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Forest Resources of Pennsylvania

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Abstract

This report presents an analysis of the results of the 1989 Pennsylvania forest inventory as well as trends that have occurred since the previous survey. Major topics include changes in forest land by ownership, forest type, and timberland component; stand structure as characterized by stand size, understory woody vegetation, dead trees, and changes in relative stocking; and harvesting by distribution of cut, species composition, and growth to removals ratios. The forest-land area of Pennsylvania has increased slightly since 1978 to nearly 17 million acres with the portion classified as timberland stable at nearly 16 million acres. The forest is maturing as evidenced by more acreage in sawtimber-size stands, larger trees, higher volumes per acre, and changes in species composition toward more shade tolerant species. Commercially desirable oak species did not fare as well as some of the underutilized shade-tolerant species such as red maple. Because of high mortality and high cutting rates, the volume of some oak species declined while red maple experienced a large increase and extended its lead as the number one species in the state by volume.

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Introduction

The USDA Forest Service, in a cooperative effort with the Pennsylvania Bureau of Forestry and the Allegheny National Forest, has completed the fourth statewide inventory of Pennsylvania's forests. Field work was carried out from 1988 through 1990, and statistical results published in "Forest Statistics for Pennsylvania - -1978 and 1989" (Alerich 1993). Previous inventories were conducted in 1955 (Ferguson 1958), 1965 (Ferguson 1968), and 1978 (Considine and Powell 1980). Many significant changes have occurred in the characteristics of Pennsylvania's forests during this time. Forests are dynamic and periodic fresh looks at the resource are needed to keep abreast of current forest conditions and monitor resource trends. Updated inventory information also can reveal new insights into the use and management of the forests.

This report presents an analysis of the resource data from the 1989 Pennsylvania inventory. The statistical report (Alerich 1993) provides information on inventory procedures, an explanation of methods used to compare results of the periodic inventories, and sampling errors associated with the data. A copy of the statistical report is useful in following this analysis.

Background

Pennsylvania's forests have been shaped by many years of human activity. During the period 1850 to 1920, most of the original forests in the state were cut. This was a period of large-scale harvesting and land clearing. Today only a few remnant stands of virgin forest remain. At the turn of the century, Pennsylvania's vast virgin forests enabled it to lead the nation in lumber production. Sustainable forestry was not a consideration then, and when the timber supply was exhaused, most lumber companies either moved or went bankrupt. Harvested areas were abandoned or converted to agriculture, though agriculture was marginal on much of this acreage and was soon discontinued. Wildfires frequently burned unchecked over thousands of acres and hindered the establishment of new stands. Because of this extensive abuse, people became concerned and organized a conservation movement. In 1886, the Pennsylvania Forestry Association was founded to promote the restoration of forests throughout the state; in 1895, the Pennsylvania Bureau of Forestry was established primarily to put out fires and to establish State Forest Reserves. After the logging industry collapsed and wildfires were brought under control, the forests began to recover through natural regeneration. Today, after nearly 100 years, the forests have made a remarkable comeback. Many forests in the state are now reaching maturity. Virtually all of the tree species that were originally present and all but a few of the indigenous animal species have returned.

Previous Inventories

Surveys of Pennsylvania have tracked the recovery and maturing of Penn's woods. Since the 1950's findings have revealed a maturing forest. Many changes have been associated with this aging--some very gradual and subtle in nature and others more obvious and abrupt.

The previous inventory of 1978 (Powell and Considine 1982) found the Pennsylvania forests generally in good shape. Growth exceeded harvest by a wide margin and total volume of all species showed a considerable increase over 1965. The major concerns in 1978 were insect and disease problems, especially those associated with gypsy moth defoliation. At that time, mortality related to gypsy moth defoliation was only a serious problem in the Northeastern and Pocono Units of the state.

Geographic Units

To provide regional as well as statewide information, Pennsylvania has been divided into eight geographic sampling units (Fig. 1). Unit boundaries were drawn to enclose reasonably distinct physiographic regions with fairly homogeneous forest conditions. Unit boundaries are identical to those of the 1978 survey, and comparisons between the two surveys can be made at this level for timber volume and forest area. But, because changes were made since 1978 in the algorithms used to calculate volume, forest type and stand size, use the recalculated 1978 data published in the latest report for comparisons (Alerich 1993). The reprocessed 1978 data, included in the 1993 report, uses the same algorithms as the new inventory. This allows valid comparisons between inventory periods. Data are also provided at the county level, but should be used with caution because of relatively high sampling errors. In many instances, county-level data should be used only as a starting point for assembling data for larger areas. Data for areas that cross county boundaries can be requested from the Forest Inventory and Analysis project (FIA).

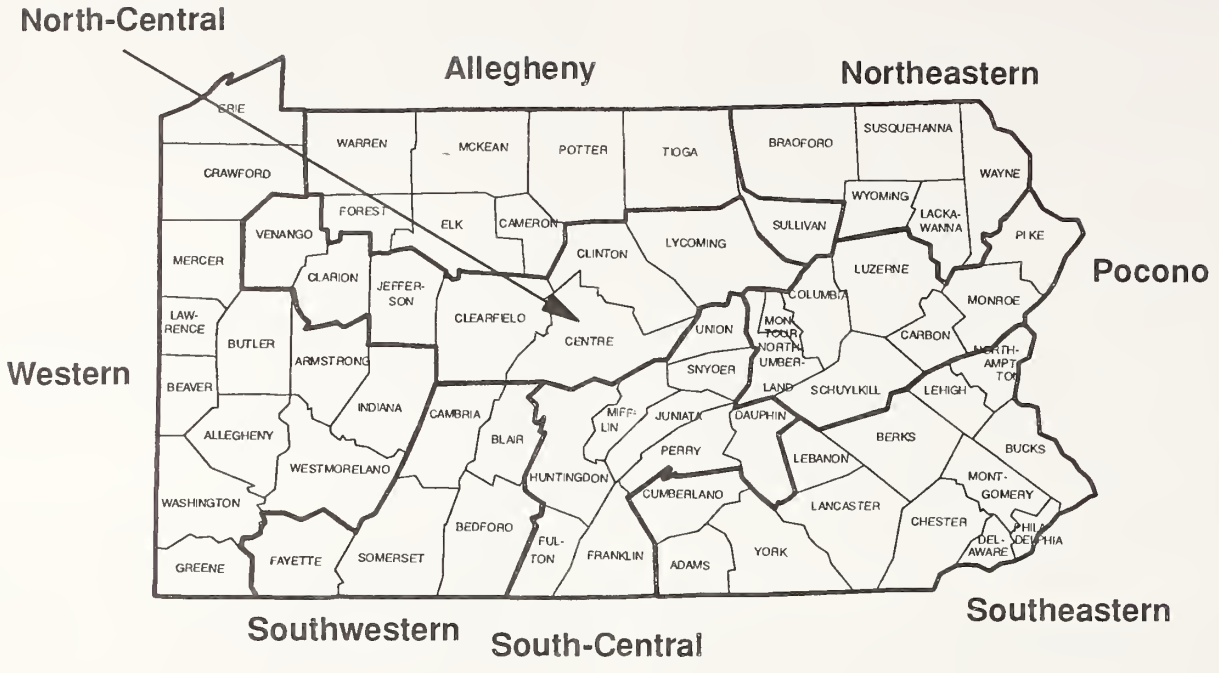

Figure 1. -- The eight geographic sampling units of Pennsylvania.

Forest Land Area

Pennsylvania's net land area, 28.7 million acres includes four major land use classes (Fig. 2). Pastureland is the smallest covering 4 percent of the area, and cropland is next with 16 percent. The "other nonforest" category includes uses such as urban, suburban, and rural development; roads and rights-of-way; and small bodies of water. This "other nonforest" category surprisingly accounts for only 21 percent of the state's land area, though it has continuously increased since William Penn established his colony in 1682. By far, the dominant land use in the state is forest, which covers nearly 17 million acres--about 3 out of every 5 acres.

Increase in Forest Area is Slowing Down

Pennsylvania forest surveys show a net increase in forest land since they began in 1955. The present survey reveals only a slight increase of 1 percent (142,400 acres) since 1978. The small net increase in forest land during this period reflects the continuation of a trend -- more land going into forests from agriculture than land being diverted from forests to other uses. Most new forest land comes from the natural reversion of abandoned farmland. Such additions to the forestbase have become smaller with each survey. Past surveys show increases in forest land of 5.6 percent (1955-68) and 1.5 percent (1968-78). Abandonment of farmland and its subsequent reversion to forest has more than offset losses of forest land to urban development and other nonforest uses resulting in small or minor net gains in forest land.

Increases in forest land were most noticeable in the Western, Southeastern, and Northeastern Units of the state. In the Western Unit, forest land increased from approximately 28 percent of the total land area in 1955 to 49 percent today. Declines were recorded in the Allegheny and North-Central Units where forest land went into a variety of other uses such as rights-of-way, strip mines, oil wells, and home construction (Fig. 3). These two units are more than three-fourths forested; hence, any land development is likely to come from forest land.

Forest land is not distributed evenly across the state (Fig. 4). The north-central part of the state is the most heavily forested. Cameron and Forest Counties are the most densely forested with 94 and 93 percent of their

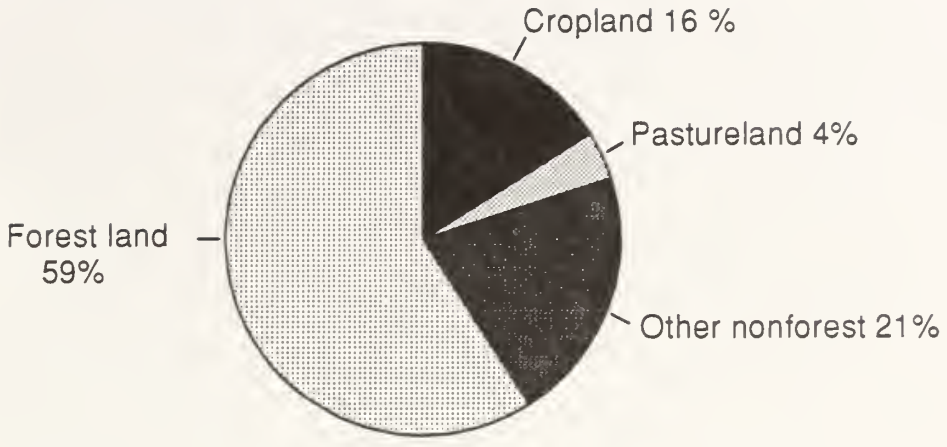

Figure 2. -- Four major land uses in Pennsylvania, 1989.

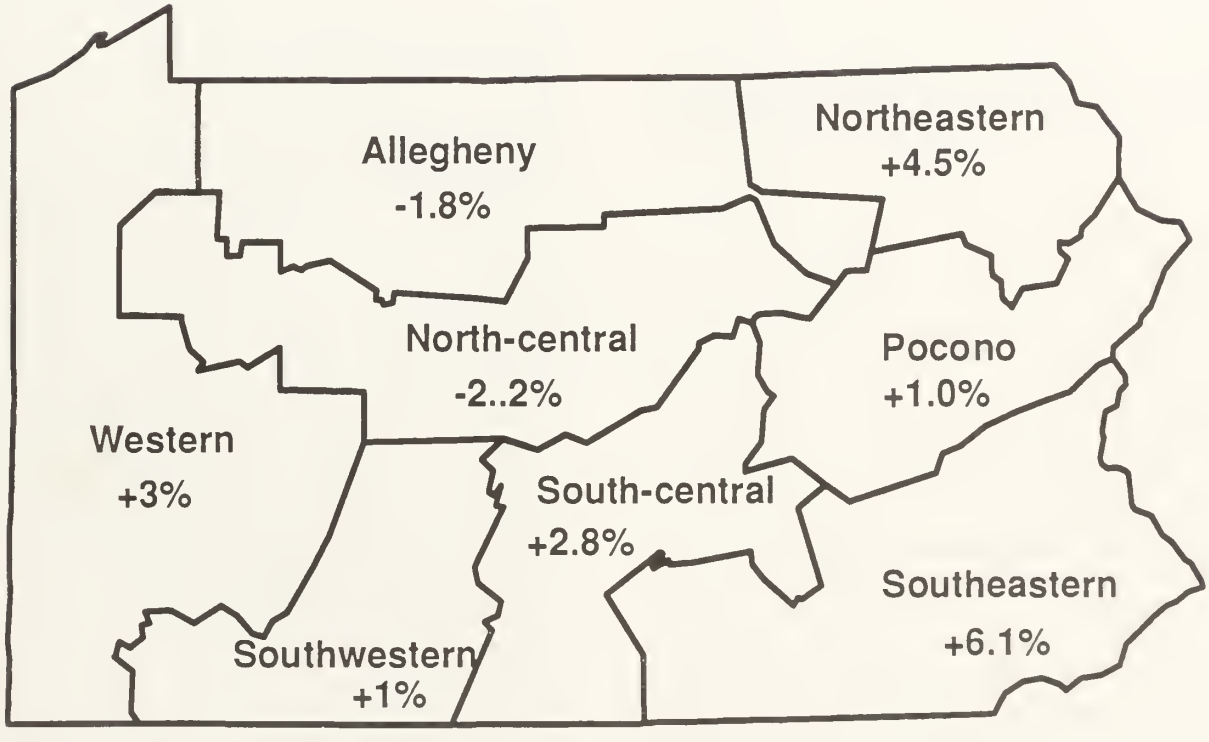

Figure 3. -- Percent change in forest land area, by unit, Pennsylvania, 1989.

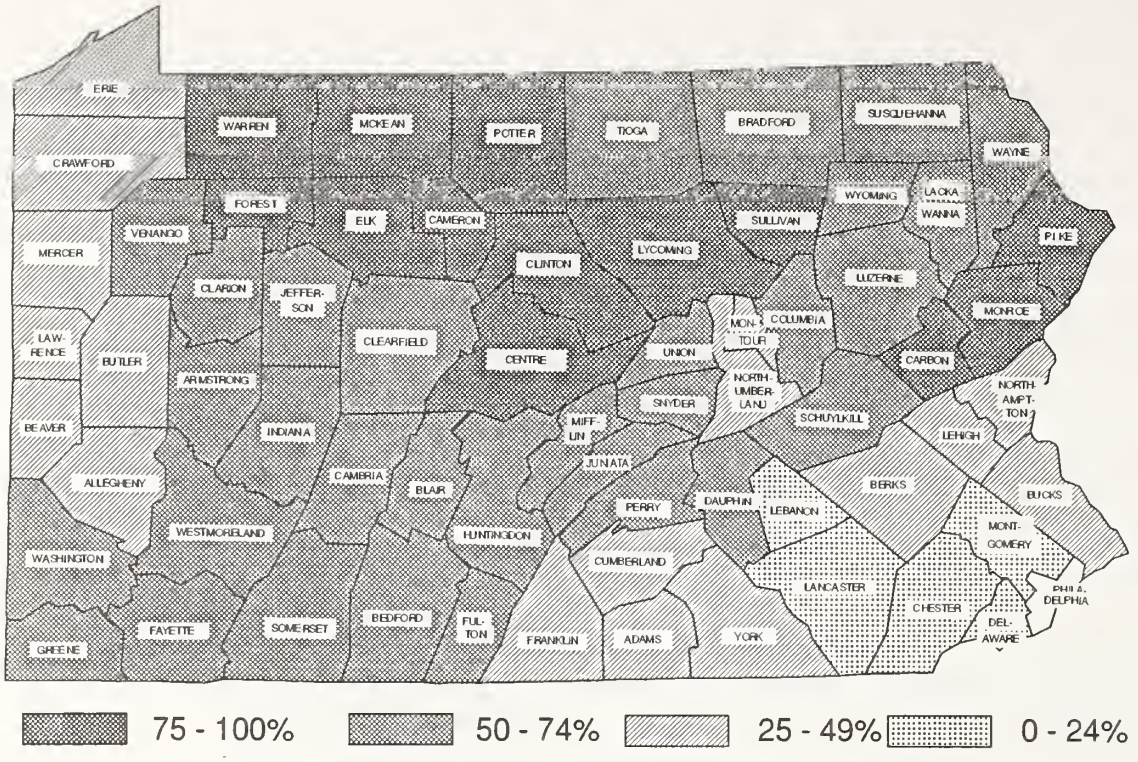

Figure 4. -- Percentage of land in forest, by county, Pennsylvania, 1989 (State average = 59 percent).

area in forest, respectively. At the other extreme, are the lightly forested counties in the southeastern part of the state, where urban development and agriculture are the primary uses.

