pennsylvania's Forests 2009 (PDF)

Pennsylvania's Forests: Statistics, Methods, and Quality Assurance (PDF)

Pennsylvania Inventory Database (CSV file folder)

Pennsylvania Inventory Database (Access file)

Field guides that describe inventory procedures (PDF)

Database User Guides (PDF)

Past Reports (PDF)

McCaskill, George L.; McWilliams,William H.; Alerich, Carol A.; Butler, Brett J.; Crocker, Susan J.; Domke, Grant M.; Griffith, Doug; Kurtz, Cassandra M.; Lehman, Shawn; Lister, Tonya W.; Morin, Randall S.; Moser, W. Keith; Roth, Paul; Riemann, Rachel; Westfall, James A. 2013. **Pennsylvania's Forests, 2009**. Resour. Bull. NRS-82. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 52 p.

The second full annual inventory of Pennsylvania's forests reports a stable base of 16.7 million acres of forest land. Northern hardwoods and mixed-oak forest-type groups account for 54 and 32 percent of the forest land, respectively. The State's forest land averages about 61 dry tons of wood per acre and almost 6,500 board feet (International ¼-inch rule) per acre on timberland. The ratio of average annual net growth-to-removals for growing-stock trees on timberland was about 2:1. Additional information is presented on forest land use, forest resources, forest sustainability, forest health (including regeneration), and timber products. Detailed information on forest inventory methods and data quality estimates are included in a DVD at the back of the report. Tables of population estimates and a glossary are also included.

KEY WORDS: inventory, timberland, forest land, sampling error, sample design, volume, growth, mortality, removals

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