Forest Inventory and Analysis surveys only report general trends in land area. This does not give a complete picture of the dynamic changes in land use. Net changes in forest land area mask some important shifts that are taking place. If shifts into and out of forest land could be accurately determined in each unit, it would help us understand the net increase in forest land. This is apparent, for example, in data for the Southeastern Unit. This area had a net increase of 6 percent in forest land. But, those familiar with the area know that a great deal of urban development has taken place. They also know that much farmland has reverted to forest land. These shifts in land use offset one another. So, it is likely that a much higher portion of the land changed use than is suggested by the relatively low overall net change. If the components of net change were known, it would give us an in-depth understanding of how and why forest land is changing in this rapidly developing area.

Sharp Gains in Noncommercial Forest Land

The inventory identifies two types of forest land: timberland and noncommmercial (Table 1). On noncommercial forest land, commercial harvesting is legally restricted or unlikely to take place. Included are lands reserved from cutting by public agencies (such as parks and natural areas), forest land in urban settings (forest land that is completely surrounded or nearly so by urban development), and unproductive forests, (such as, very rocky slopes in central Pennsylvania). Also, included in this class are Christmas tree plantations. Although it represents a relatively small part of the state, noncommercial forest land has increased significantly since the first survey. Principally because more forest land continues to be set aside by the state and national forest, but also because of increases in land classified as urban forest. These lands are important for recreation, wildlife, water resources, and preserving diversity in the urban landscape. By permitting the development of old-growth forest conditions, reserved lands also contribute to the enrichment of biological diversity. Old-growth conditions are unlikely to develop in areas not reserved from cutting because forests become economically mature and ready to harvest long before they are biologically mature (Hunter 1990).

Table 1.--Acres of forest land, by timberland and noncommercial forest, Pennsylvania, 1955, 1968, 1978, and 1989

Forest land	1955	1968	1978	1989
Timberland	15,607,500	16,230,900	15,923,700	15,872,800
Noncommercial	97,000	354,000	902,200	1,119,900
Total	15,704,500	16,584,900	16,825,900	16,992,700

Areas classified as noncommercial forest land total 1,119,900 acres--4 percent of total land area and 7 percent of forest land. This is an increase of 217,700 acres from the 1978 inventory. The urban forest portion increased from 72,000 to 141,400 acres as urban centers spread into rural areas. Additional increases (69,800 acres) occurred because the Bureau of Forestry revised the management plans on state forests and now exclude more acreage from the timberland base, because the site or topography inhibit timber harvesting. No forest management practices are anticipated on these lands because of short merchantable stems, excessive rocks, or steep terrain. During the 1989 inventory, it was found that some Bureau of Forestry land that was previously classified as unproductive met the USDA Forest Service definition of timberland (potentially capable of producing 20 cubic feet per year). Subsequently, this land was reclassified into the reserved timberland class, because the Bureau of Forestry excludes it from its timberland base. This change within the noncommercial category did not affect the timberland category.

Noncommercial areas classified as state natural areas and special use areas also increased. Previous surveys classified some of the land within these areas as timberland. The 1989 survey completely excluded all acreage within natural and special-use areas from the timberland base, thereby increasing noncommercial acreage. Like the state, the national forest has increased its acreage reserved from cutting. Natural areas on state and national forest lands protect representative and unique natural features for scientific, educational, and aesthetic purposes. Some of the finest examples of old-growth forest, wet lands, and endangered vegetation are on these lands.

The 1989 inventory shows an eleven-fold increase in non-commercial forest land over the initial inventory. This trend will likely continue as urban areas increase and cutting becomes more restricted. Also pressure to reduce cutting on national forests to accommodate biodiversity, ecosystem management research, and other uses could result in more conservative cutting practices and more land set aside as reserved.

Timberland Remains Stable

The remaining forest-land category, which accounts for 93 percent, is timberland. This report focuses on that resource base. This land base supports a significant forest products industry employing 100,000 Pennsylvanians, with $2.3 billion in payroll and producing more than $4 billion in products making forestry one of the principal industries in the state. A diverse group of approximately one-half million private landowners own more than three-fourths of the timberland. These lands are held for a multitude of reasons such as being part of a homestead, enjoyment of woodland recreation and solitude, or timber growing. All privately owned forest land, with the exception of those acres classified as urban forest or unproductive, are considered timberland and available for harvesting. Timber production, however, is not the primary reason of ownership for most timberland owners (Birch 1980). This inventory did not consider cutting restrictions by local municipalities, which are becoming more common, when classifying timberland, though future surveys may need to consider this issue.

The acreage of forest land classified as timberland did not change significantly, since the previous inventory (-0.3 percent). Additions to timberland from abandoned farmland were offset by the reclassification of timberland into the noncommercial category and losses of timberland to nonforest uses.

The inventory divides timberland into broad ownership categories. Public ownership (Fig. 5a) includes the Allegheny National Forest, state forests and state game lands, and other miscellaneous public ownerships; such as municipal watersheds and lands administered by the Army Corps of Engineers. Public ownership is concentrated in the Allegheny Unit where 41 percent of the timberland is in public ownership (Fig. 5b). Statewide, public ownership accounts for 21 percent of

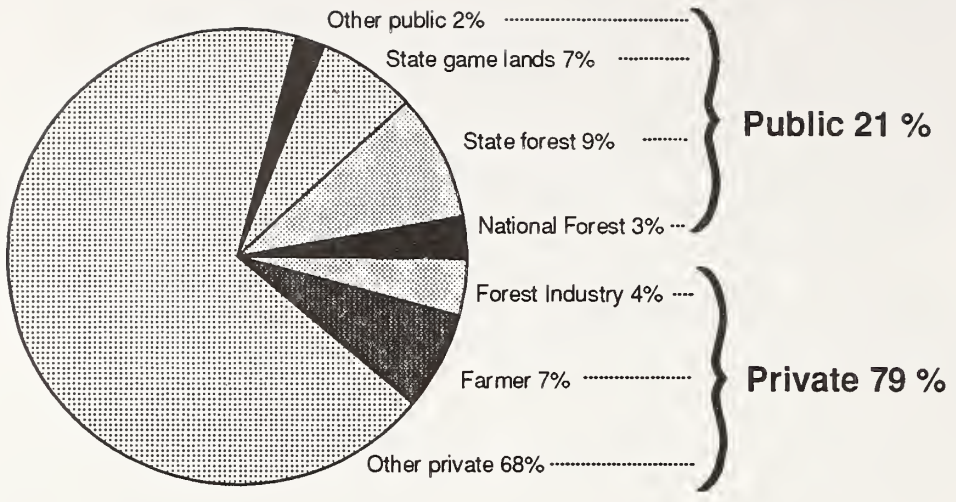

Figure 5a. -- Percentage of timberland by ownership, Pennsylvania, 1989.

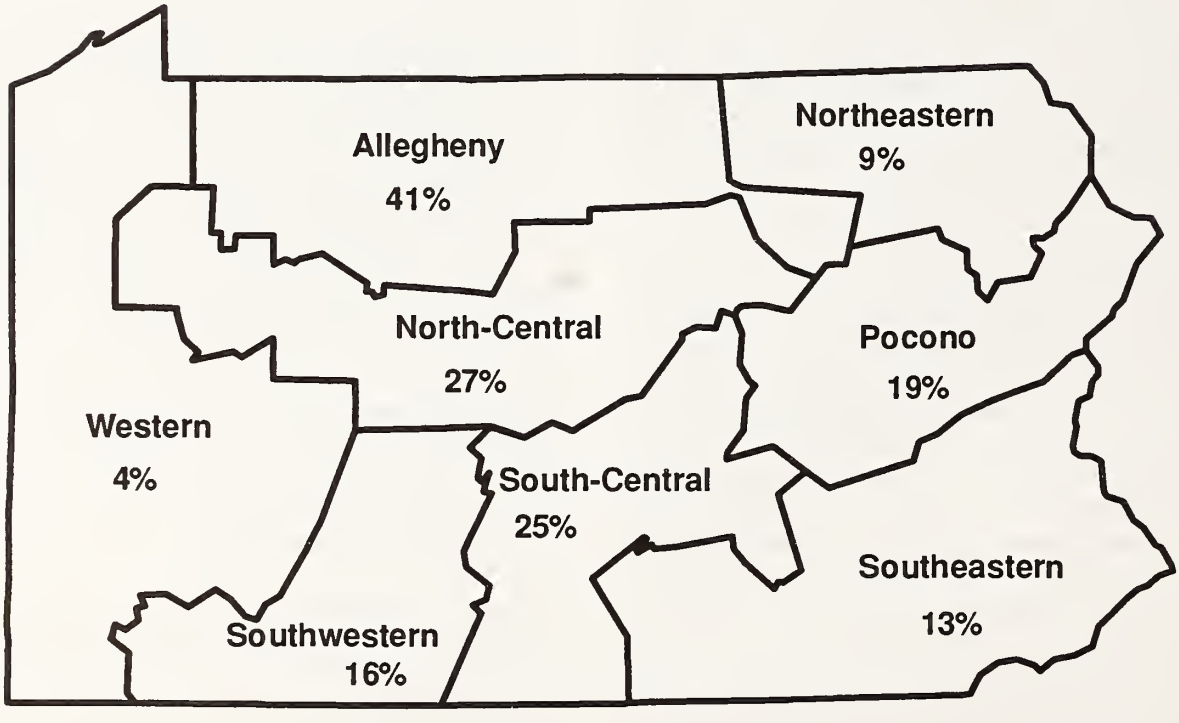

Figure 5b. -- Percentage of timberland in public ownership, by unit, Pennsylvania, 1989.

the timberland. Since public ownerships amount to less than a quarter of the timberland, how the majority of Pennsylvania's forests are managed is in the hands of thousands of individual private landowners who own 79 percent of the timberland. These private owners include forest industry, farmers, and other private owners such as individuals, partnerships, and corporations.

Change in Stand Structure

Change in Size Classes

Timberland can be classified according to the size of the trees growing on the land: sawtimber stands, poletimber stands, sapling-seedling stands, and nonstocked areas (Fig. 6). These size classes are based on commercial uses for forest products; they also relate to the seral stage of the forest and to habitat requirements for wildlife species. Sawtimber stands, which have the majority of their stocking in sawtimber-size trees, make up 54 percent of Pennsylvania's forest. The proportion has increased mainly because poletimber stands grew into the sawtimber-size class. Sawtimber stands are most attractive to forest industry because of high volume and value associated with potentially higher quality trees. Sawtimber stands contain 71 percent of the growing stock volume in the state. Stands dominated by large trees are aesthetically pleasing--people enjoy hiking and camping in such stands because they are easier to move in and are perceived to be more attractive. Large trees are an important attribute of forests that the public finds attractive (Ribe 1991). Sawtimber stands also benefit a variety of wildlife species that require stands with large trees for at least part of their habitat or life cycle.

The proportion of forest in poletimber-size stands remained at 31 percent since the previous survey. Poletimber stands have the potential for rapid increases in value as they grow into sawtimber stands. Releasing poletimber-size trees by thinning can increase growth of residual trees and provide some income to the landowner. Silvicultural treatments in these stands are mainly focused on enhancing future value. Historically, crop tree release, thinnings, and improvement treatments have not been common practice in Pennsylvania (Bowersox 1985). Poletimber-size stands have fewer wildlife species associated with them than either the sapling-seedling class or the sawtimber class. Trees in these stands are not yet mature enough to produce hard mast, and the dense closed overstory can inhibit the growth of herbaceous plants and shrubs in the understory that provide wildlife food and cover habitat.

Sapling-seedling stands and nonstocked stands are usually the result of clearcutting, salvage cutting, or reverting agricultural land. They are in a developing stage and have a larger proportion of noncommercial tree species than larger size classes. Together, sapling-seedling stands and nonstocked forest land decreased by 29 percent (Table 2). Growth of these stands into the poletimber class was not offset by regeneration harvests or farmland reverting to forest land. The nature and extent of harvesting activities in Pennsylvania are not well documented, but Forest Inventory and Analysis plot information reveals that contemporary harvesting activities are not reducing many stands down to these early successional stages. With the commonly used practice of selective cutting, only a portion of the overstory trees is removed, and the residual trees respond by quickly filling gaps created in the canopy. The nonstocked portion is very small, amounting to less than two-tenths of a percent of the total timberland. Natural regeneration usually occurs quickly in Pennsylvania, and areas do not stay in a nonstocked condition for extended periods of time. Some deterrents to early stand establishment are: deer browsing, competing vegetation such as ferns and vines, and failure in establishment of desirable species--oak regeneration.

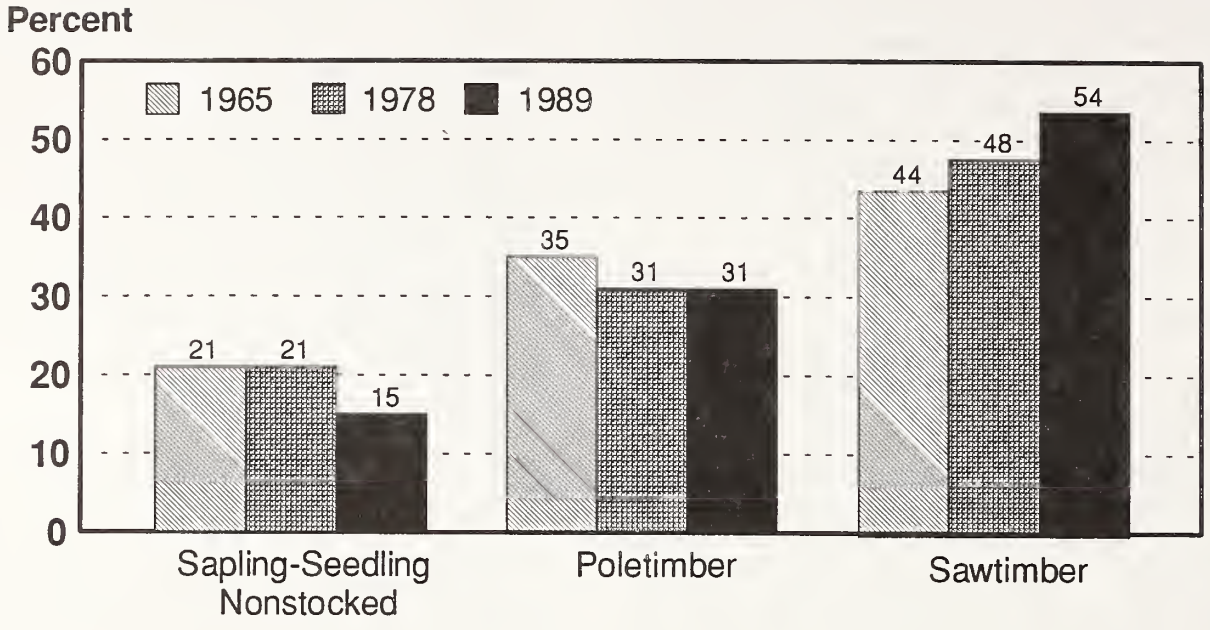

Figure 6. -- Timberland by stand-size class, Pennsylvania, 1965, 1978, 1989.

Table 2.-- Percent change in timberland area, by stand-size class and unit, 1978-89.

Unit	Sapling-Seedling, Nonstocked	Poletimber	Sawtimber
Western	-36	+6	+25
Southwestern	-9	-2	+6
Allegheny	+6	-26	+17
North-Central	-35	+23	-<1
South-Central	-32	+6	+9
Northeastern	-29	-15	+38
Pocono	-54	+23	+20
Southeastern	-7	+89	-16
State Average	-29	+2	+11

The reduction in sapling-seedling stands and nonstocked forest land represents a decrease in early successional stages. Because some wildlife species depend on these stages as nesting or feeding habitats, it is desirable to have a balanced distribution of size classes. A forest with a balanced distribution of age classes also may be more resistant to insect and disease problems and provide a more even flow of forest products. Early successional forests provide unique habitat conditions that are critical to a suite[1] of wildlife species, particularly birds (Brooks 1993). If the acreage coming into forest land from reverting fields continues to decline, and as clearcutting becomes less acceptable to the public, the portion of timberland in the sapling-seedling stands and nonstocked class will progressively decline, resulting in an imbalance in stand-size classes. This is occurring on a regional scale and is resulting in declines among early successional species. Declines are occurring in several eastern North American bird species that breed in young forests; and although the loss of young and old-field, or shrubby, thicket-type forests cannot be solely blamed for the declines, loss of summer-breeding habitats is certainly a partial cause of these trends (Brooks 1993). To increase sapling-seedling stands, more regeneration harvests would have to be done. This of course assumes that regeneration of acceptable species would be successful.

The distribution of stands by size class varies between units. Shifts in stands to larger size classes took place across the entire state. All units experienced a shift out of the sapling-seedling and nonstocked class, and except for the North-Central and Southeast Units all units had an increase in the percentage of timberland in the sawtimber class (Fig. 7).[2]

Stand Size by Ownership

The four major ownership categories in Pennsylvania show some interesting trends in stand-size distribution.

The Allegheny National Forest (ANF) was the only ownership to show an increase in the sapling-seedling and nonstocked class (Fig. 8). The ANF also had the highest portion of stands in sawtimber-size trees. Increases in the sapling-seedling stands were the result of regeneration cuts designed to promote shade intolerant species. The inventory did not record any national forest stands in a nonstocked condition. Poletimber stands on the ANF dropped from 40 percent in 1978 to 12 percent in 1989. Besides normal growth of poletimber trees into sawtimber, thinning of poletimber stands hastened the shift of these stands into the sawtimber-size class. This occurred when smaller poletimber-size trees were removed, thereby increasing the average diameter of trees in the stand and concentrating growth on fewer large trees.

The other public group is dominated by state ownership (91 percent). This was the only ownership with a decrease in sawtimber-size stands. This reduction in sawtimber stands was probably the result of mortality due to gypsy moth defoliation and drought and the subsequent salvage harvests of these stands. The state owns a large portion of the chestnut oak stands that run along the ridge tops in central Pennsylvania; these oaks were severely defoliated by the gypsy moth.

Forest industry owners have the smallest portion of land in the sapling-seedling and nonstocked class and a high portion in sawtimber. These owners manage their lands more intensively for the production of wood products than other owners. The small amount of land in the sapling-seedling and nonstocked class may be surprising, considering the need to harvest trees to operate mills. Relatively few stands are being reduced to early successional stages through harvesting, and those stands that are, are encouraged to regenerate quickly. Also, these owners may hold their stands in reserve to ensure a steady supply of wood to their mills.

The other private owners have the most diverse range of reasons for owning forest land. This variation is reflected in the shear number of owners--nearly 500,000 private owners hold timberland in Pennsylvania (Birch and Stelter 1993), and they have the widest distribution of stand-size classes. This was the only group to include any nonstocked timberland (nonstocked timberland was estimated at 26,200 acres, less than 1 percent of timberland). They also have the highest portion in the sapling-seedling and nonstocked condition; this may be more attributable to large amounts of nonforest land reverting to forest than to harvesting reducing stands down to this smaller size class.

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[1]"Suite" refers to a collection of faunal species with some characteristic in common. Here, the characteristic is the use, and with some birds, exclusive use of the structure offered by early successional forest.

[2]This comparison is based on growing-stock trees only so that comparisons can be made to previous inventories. A new definition for Stand-size uses all live trees, this includes cull trees and noncommercial species; for example, sassafras, pin cherry, and striped maple. This change, though small, had the greatest effect on nonstocked areas.

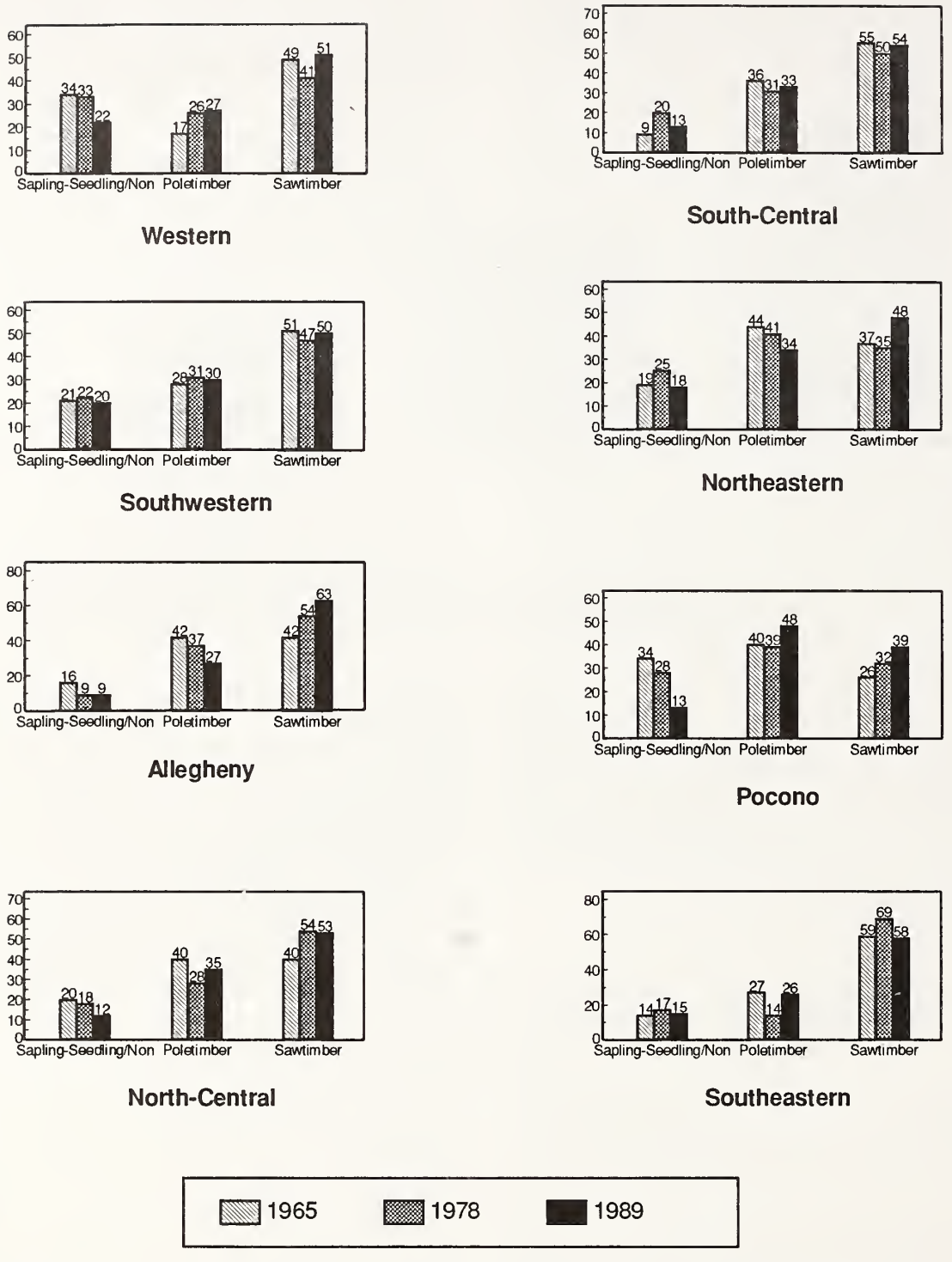

Figure 7. -- Distribution of timberland by stand-size class and geographic unit, Pennsylvania, 1965, 1978, 1989.

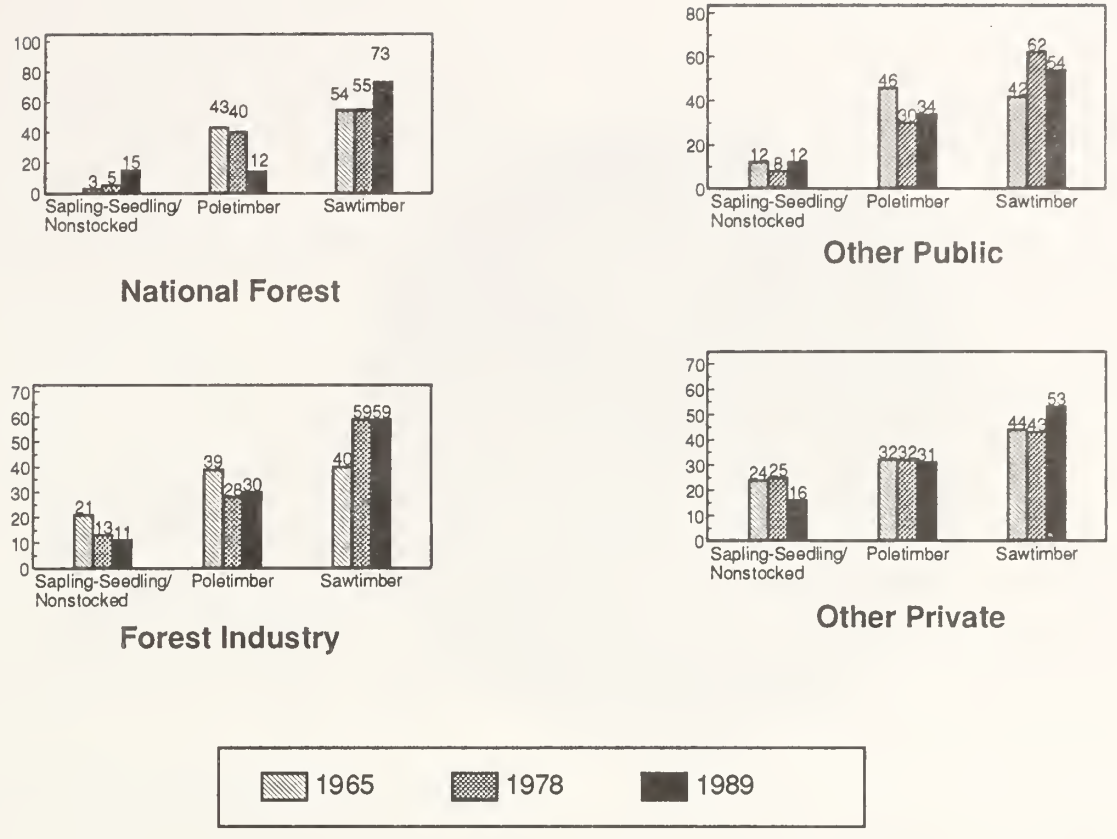

Figure 8. -- Distribution of timberland by stand-size and ownership class, Pennsylvania, 1965, 1978, 1989.

Major Forest Type Groups

When it comes to species, Pennsylvania's forests are quite diverse. More than 90 species of trees were encountered during the inventory and were assigned to eight forest-type groups. The two major forest-type groups are oak/hickory, which covers 47 percent of the state, and northern hardwood (also known as maple/beech/birch), which covers 38 percent (Fig. 9). Between surveys the acreage in these groups has declined slightly. The remaining timberland (15 percent of total timberland) is divided among six other forest-type groups. Overall, these minor forest-type groups increased in acreage; an indication of increased species diversity in the forest (Table 3).

Since 1978, the white/red pine and oak/pine groups have increased significantly. The white/red pine group, which includes the hemlock forest type, increased by 36 percent; yet represents only 5 percent of the total timberland. Hemlock, a very shade-tolerant species, increased in volume in all units. Some hardwood stands with hemlock understories have been converted to nearly pure hemlock stands when the overstory was harvested and the hemlocks left. Although stands of hemlock have been increasing, there is some doubt whether these increases will continue. The hemlock woolly adelgid has caused heavy mortality in hemlock stands along the eastern border of the state. If this insect spreads across the state, it could cause severe hemlock mortality. The area in the relatively minor oak/pine group more than doubled between inventories and now represents 2 percent of the timberland. This increase is supported by field observations. Where seed sources are available, white pine has taken advantage of openings in the canopy caused by gypsy moth-related mortality, and is growing up through some hardwood stands. We can expect the white pine forest type to be an increasingly important component of Pennsylvania forests in the future.

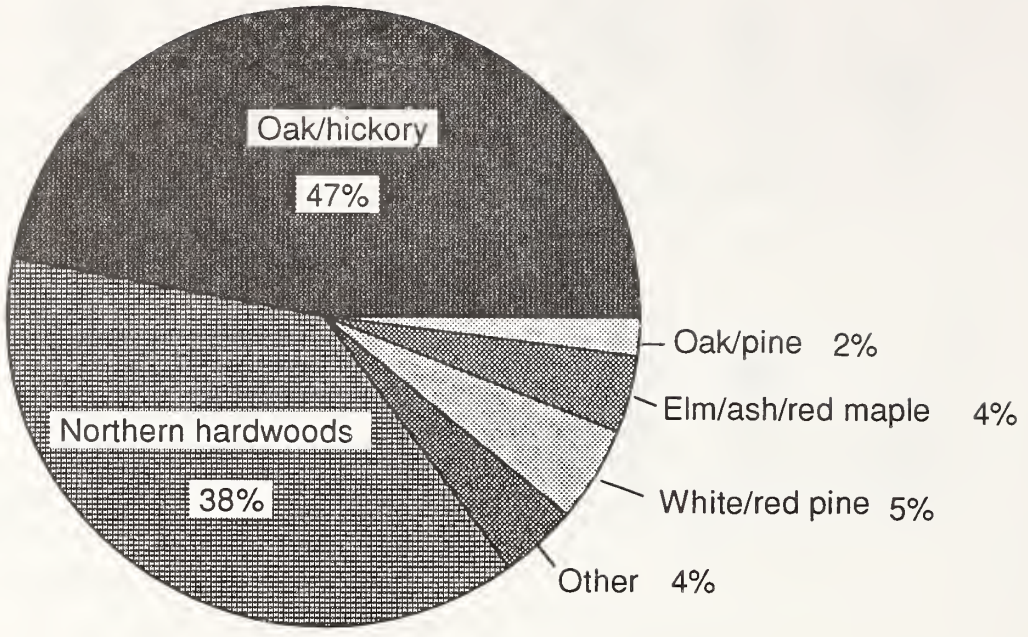

Figure 9. -- Percentage of timberland area, by major forest-type group, Pennsylvania, 1989.

Table 3.--Total acres, by forest-type group and percent change, Pennsylvania

Forest-type group	Acres (thousands)	Percent change 1978-89
White/red pine	797.8	+36
Spruce/fir	64.7	-18
Loblolly/shortleaf	138.2	-30
Oak/pine	339.3	+155
Oak/hickory	7,459.0	-1
Elm/ash/red maple	670.4	+12
Northern hardwoods	6,048.5	-4
Aspen/birch	354.8	-29
All groups	15,872.8	-0.3

Because the oak forest types are being cut at a higher rate than the other types, one might surmise that the oaks would have a higher proportion in the sapling-seedling size class. However, the proportion of stands in the sapling-seedling size class is lower in oak forest types than for all other types combined--11 percent compared to 16 percent. This suggests that oak stands are not replacing themselves.

Changes in Relative Stocking

Full stocking can occur over a wide range of stand densities, and is variable from stand to stand because of differences in species composition, number, size, and basal area of trees. Fully stocked refers to conditions defined by Gingrich (1967) between an "A-level" and a "B-level", with the upper "A-level" given 100 as a reference. Forest Inventory and Analysis (Gansner et al. 1994) applied stocking algorithms developed by Stout and Nyland (1986) to calculate the percentage of "A-level" stocking for each of its remeasured field plots.

This procedure uses formula developed for each species and applies these to individual trees, then sums each tree's stocking contribution to estimate the total stocking of the stand. Subtotaling the trees by species gives a sum of how much the species contributed to the total stocking of the plot; this ratio is then referred to as relative stocking. Looking at changes in how different species contribute to the total stocking on remeasured plots gives a measure of how these species are changing relative to one another. Those species with positive changes in relative stocking can be thought of as gaining ground or increasing in importance as they occupy more of the space in the forest relative to other species, and those with negative changes are losing ground or decreasing in importance (Fig. 10).

A species can increase in absolute stocking but if other species increase more than it did, it will actually result in a negative change in relative socking. For example, if a species changed from 16 to 18 percent of total stocking and the stand as a whole changed from 64 to 90 percent stocking, the species would have represented 25 percent (16/64 = 25%) of the stocking initially and then drop to 20 percent (18/90 = 20) total stocking subsequently, even though the absolute stocking of the species increased.

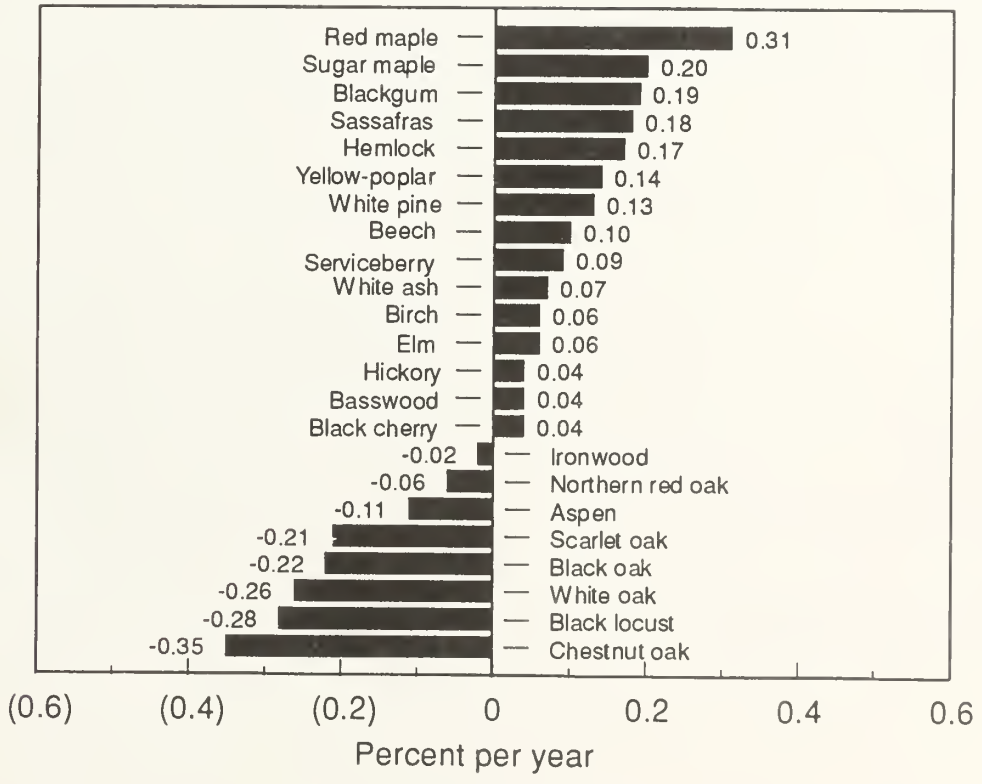

Figure 10.-- Average annual change in the relative stocking of some common forest tree species in Pennsylvania, 1978-89.

Statewide, red maple had the largest increase in relative stocking, and all oaks together had the largest decrease. In general, the shade-tolerant species such as hemlock, sugar maple, beech , and blackgum did better than the shade-intolerant species such as aspen and black locust, which are also associated with early successional stands. Changes in stocking due to natural mortality as well as those caused by man (such as timber harvesting) were included. Hence, these changes represent the total shift in species stocking from all causes. The extent to which species are gaining or losing ground in the forest can help us gain insight into the dynamics of the forest ecosystem.

At the time of the 1978 forest inventory, the stocking of all live trees 5.0 inches d.b.h. and larger on timberland in Pennsylvania averaged 57.3 percent. After 1978, growth of original trees plus ingrowth of new trees into the 5.0-inch size class more than offset losses to cutting and mortality. So, by the 1989 inventory, average stocking had increased to 63.4 percent.[3] This shows that on the average acre, trees are now denser and taking greater advantage of that site's growth potential.

All units shared in stocking gains, but some gained more than others (Fig. 11). In the Southwestern and South-Central Units, gypsy moth-related mortality, drought, and cutting took a heavy toll on the oak resource during the 1980's (Gansner et al. 1993b). Growth on red and sugar maple, black gum, yellow-poplar, black cherry, and other species offset the oak loss. However, gains in average stocking for all species combined remained minimal. At the other extreme, were the Western and Northeastern Units, which ranked lowest in average stocking in 1978, and recorded significant gains between inventories.

Looking at changes in stocking at the state and unit level only gives a rough idea of how a species is changing in relative stocking across the state. Mapping changes in relative stocking by county reveals a striking amount of variability in how individual species are performing within the state. Figures 12 to 16 show changes in relative stocking for five major species.

[3]This comparison uses only plots measured in 1978 and remeasured in 1989 with results expanded to represent the whole state.

Understory Woody Vegetation Varies by Stand-size

Seedlings, saplings, and shrubs form the lower layer of woody vegetation in a forests' vertical structure of the forest. Stands with more layers or strata of vegetation are considered to be more diverse than stands with fewer layers (Hunter 1990); hence, it is desirable to have understory vegetation. Seedlings and saplings are important for regenerating stands after disturbance and, together with shrub species, provide wildlife with habitat cover and nesting sites, and food as browse and mast. The 1989 inventory estimated the number of understory woody stems for the first time. Though trends cannot be calculated, comparisons of current conditions can be made between geographic units and stands of different size classes (Table 4).

On a per-acre basis, the number of all species combined, less than 1 inch in diameter, varied across geographic units and stand-size classes. As expected, statewide sapling-seedling stands averaged the highest number of stems of all species with nearly 15,000 per acre. The Pocono Unit had the highest number of stems in the sapling-seedling size class, with nearly 24,000 stems per acre, and the Western and Southwestern Units the lowest 10,000 and 12,000, respectively. The lower numbers of stems in the Southwestern and Western Units may be related to the high portion of these stands originating as reverting fields as opposed to stands regenerating after disturbances such as a timber harvest. Sawtimber stands had the lowest number of stems in all units, averaging 7,000 per acre statewide, and ranged from more than 11,000 in the Pocono Unit to less than 4,000 in the Allegheny Unit.

The number of woody stems and species composition of the understory shifts as stands grow from the sapling-seedling stage to sawtimber size (Table 5). The number of blueberry bushes and rubus species stems (includes blackberries and raspberries) in sawtimber stands is only about one-third that in sapling-seedling stands. Blueberry bushes are still the most numerous species in all size classes followed closely by species of rubus. Not all species decrease in number as stand size increases. The number of American beech and common spicebush stems (both very shade-tolerant species) in sawtimber stands were three times that in sapling-seedling stands. Understory tree species were more prevalent in sawtimber stands. For all woody stems less

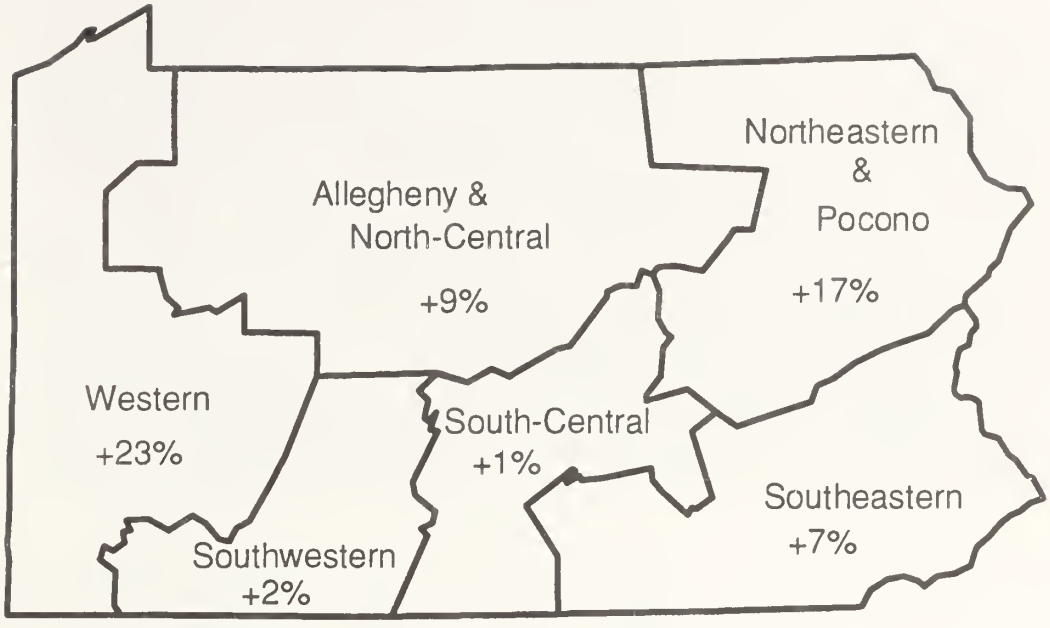

Figure 11. -- Percent change in stocking, by unit, Pennsylvania, 1989.

Table 4.--Number of seedling, sapling, and shrub stems per acre, by stand-size class and geographic unit, Pennsylvania, 1989

	Stand-size Class			
Unit	Sawtimber	Poletimber	Sapling-seedling	All classes
Western	7,787	8,166	10,063	8,354
Southwestern	7,977	10,051	11,771	9,326
Allegheny	3,805	6,444	15,107	5,607
North-Central	8,405	10,818	15,048	10,028
South-Central	8,636	11,136	17,626	10,589
Northeastern	5,887	8,057	14,957	8,255
Pocono	11,132	16,447	23,858	15,451
Southeastern	9,766	12,546	12,737	10,913
State Average	7,340	10,403	14,493	9,359

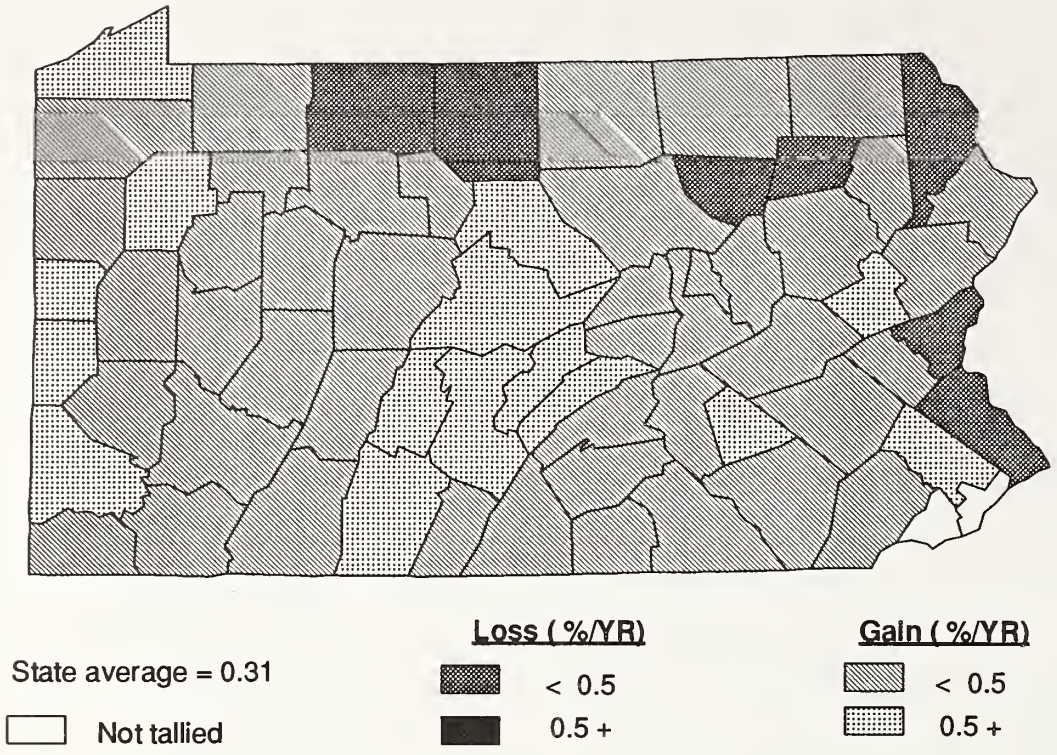

Figure 12.-- Average annual percent change in relative stocking of red maple.

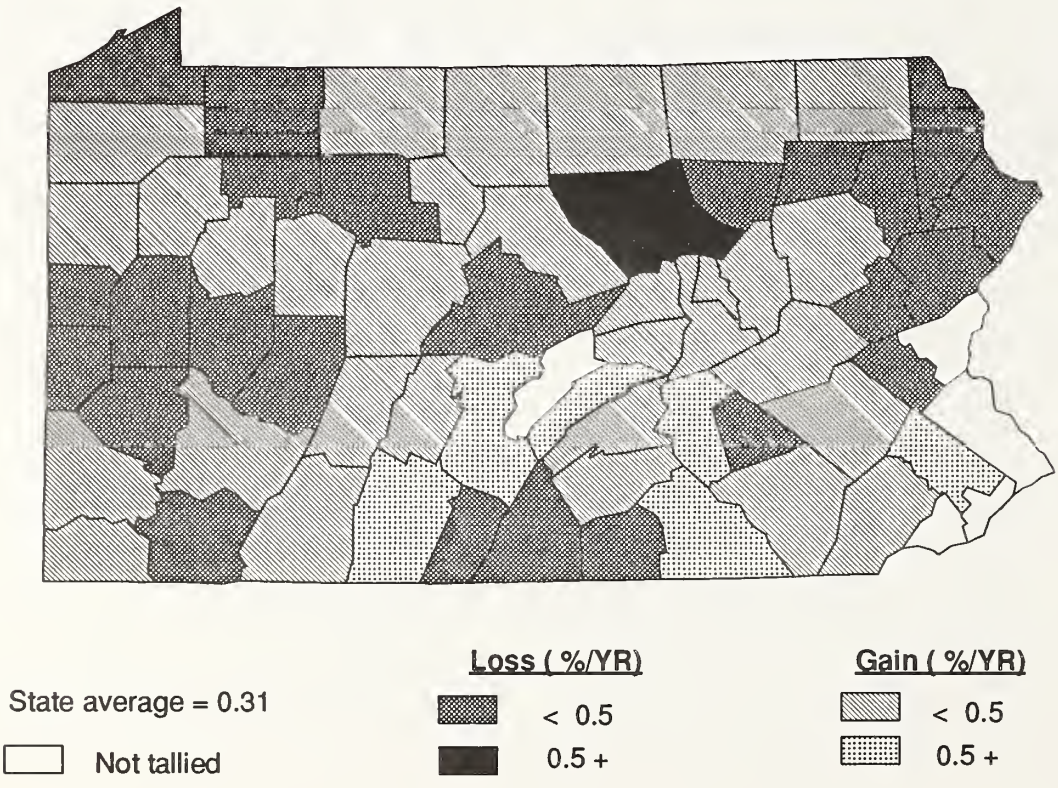

Figure 13.-- Average annual percent change in relative stocking of black cherry.

Figure 14.-- Average annual percent change in relative stocking of all oak.

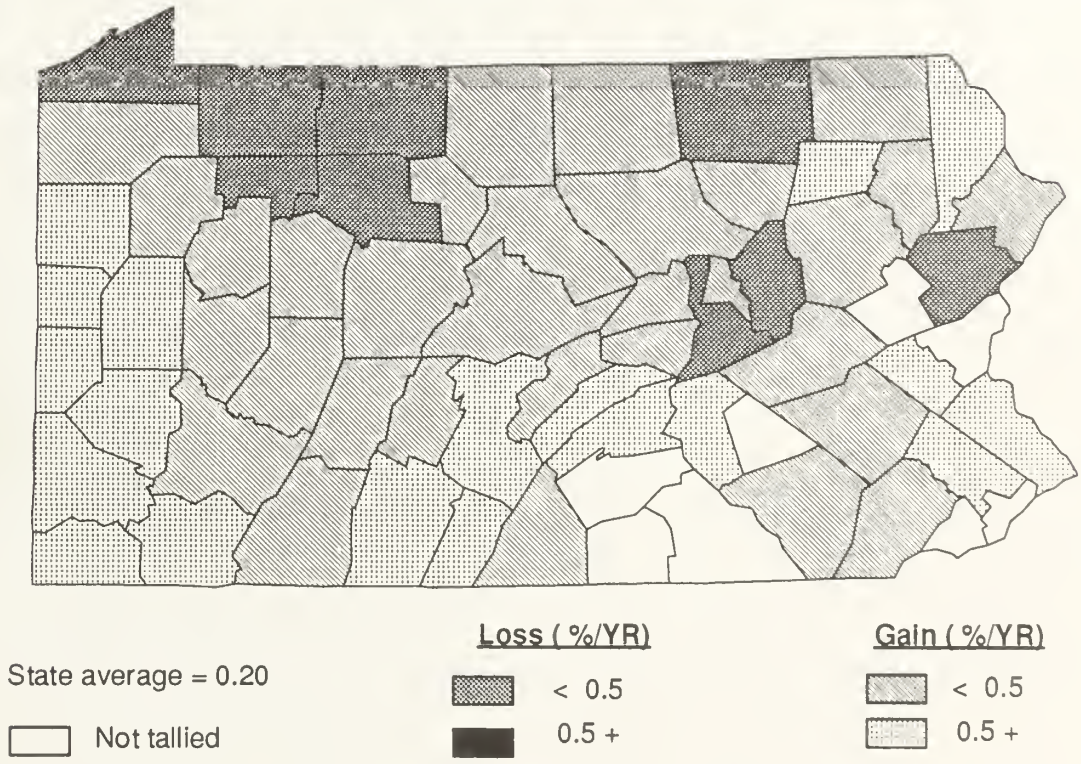

Figure 15.-- Average annual percent change in relative stocking of sugar maple.

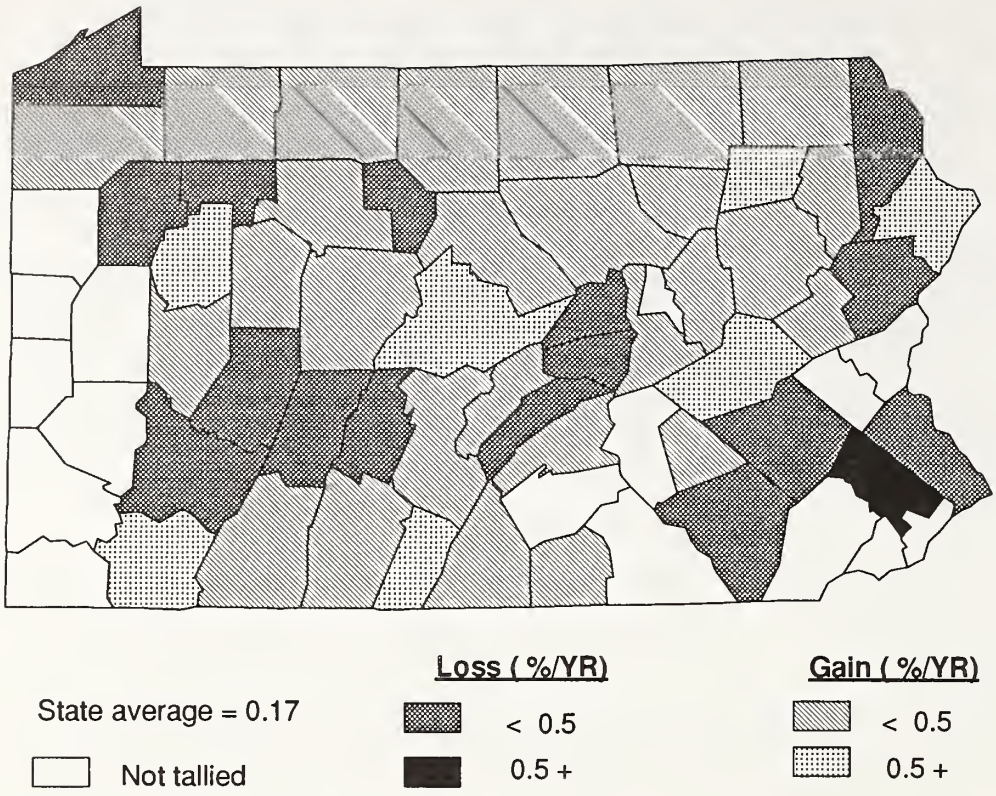

Figure 16.-- Average annual percent change in relative stocking of hemlock..

than 1 inch in diameter, tree species represented 32 percent of the stems in sapling-seedling stands and 42 percent in sawtimber stands.

Standing Dead Trees Plentiful

Standing dead trees contribute to wildlife habitat in various ways and their contribution changes as they decay (DeGraaf and Shigo 1985). Raptors and insectivorous birds use the bare branches as perch sites. Chickadees and nuthatches use the bark as a foraging substrate and also loose bark can be used as a nesting site by some birds and bats (Brooks 1993). Primary excavators (woodpeckers) prefer trees with central decay for nesting. The cavities they excavate are used by a variety of secondary cavity nesters such as flying squirrels, chickadees, and bluebirds (Brooks 1993). When dead trees fall to the ground they are used by a variety of different mammals, amphibians, reptiles, and birds.

Results from the 1989 survey show that dead trees are plentiful in Pennsylvania, averaging 18.4 per acre (Table 6). The Southwestern and South-Central Units have the highest number of dead trees averaging 27 and 24 per acre, respectively; and the Western Unit has the least averaging 13.3. The higher numbers of dead trees in some units can be attributed to gypsy moth defoliation that stressed trees and caused high mortality. Another major contributing factor was stress caused by overstocking. Most of the dead trees were in the lower diameter classes and were likely to have been in the understory in an overtopped position. Suppressed trees are especially susceptible to mortality after gypsy moth defoliation (Gottschalk, et al. 1993) The lower number of dead trees in the Western Unit may be because these stands are younger and have less volume in oak species--a gypsy moth susceptible species. Oaks comprise 37 percent of the standing dead trees statewide.

Table 5.--Average number of seedlings, saplings, and shrubs per acre for some major understory species, by stand-size class, Pennsylvania, 1989

Species	Stand-size class			
	Sawtimber	Poletimber	Sapling-Seedling	All Classes
Blueberry	1,062	2,990	3,418	1,878
Rubus spp.	1,124	1,251	3,414	1,508
Black cherry	665	533	960	667
Mountain laurel	390	1,052	366	593
Red maple	366	472	750	456
Huckleberry	188	525	331	314
American beech	354	184	119	265
White ash	238	235	338	252
Sweet birch	191	190	345	214
Witch-hazel	210	200	212	205
Common spice bush	252	133	89	190
Sassafras	101	214	296	166
Panicled dogwood (Grey Stemmed)	54	111	405	125

Table 6.--Number of standing dead trees per acre, by diameter class and geographic unit, Pennsylvania, 1989

Unit	Average number of dead trees, 5" d.b.h.+, per acre			
	5.0"-10.9"	11.0"-14.9"	15+"	All classes
Western	11.7	1.0	0.6	13.3
Southwestern	22.5	2.9	1.6	27.0
Allegheny	15.0	2.7	0.6	17.3
North-Central	14.8	1.9	0.7	17.5
South-Central	18.2	3.7	2.1	24.0
Northeastern	12.2	1.2	0.5	14.0
Pocono	17.8	1.5	0.4	19.7
Southeastern	14.7	1.7	0.8	17.2
State Average	16.6	1.9	0.9	18.4

Timber Inventory Volume and Biomass

Growing-Stock Volume

Since the first FIA survey of Pennsylvania in 1955, the volume of timber has been building. Timber volumes today have rebounded from lows reached around the turn of the century. Most of the Allegheny Plateau was clearcut during the period 1890 to 1920 (Marquis 1975). Our fundamental measure of timber volume is called growing-stock volume. It is the net-cubic foot volume of wood in the main stem of well-formed sound trees over 5 inches in diameter. Pennsylvania has more hardwood growing-stock volume than any other state (Fig. 17). Hardwood species represent 91 percent of the state's growing-stock volume. The volume for all species increased 19 percent since the 1978 survey, but this increase was not evenly distributed across the state. Volume in the Western Unit increased by 32 percent, but in the South-Central Unit it increased by only 6 percent (Fig. 18). The difference in species composition between the two units helps explain this. The leading species in the Western Unit are black cherry and red maple, which increased by 43 and 55 percent, respectively. This contrasts with the South-Central Unit where the leading species are chestnut oak, northern red oak, and the other oak group. These species decreased by 26, 7, and 6 percent, respectively--pointing out the impact that gypsy moth infestations, drought, salvage cutting, and high harvesting rate on oak species statewide have had on the South-Central Unit.

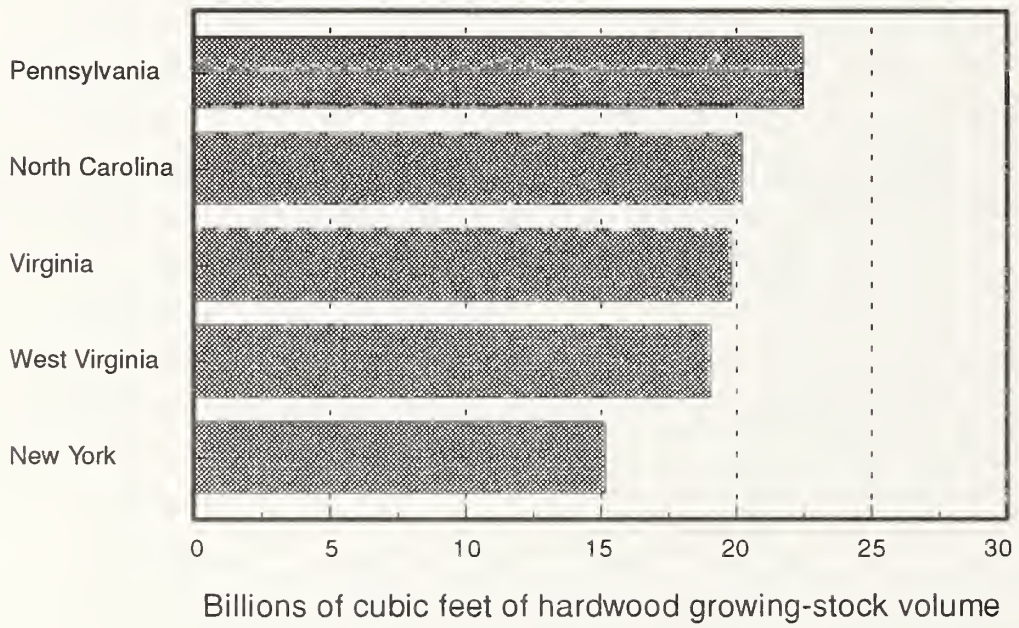

Figure 17. -- States with the largest hardwood inventory in the Nation, 1989.

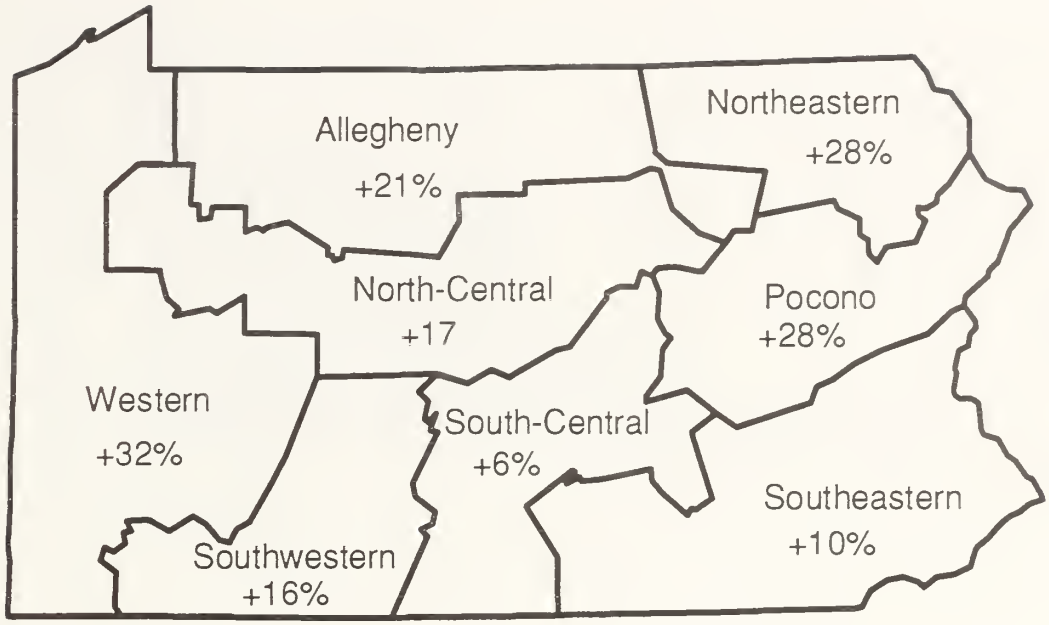

Figure 18. -- Percent change in growing-stock volume, by unit, Pennsylvania, 1989.

Figure 19 shows the 1978 and 1989 total volume for all species by diameter class. The difference between the two lines clearly indicates a volume increase. The 1989 inventory, is greater than the 1978 inventory for all diameter classes. The lines are very close together in the smaller diameter classes. The volume of trees in the 6-inch class increased by less than 1 percent, whereas the volume in the 20-inch class increased by 42 percent. In general, the larger the diameter, the larger the percentage increase in volume (Fig. 20), which characterizes a maturing resource. In Pennsylvania, most of the growth is occurring on the larger trees. Small increases in volume in the poletimber diameter classes can be attributed to a number of factors, including increased competition, gypsy moth defoliation, and drought. Also deer browsing of seedlings may have reduced the numbers of stems growing into this size class. Timber volumes vary across the state. Figure 21 shows the average growing-stock volume per acre of timberland by county. Highest volumes per acre occur in the Allegheny Unit. Potter and Forest Counties have the highest volumes, averaging almost 2,200 cubic feet per acre. The Allegheny Unit has a large portion of its timberland in public ownerships that have high volumes per acre. In the central part of the state, the rugged Ridge and Valley section generally has the lowest volumes per acre. Pennsylvania now averages 1,561 cubic feet per acre across the state; no county has less than 1,000 cubic feet per acre. This represents a vast improvement since the 1955 survey when the state averaged only 802 cubic feet per acre.

Timber volumes also vary by ownership, with the highest volumes per acre on the ANF and the lowest on private lands (Table 7). These differences reflect the different management philosophies of the owners and the productivity of the sites. Public lands are managed for many uses other than timber and have longer planning horizons than private ownerships. Studies of private landowners have concluded that over long periods of time, most merchantable timber growing on smaller nonindustrial private forests in areas with good markets will be harvested and sold, either by the person who has owned the tract for a considerable number of years or by a new owner (Clawson 1979). Volume on the ANF, averages 2,346 cubic feet per acre; the "other public" category (public ownership excluding national forest land) averages 1,666 cubic feet per acre statewide (2.6 million of the 2.9 million acres included here is either state forests or state game lands), and private ownerships average 1,508 cubic feet per acre.

Table 7.--Volume per acre (cubic feet), by ownership class and geographic unit, Pennsylvania, 1989

Unit	National forest	Other public	Forest* industry	Other private	All classes
Western	--	1,663	--	1,365	1,379
Southwestern	--	1,259	2,274	1,511	1,464
Allegheny	2,346	2,288	2,022	1,883	2,070
North-Central	--	1,614	1,279	1,526	1,547
South-Central	--	1,414	1,349	1,332	1,353
Northeastern	--	1,742	2,442	1,522	1,562
Pocono	--	1,189	2,658	1,365	1,338
Southeastern	--	1,592	1,983	1,670	1,661
State Average	2,346	1,669	1,955	1,507	1,581

*This ownership class has high sampling errors because of low acreage.

Although the 1989 survey identified 90 different tree species, many are not very common. The 10 most common species account for more than three-fourths of the growing-stock volume. All of these, except eastern hemlock, are hardwoods (Fig. 22). The top 10 species (by volume) has not changed since the last survey, but the ranking has. Black cherry has moved ahead of sugar maple to the number three spot, and eastern hemlock has jumped two places from 10th place to 8th place.

Red maple led the state in volume in the 1965 survey and has consistently increased its lead. Since 1978, it has increased by 37 percent in growing-stock volume. This is an increase of 1.2 billion cubic feet, which is twice the volume increase of its nearest rival (in growth), black cherry. Red maple is widely distributed, an aggressive competitor, and not heavily cut. It will, no doubt, continue to lead the state in volume. Other species in the top 10 that are coming on strong are hemlock, up by 44 percent; black cherry, up by 33 percent; and white ash, up by 32 percent. Species not in the top 10 with large volume increases are black gum, up by 53 percent; sweet birch, up by 38 percent; aspen, up by 38 percent; and yellow-poplar, up by 31 percent.

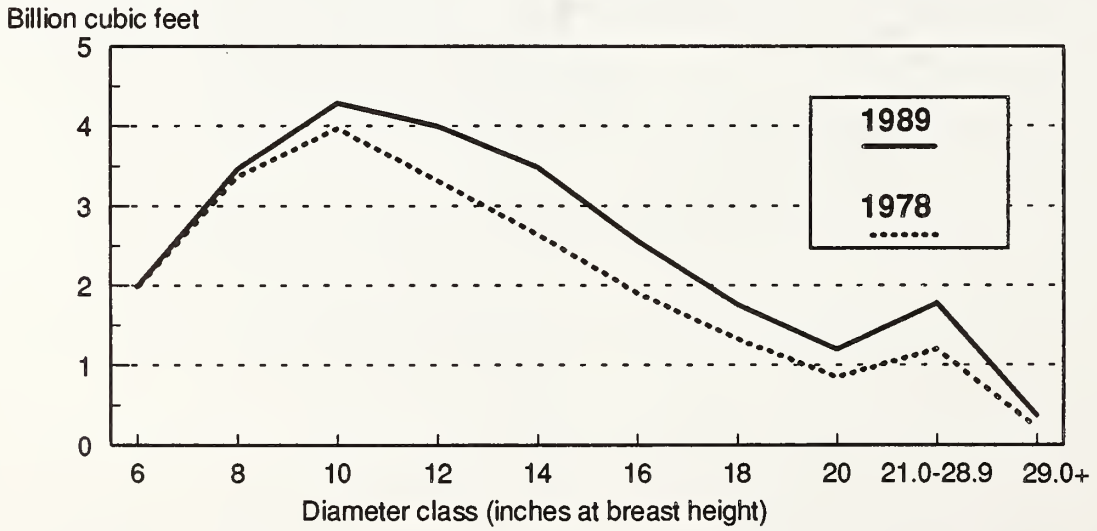

Figure 19. -- Volume of growing-stock trees on timberland by diameter class, Pennsylvania, 1978 and 1989.

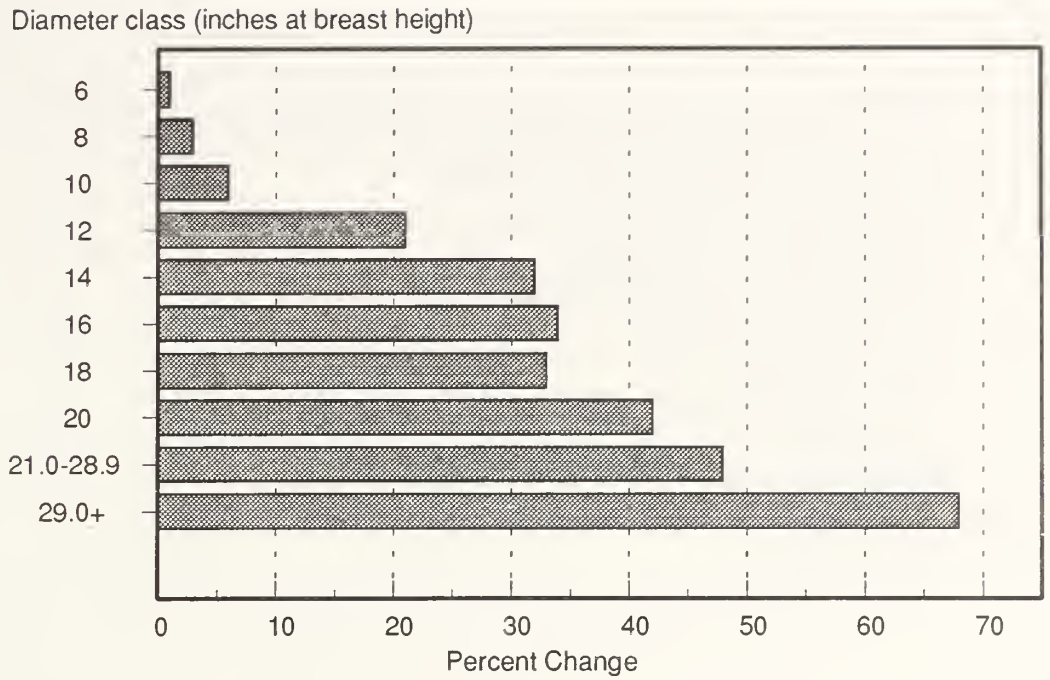

Figure 20. -- Change in Volume of growing-stock trees by d.b.h. class, on timberland, Pennsylvania, 1978 and 1989.

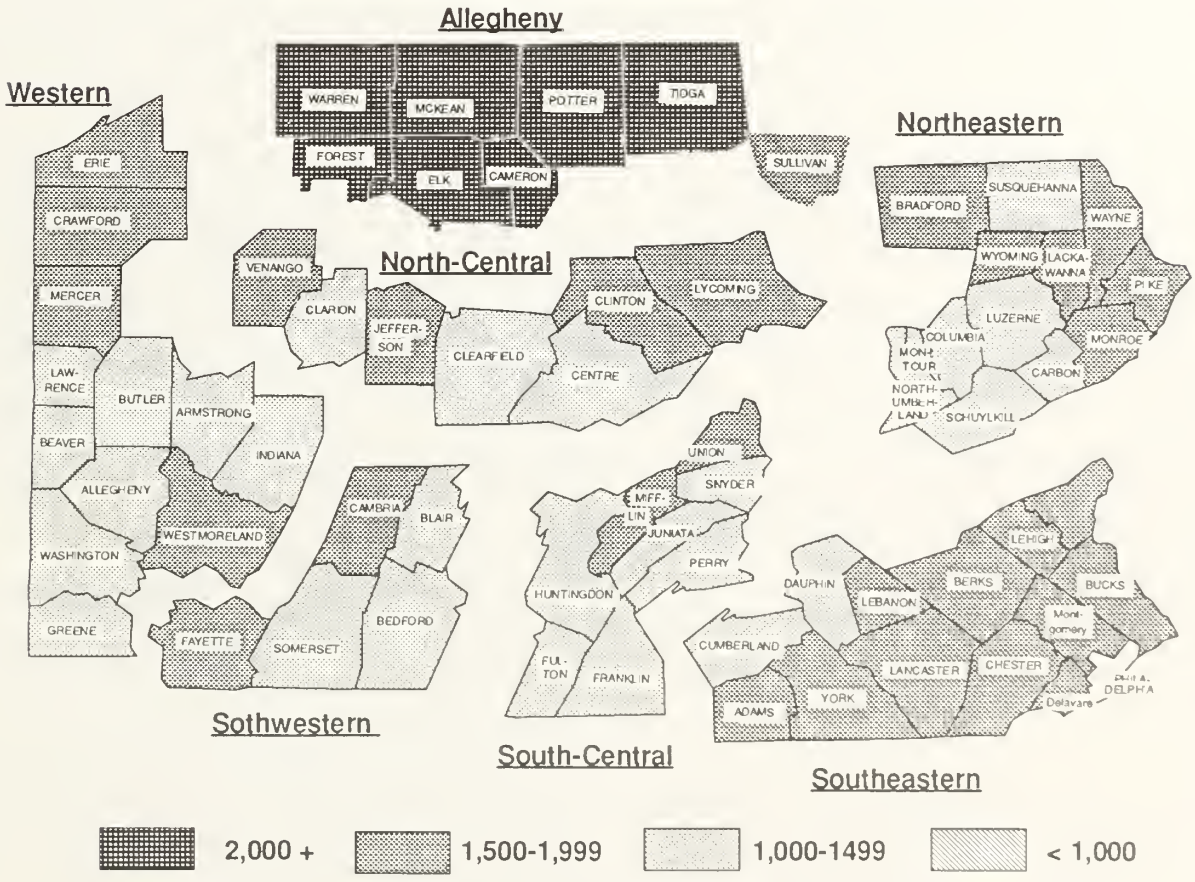

Figure 21. -- Average growing-stock volume per acre of timberland, by county, Pennsylvania, 1989.

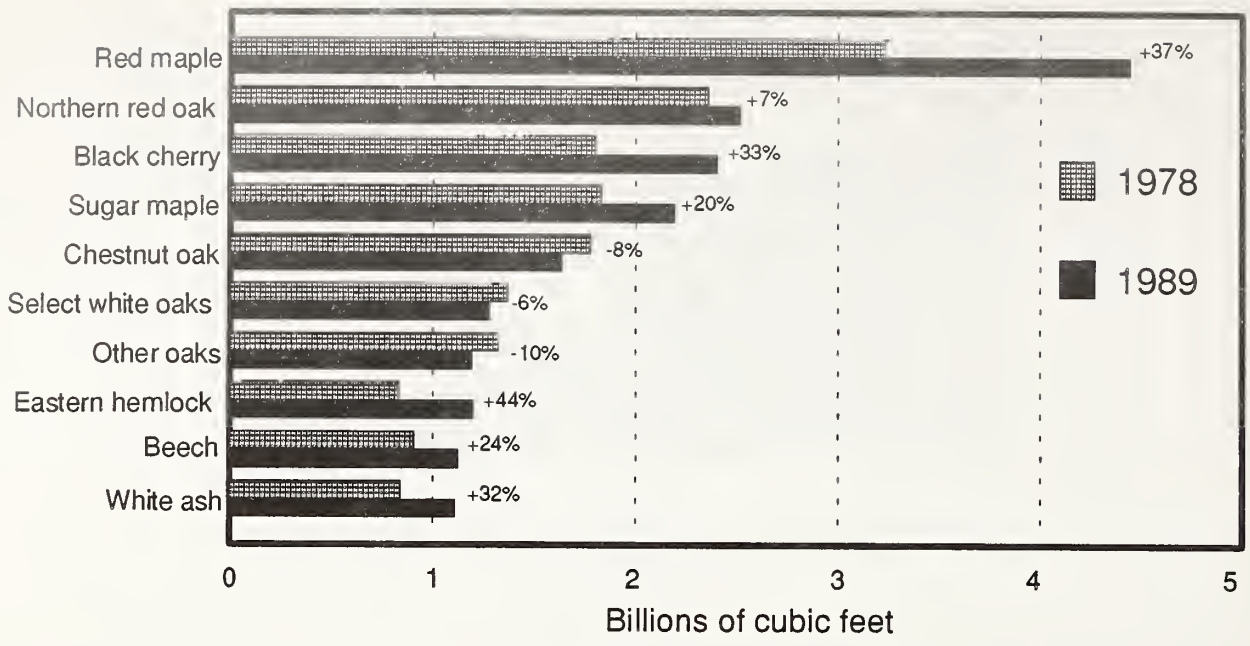

Figure 22. -- Change in volume of top 10 species in Pennsylvania, 1978 and 1989.

Generally, oaks have done poorly in the state, being the only major species group suffering a decrease since 1978. Combined, oaks comprise 27 percent of the growing-stock volume, down from 33 percent in 1978. High mortality and reductions in growth caused by gypsy moth and drought, high cutting rates, and low ingrowth due to heavy deer browsing on oak regeneration have all had negative impacts on the oaks. Few stands in the Alleghenies contain a sufficient number of oak seedings to regenerate oak after cutting (Marquis, et al. 1992). Nevertheless, northern red oak, in spite of a relatively small increase, maintained its number two ranking in total volume. Chestnut oak, white oak, and the "Other oak" group, which is mostly black oak, all show decreases in volume between surveys. All oak volume decreased by 3 percent between surveys.

To better illustrate what is going on with oaks, a look at the number of trees across diameter classes is helpful (Fig. 23). Graphs of the number of trees by diameter normally assume a reverse "J" shape; that is, many trees appear in the smaller diameter classes with gradual declines in numbers as diameter increases. Red maple and black cherry assume a reverse "J" shape, but for northern red oaks, the line is nearly flat across all diameter classes. This points out the magnitude of the regeneration problem with the oaks: there are not many oaks in the smaller diameter classes. Regeneration data analyzed by Nowacki and Abrams (1991) on undisturbed oak stands in central Pennsylvania suggest that succession to more shade-tolerant species, primarily red maple, is occurring in all but the most xeric oak stands.

Even though the volume of oak has declined significantly in some units, the total volume of all species combined is up across the state. Other species have responded to openings created by high oak mortality and cutting. Species other than oak have had large increases in volume where oaks have done poorly (Fig. 24). Primary among these is red maple, which by itself more than offset the losses in oaks. Red maple had its largest percentage increase (64 percent) in the South-Central Unit where oaks suffered a loss of 14 percent.

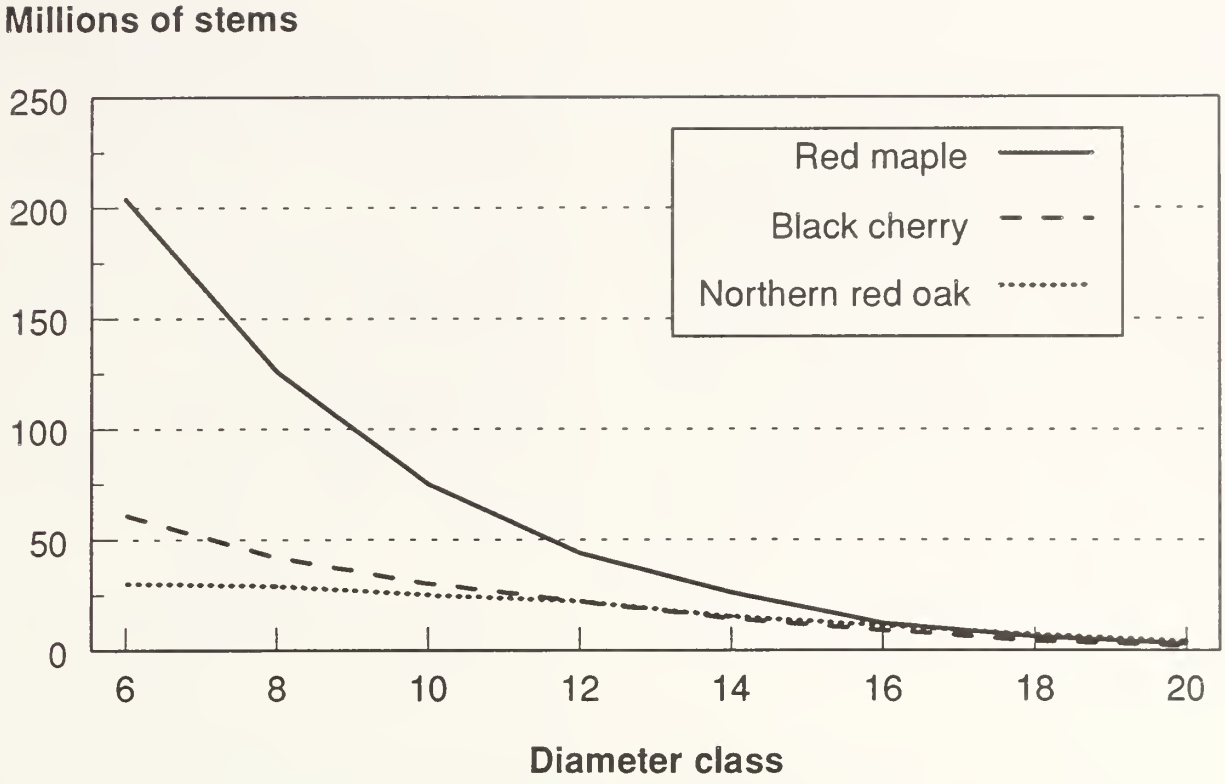

Figure 23. -- Number of live trees by diameter class for red maple, black cherry, and northern red oak, Pennsylvania, 1989.

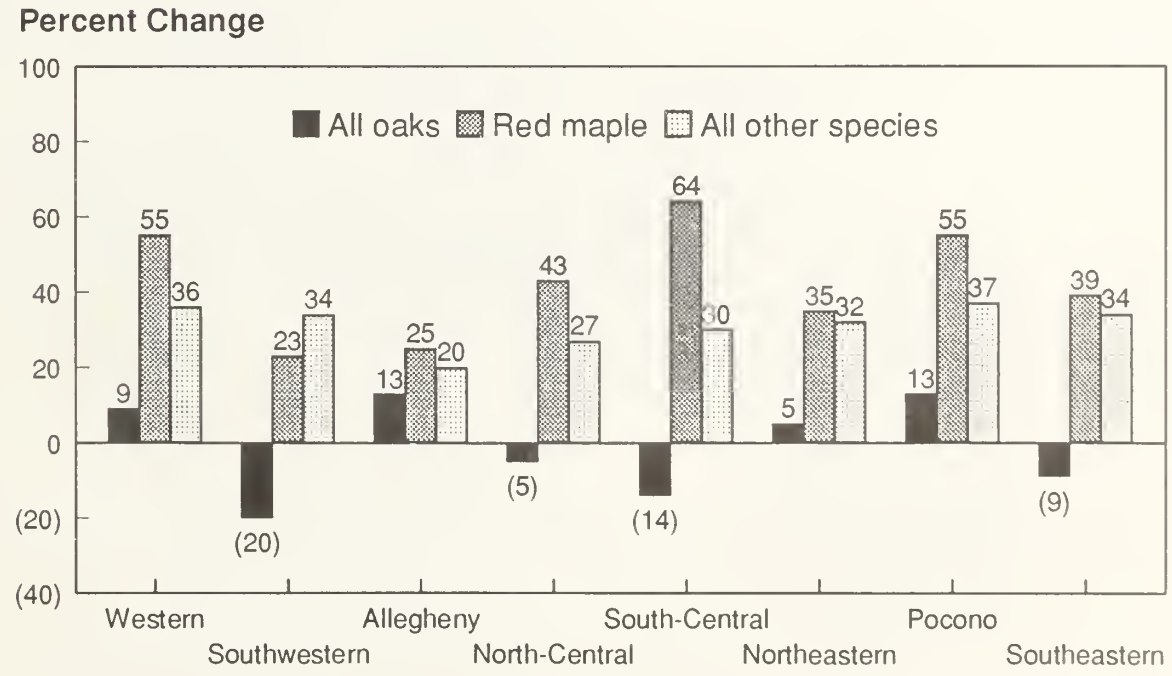

Figure 24. -- Comparison of changes in growing-stock volume between all oaks, red maple, and all other species, by unit , Pennsylvania, 1978-89.

Board-Foot Volume

In Pennsylvania, the total board-foot volume for all species increased by 39 percent to 66.7 billion board feet (international 1/4-inch role). If only changes in board-foot volume are considered, the outlook for Pennsylvania's forests is good. But, because so much of the timber growth is being concentrated on the sawtimber-size trees, this measure of volume can be misleading. It does not include the poletimber-size classes, which had small increases. Ninety-four percent of the increase in volume between inventories occurred in the sawtimber-size classes. All the major species recorded increases in board-foot volume (Fig. 25). Although not expressed in this figure, oaks showed losses in some subregions. In terms of board-foot volume, the list of the top 10 species is a little different from that for all growing-stock volume. White ash drops out and yellow-poplar comes in. Black cherry had the highest percentage increase in board-foot volume (up by 66 percent), followed closely by red maple (up by 65 percent).

Percentage increases in board-foot volume occurred in all units of the state and were greater than those in growing-stock volume (cubic-foot volume) (Fig. 26). Units with increases below the state average (39 percent) were pulled down by losses in the oaks. The South-Central Unit--where again losses to gypsy moth defoliation, drought, and other agents was most severe--had the smallest increase.

Slightly more than half the black cherry sawtimber is located in the Allegheny Unit, much of it growing in overstocked, even-aged stands approaching 90 years of age. Marquis (1990), in "Silvics of North America," states: "Beyond age 80 to 100 years, diameter growth slows, mortality of cherry increases rapidly and the importance of the species in the stand declines". This could become a serious issue in the near future, as stands of this pioneer species reach biological maturity.

All oaks were up by 14 percent in board-foot volume. Included in this volume, northern red oak had the largest increase--up by 23 percent across the state. Oaks did poorest in the Southwest Unit, where they accounted for almost half the 1978 board-foot volume. Oaks decreased here by 10 percent in sawtimber volume and 20 percent in cubic-foot volume between surveys. The biggest declines were in the poletimber-size; classes, hence, the larger percentage decrease in cubic-foot volume.

The distribution of species varies by unit across the state. Figure 27 shows the top three species in sawtimber volume for the eight geographic units. Here again, the prevalence of red maple is striking. Red maple ranks first or second in six of the eight units. The oaks still are the most abundant species in the South-Central Unit and yellow-poplar leads the Southeastern Unit. Yellow-poplar has shown some large increases across the state, but because it does not grow in abundance in the northern part of the state, it does not rank in the top 10 species statewide. Yellow-poplar is resistant to gypsy moth defoliation and grows quickly. Black cherry grows best in the Allegheny unit, where it has increased by 55 percent in board-foot volume between inventories. Here it ranks second to red maple in volume.

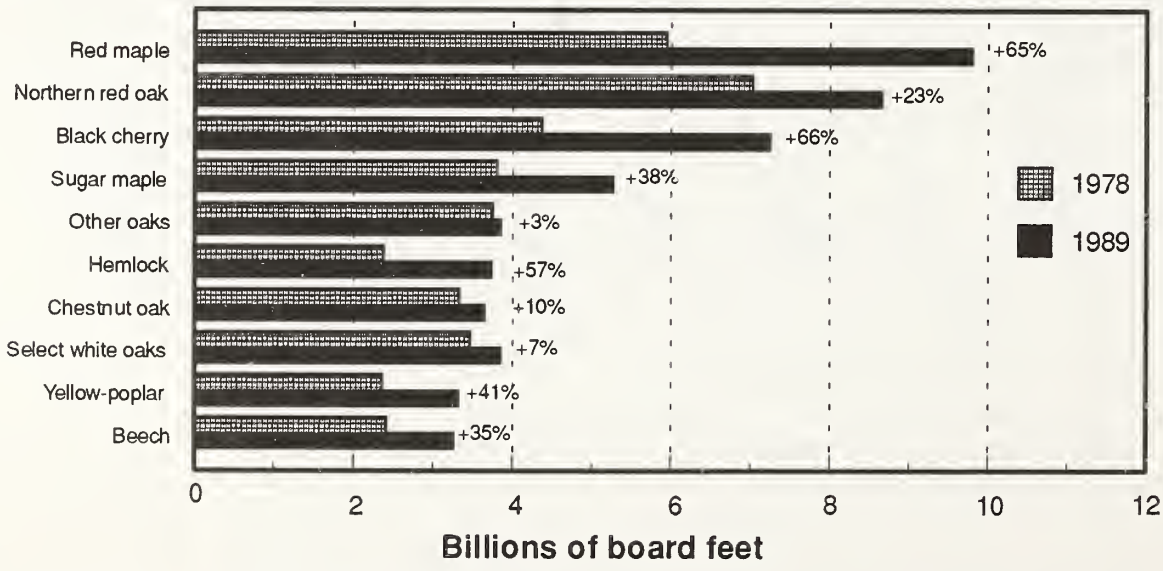

Figure 25. -- Change in board-foot volume of major species, Pennsylvania, 1978 and 1989.

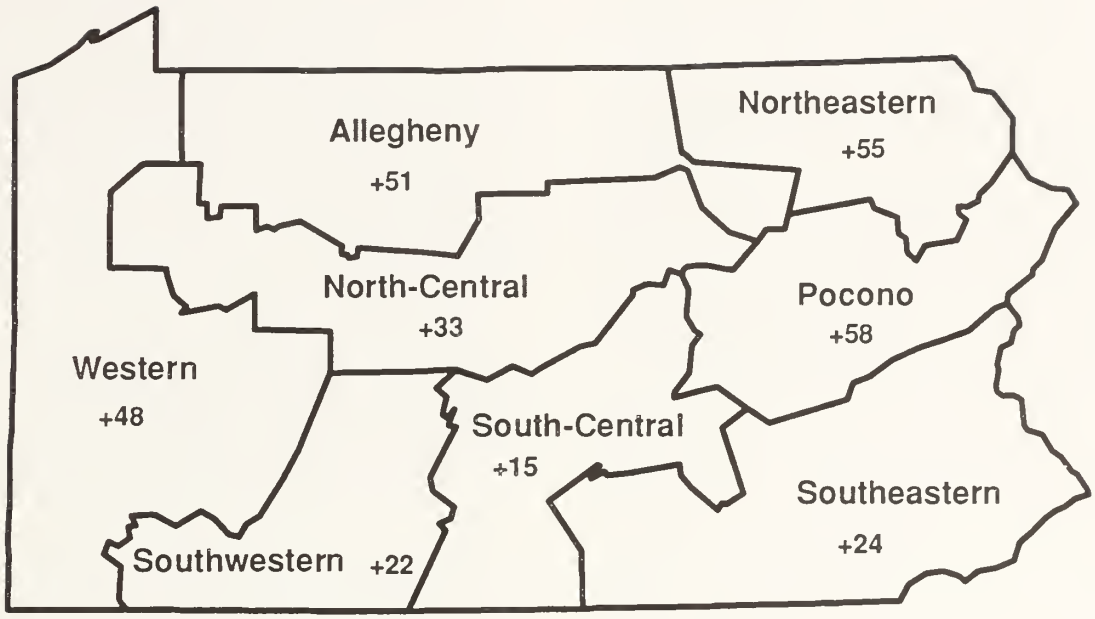

Figure 26. -- Percent change in total board-foot volume, by unit, Pennsylvania, 1978-89.

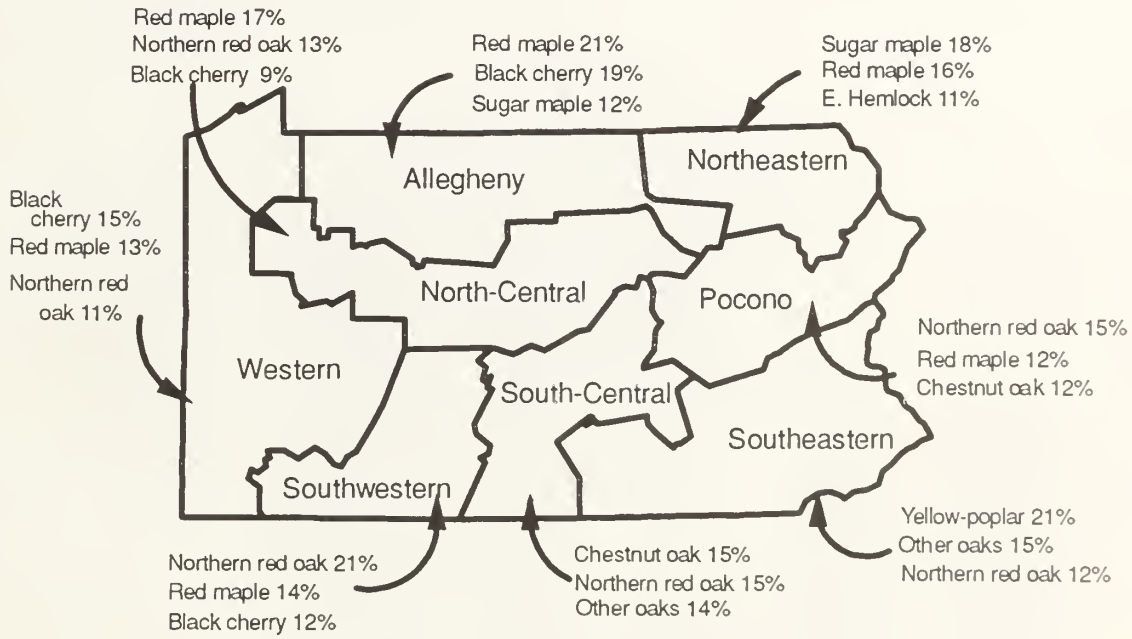

Figure 27. -- Top three sawtimber species and percent of total board-foot volume, by unit, Pennsylvania, 1989.

Pennsylvania's hardwood sawtimber volume totals 59.5 billion board feet. The use of this resource is determined to a large extent by the quality of the trees--the best trees are used for furniture, cabinets, and other millwork; and the lower quality trees used for pallets, pulpwood, and particle board. Quality is indicated by the tree grade assigned each tree on inventory sample plots. Tree grade is based on the number of clear surfaces, amount of cull, and diameter of the butt log of the tree. Tree Grade 1 yields the most high grade lumber and Tree Grade 5 the least. Ten percent of the total sawtimber volume is contained in trees with a Tree Grade of 1, 20 percent in Tree Grade 2, 39 percent in Tree Grade 3, and 31 percent in Tree Grades 4 and 5 combined. The quality of trees varies with species. Figure 28 compares tree grades for five major Pennsylvania species. In this chart, only trees greater than 15 inches in diameter are used in order to reduce the influence that size alone has on the quality of small sawtimber-size trees. Sixty percent of the northern red oak volume was in trees with Tree Grade 2 or better, whereas only 23 percent of the red maple volume is in the better grades. These differences in grade between species have important implications for the future supplies of high-quality lumber. Future forests will contain significantly more red maple sawtimber volume and a lower proportion of oak species; so, the yield of high-quality lumber from these forests will not increase proportionally with increases in total volume because of differences in species characteristics.

Shade-tolerant species tend to retain their lower limbs longer, thereby reducing the yield of high-quality lumber; whereas shade-intolerant species naturally prune their limbs at an earlier age, producing fewer and smaller knots. In general, the more shade-tolerant species, such as red maple do not grade out as well as the intolerant species such as red oak. The utilization of low-quality trees has been a persistent problem for forest managers, and these problems will probably increase along with the increases in red maple volume.

Because it is important to measuring trends in the quality of the timber resource, FIA measured the log grade of sample trees during the last two surveys to capture the trend. Ordinarily, tables showing volume by log grade for two surveys could be computed and compared. Such is not true for the latest statistical report for Pennsylvania. Tables presenting volume by log grade for only the last inventory were published (Alerich 1993). After field work was completed for the latest inventory, it was discovered that the trends in log grade were not consistent with the previous inventory (Considine and Powell 1980). Although field crews used the same log-grading standards at both occasions, the standards were applied differently in each of the two surveys. Field crews received more training, and much greater emphasis was placed on quality assurance during the 1989 survey; so, it is felt the latest data are more valid and analyses of change in quality based on previous log-grade data should be avoided.

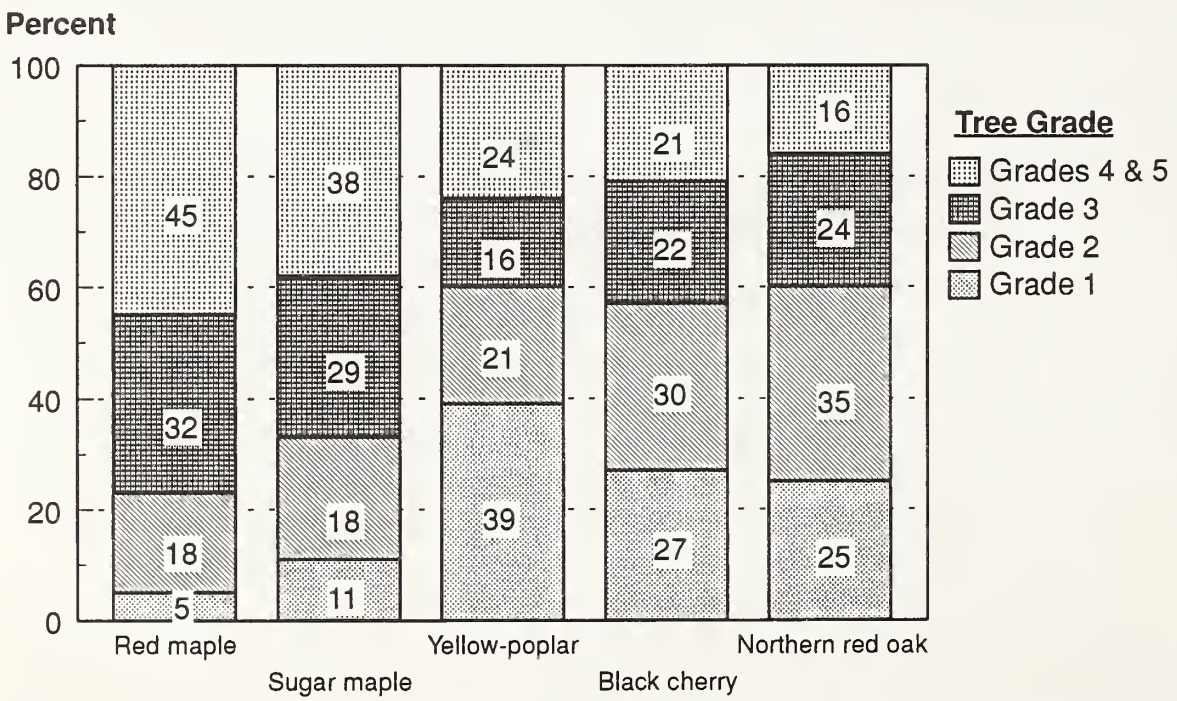

Figure 28. -- Percentage of sawtimber volume in each tree grade, for trees 15 inches and greater in diameter, top five species, Pennsylvania, 1989.

Estimates of Total Biomass

Biomass estimates have become important because of the role of forests in carbon sequestration and as a source of energy. Woody biomass includes the total weight of all trees at least 1.0 inch d.b.h.; included are salvable dead trees, rough and rotten trees, the upper stems and branches of growing stock trees, and noncommercial species such as chokecherry and gray birch; excluding fruits, leaves, stumps, and roots. Trees play an important part in the world's carbon cycle. They act as a sink for carbon, removing carbon from the atmosphere in the form of carbon dioxide (a greenhouse gas) and storing it in the form of cellulose. In this role, forests help mitigate the effect of burning fossil fuels and the resulting global climate changes associated with increased levels of carbon dioxide in the atmosphere.

Biomass is also a renewable energy source with the potential to provide more of our energy needs in the future. In some areas of the country, the use of biomass to fuel commercial power generating plants has provided markets for low-grade rough-and-rotten trees; and in Pennsylvania research has been done on the feasibility of using fast-growing genetically improved tree species to grow in plantations to produce fuel wood. But to date, the commercial use of biomass for fuel has been insignificant in Pennsylvania.

The total dry weight of all biomass on Pennsylvania's timberland is 925 million tons (net dry weight); averaging 58 tons per acre. The majority (63 percent) is contained in the growing-stock portion of commercially important trees. But woody material other than growing stock contributes a substantial amount of additional material to total biomass. The largest share of this comes from the upper stem and branches of growing-stock trees (Fig. 29). The growing-stock portion of biomass is valued for conversion to higher value wood products, but the underutilized nongrowing-stock portion is considered a potential source of fuel for commercial power generation. Most of this is now left in the woods after harvesting operations as logging residues or slash.

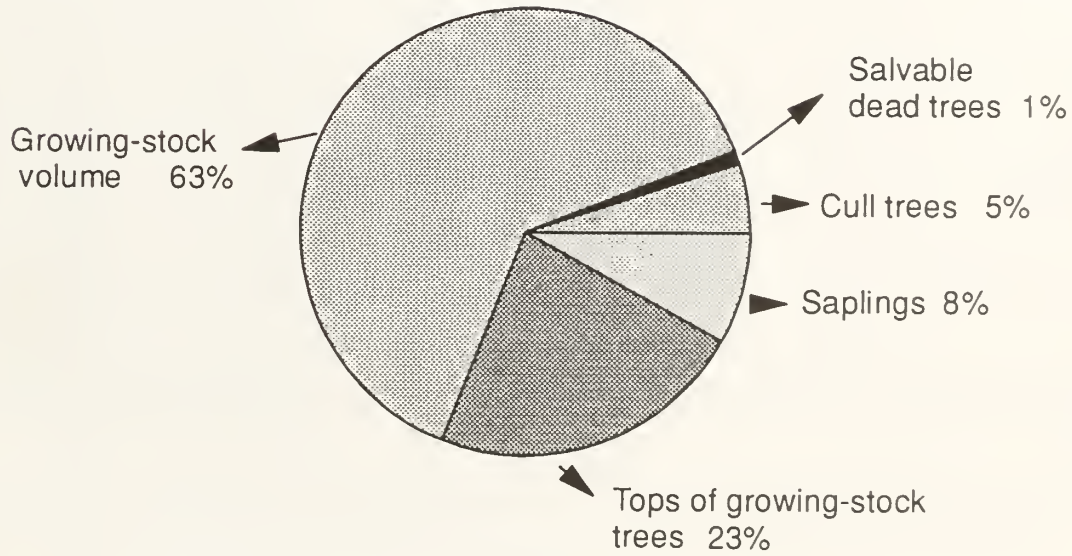

Figure 29. -- Biomass of all trees on timberland by class of material, Pennsylvania, 1989.

Components of Inventory Change

Growth Outpaces Removal

Pennsylvania has experienced a sizable increase in growing-stock and sawtimber volumes. A look at the components of inventory change help to understand the changes. Between 1977 and 1988, annual net growth for all growing stock species was 618.5 million cubic feet and for the top 10 species, 462.3 million cubic feet (Table 8). Net growth includes accretion (growth on the initial inventory), ingrowth (volume of trees that grew large enough to measure), mortality, and changes in cull volume. The average annual removals (or cut) for all species between surveys was 289.1 million cubic feet. Dividing the average net growth by the average removals gives an annual growth to removals ratio of 2.1 to 1; that is, on average, Pennsylvania grew slightly more than 2 cubic feet of timber for each cubic foot cut. Therefore, the inventory in stands across the state increased by 329.3 million cubic feet annually. Surplus growth over harvest has been accumulating in the forest since the first FIA inventory in 1955, and today's well-stocked forests are a product of these steady improvements over time.

Growth to removals ratios vary considerably between species. Red maple's high growth and relatively low removals give it a growth-to-removals ratio of more than 4 to 1. This is more than twice the average for all species, and much higher than the oaks. The oaks have low growth rates (due to high mortality and low ingrowth) and high removal rates; so, the growth to removal ratio for oaks is far below the average for all species. Comparing individual species to the all-species average ratio (2.1 to 1) gives an indication of which species are increasing in importance and which are decreasing. Red maple clearly will play a larger roll in Pennsylvania's forests especially as the oaks continue to fade in importance.

Table 8.--Average annual net growth, removals, and change in growing-stock volume, Pennsylvania, 1977-88

Top 10 species	Net growth	Removals	Growth/ Removals	Net Change
	(Million cubic feet)	*(Million cubic feet)*	*(Ratio)*	*(Million cubic feet)*
Red maple	128.0	(30.3)	4.2:1	97.7
Northern red oak	59.4	(46.6)	1.3:1	12.8
Black cherry	79.8	(29.8)	2.7:1	49.9
Sugar maple	52.1	(22.0)	2.4:1	30.1
Chestnut oak	12.3	(23.4)	0.5:1	(11.1)
Select white oaks	15.4	(22.6)	0.7:1	(7.1)
Other oaks	16.3	(26.7)	0.6:1	(10.1)
Hemlock	37.8	(8.1)	4.7:1	29.8
Beech	27.7	(10.2)	2.7:1	17.5
White ash	33.5	(11.6)	2.9:1	21.9
Total	462.3	(231.3)	2.0:1	33.5
Total all growing stock	618.5	(289.1)	2.1:1	329.3

Species Differ In Rates of Annual Change

Annual changes in net growth and removals data also can be expressed as a percentage of growing-stock inventory (Table 9). All growing stock grew by an average of 2.7 percent per year between inventories; the average annual harvest equaled 1.3 percent of the inventory. Subtracting the removals from the growth gives the change in inventory per year. On average, growing-stock volume increased by 1.4 percent per year between 1977 and 1988.

Among the top species in volume, black cherry had the highest growth rate (3.8 percent) followed closely by hemlock (3.7 percent). However, because black cherry had a higher removals rate, hemlock led in net change per year, averaging an increase of 2.9 percent per year. Chestnut oak, select white oaks, and other oaks had the only negative net changes. Yellow-poplar, although not on the top 10 species list, had a remarkable growth rate. It grew at a rate of 4.4 percent, and with annual removals of 2.2 percent, its average net change per year was 2.2 percent.

In terms of volume change, the South-Central, Southwestern, and Southeastern Units fared worse than other units (Table 10). Each of these units had higher mortality rates (a component of net growth) and higher removal rates than the state averages, resulting in lower increases in volume. The South-Central unit had the lowest net change-- 0.5 percent per year. Surprisingly, the Southeastern Unit had the highest removal rate in the state. This densely populated area has had many restrictions put on timber harvesting through local town ordinances. The 1978 inventory also showed this area to have the highest average sawtimber volume per acre in the state with a large portion of this volume in the more valuable oak species. Apparently the high value of trees combined with easy access made possible by an extensive road network more than offset the effects of restrictions on cutting in the Southeastern Unit.

Table 9.--Average annual net growth, removals, and change in growing-stock volume, per year, in percent, Pennsylvania, 1977-88

Top 10 species	Net growth	Removals	Net change
	(Percent per year)		
Red maple	3.3	0.8	2.5
Northern red oak	2.4	1.9	0.5
Black cherry	3.8	1.4	2.4
Sugar maple	2.6	0.1	1.5
Chestnut oak	0.7	1.4	-0.7
Select white oaks	1.2	1.7	-0.5
Other oaks	1.3	2.1	-0.8
Hemlock	3.7	0.8	2.9
Beech	2.7	1.0	1.7
White ash	2.7	1.0	1.7
Total all growing stock	2.7	1.3	1.4

Table 10.--Average annual mortality, removals, net growth, and change in growing-stock volume, per year, in percent, by geographic unit, Pennsylvania, 1977-88

Geographic units	Mortality	Net growth	Removals	Net Change
	(Percent per year)			
Western	0.6	3.8	1.5	2.3
Southwestern	1.2	2.2	1.5	0.7
Allegheny	0.6	2.6	1.0	1.6
North-Central	0.9	2.6	1.3	1.3
South-Central	1.1	1.9	1.4	0.5
Northeastern	0.5	3.1	1.1	2.0
Pocono	0.7	2.9	0.9	2.0
Southeastern	0.9	2.5	1.7	0.8
Average	0.8	2.7	1.3	1.4

Robust Timber Industry

Pennsylvania has more than 1,500 primary wood processors. These include sawmills, pulpmills, veneer mills, and other manufacturing facilities that convert roundwood (logs, bolts, and other wood harvested from the forest) into products such as lumber, pulp, and veneer. Sawmills are located across the state and are a principal employer in many small rural towns. Milling capacity is concentrated in the heavily forested Allegheny, North-Central and South-Central Units. But, nearly every county in the state has at least one sawmill.

To complement forest inventories, a complete canvass of the primary wood-using mills was conducted during 1976 and 1988 (Bones and Sherwood 1979; Wharton and Bearer 1993). These studies determined the quantity and types of industrial products produced from Pennsylvania's forests. Complete results of the 1988 study are reported in "The Timber Industries of Pennsylvania, 1988" (Wharton and Bearer 1993).

The 1988 mill canvass revealed that the majority of the commercial timber harvested in Pennsylvania went to sawmills (Fig. 30). Sawlogs accounted for 70 percent of the harvest and pulpwood accounted for 25 percent. The remaining 5 percent was divided between many other uses including veneer logs, mine timbers, cabin logs, cooperage, and bat and handle stock. Between 1976 and 1988, the annual harvest of sawlogs rose by 68 percent to reach nearly 1.1 billion board feet, and the pulpwood harvest rose by 14 percent to total 673,000 cords. Additionally, pulpmills received the equivalent of 421,000 cords of pulpwood in the form of chipped sawmill residues from Pennsylvania sawmills in 1988. Availability of sawmill residues has reduced the need for pulpmills to cut roundwood from the forest. As the harvest of sawlogs has risen, pulpmills have begun to rely more heavily on chipped residues as a source of pulpwood.

The 1988 sawlog harvest was predominantly hardwood species (96 percent), with oak accounting for 57 percent of the total log production. The 612 million board feet of oak harvested was twice the amount harvested in 1978 when oaks accounted for 50 percent of the sawlog harvest. In the long run, the harvest of a species tends to be related to its abundance in the resource base. But, in 1989 oaks represented only 27 percent of the growing-stock volume and 30 percent of the board-foot volume. The higher percentage of oak in the harvest and considerably lower portion of oak in the resource base points to an imbalance in the species composition of the sawlog harvest with respect to the resource base. The current mix of species being harvested puts heavy cutting pressure on the oaks and encourages the growth of other less desirable species such as red maple. A sustainable harvest of oak at present levels is doubtful, while other underutilized species continue to increase their portion of the resource base. Red maple volume had its largest increases in areas where oak species comprised a large portion of the harvest. This is illustrated in the South-Central Unit, where between inventories red maple growing-stock volume increased by 63 percent and the sawlog harvest consisted of 68 percent oak species.

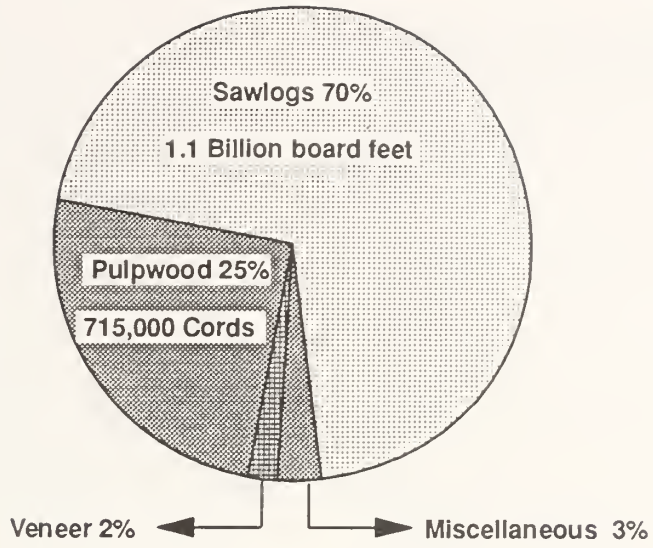

Figure 30. -- Distribution of harvest by major industrial product, Pennsylvania, 1989.

Distribution of Harvest Uneven

Where harvesting is taking place is important in understanding Pennsylvania's forests and its management. The latest inventory remeasured about 2,000 permanent inventory plots. These plot records give a tree-by-tree history of removals for stems that were alive and 5 inches and larger in d.b.h. at the time of the previous inventory in 1978. The data provide an opportunity to analyze where cutting activity is taking place on timberland.

Even with the increase in harvesting, timber cutting continues to be a fairly concentrated activity. Remeasured data indicate that only 30 percent of the state's timberland had cutting during the 12 years between inventories (Table 11) (Gansner et al. 1993a); and of those acres where harvesting did take place, only a small portion of the original basal area was removed; that is, live trees 5 inches and larger in d.b.h. at the time of the previous 1978 inventory. On two-thirds of the harvested acres (20 percent of total timberland), less than 40 percent of the original basal area was removed. But on 7 percent of the acres harvested (2 percent of total timberland), 80 percent of the original basal area was removed. Statewide, about 12 percent of the original 1978 basal area was removed, amounting to an average cutting rate of about 1 percent per year.

All parts of the Commonwealth contributed to the cut, but regional shares varied. More than two-fifths of the cut came from the Allegheny and North-Central Units where much of the state's forest industry and timber resource are located. The Pocono Unit, not particularly known for its timber, produced only 5 percent of the total. Rates of cutting were highest in the South-Central and Southwestern Units where loggers have been salvaging oak mortality. In the Pocono Unit, the cutting rate was far below the state average (Table 12) (Gansner et al. 1993a). From the data collected during the remeasurement of plots, there is no way to determine if a harvested tree was alive or dead when cut. For the most part, dead trees contribute very little to the total harvest, but this was probably not true in the South-Central and Southwestern Units, where large amounts of standing dead and dying trees were salvaged during gypsy moth outbreaks that occurred between inventories.

Nonindustrial private forest-land owners own most of Pennsylvania's timber, so it should come as no surprise that they account for most of the cutting (Table 13) (Gansner et al. 1993a). The rate of cutting on federal lands was slightly higher than the state average.

Together, cutting on public land accounted for 17 percent of the harvest. This compares with public ownership accounting for 21 percent of the timberland. Cutting rates were much lower than average on state forest and other public holdings.

Table 11.-- Distribution of harvest on timberland by basal area removed, in percent, Pennsylvania, 1978-89

Basal Area removed	Timberland affected
	(Percent)
0	70
1-19	12
20-39	8
40-59	5
60-79	3
80+	2
Total	100

Table 12.-- Distribution and rate of cutting on timberland by unit, Pennsylvania, 1978-89

Unit	Distribution of total basal area in state	Distribution of total cut	Rate of Cutting
	Percent		*Percent of basal area cut per year*
Western	14	14	1.0
Southwestern	10	12	1.1
Allegheny	25	23	0.9
North-Central	17	18	1.0
South-Central	11	14	1.2
Northeast	8	8	0.9
Pocono	8	5	0.6
Southeastern	7	6	0.8
Total	100	100	1.0

Table 13.--Distribution and rate of cutting on timberland, by ownership, Pennsylvania, 1978-89

Owner	Distribution of total basal area in state	Distribution of total cut	Rate of cutting
	Percent		*Percent of basal area cut per year*
Federal	4	5	1.1
State forest	9	5	0.5
Other public	11	7	0.6
Forest Industry	5	5	1.0
Other private	71	78	1.0
Total	100	100	1.0

Conclusion

Pennsylvania's forests are maturing, as evidenced by more sawtimber stands, larger trees, higher volumes per acre, and changes in species composition toward more shade-tolerant species. Although it is natural for shade-tolerant species to increase in a maturing forest, higher cutting rates for the shade-intolerant species and oak mortality caused by gypsy moth have probably accelerated the process. All the changes that will occur with maturing are unpredictable because information on what occurs as hardwood forests mature over large areas is lacking. As many stands of trees approach 90 years old and beyond, we are sailing into uncharted territory. But we can be certain that changes will continue to occur.

We can speculate about the future. It would seem that species with lower relative value, such as red maple, beech, and hemlock, will increase, while the higher value oaks will continue to lose ground. The plentiful supply of oak that industry has enjoyed is not being replaced in large enough quantities to sustain current cutting rates. This is evidenced by the lack of oak in lower diameter classes and shifts in species composition. But, oak volumes still represent a viable resource base with 27 percent of the growing-stock volume and 30 percent of the board-foot volume. The inventory of all species combined is up and should continue to increase. We are growing timber at twice the volume being cut. Forest stocking continues to improve, and the majority of the growth is on larger, more valuable sawtimber-size trees. Changes in species composition have made the forests less susceptible to gypsy moth defoliation. This should result in lower mortality and thus an increase in growth. Industry is already adapting to changes in species composition. New uses are being found for red maple and other species with limited markets. This should lead to a better balance between species being harvested and those growing in the forest. Red maple, once considered a "junk tree," is now in demand and its price is up. Certainly, a red flag should be raised for the oak situation. But the forests still have much untapped potential. New programs that aim to improve forest management, by focusing on better stewardship, enhancing biodiversity, improving wildlife habitat, and developing recreational opportunities can shape tomorrow's forest so as to provide more of the benefits the people of Pennsylvania have come to expect from their precious resource.

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Definition of Terms

Accretion. The estimated net growth on growing-stock trees that are measured during the previous inventory (divided by the number of growing seasons between surveys to produce average annual accretion). It does not include the growth on trees that were cut during the period, nor those trees that died.

Basal-area class. A classification of forest land in terms of basal area (cross-sectional area of a tree stem at breast height in square feet per acre) of all live trees of all sizes.

Board foot. A unit of lumber measurement 1 foot long, 1 foot wide, and 1 inch thick, or its equivalent.

Board-foot stand-volume class. A classification of forest land in terms of net board-foot volume of sawtimber trees per acre.

Commercial species. Tree species currently or prospectively suitable for industrial wood products; excludes species of typically small size, poor form, or inferior quality, such as hawthorn and sumac.

County and municipal lands. Lands owned by counties and local public agencies or municipalities or leased to them for 50 years or more.

Cropland. Land that currently supports agricultural crops including silage and feed grains, bare farm fields resulting from cultivation or harvest, and maintained orchards.

Cubic-foot stand-volume class. A classification of forest land in terms of net cubic-foot volume of all live trees per acre.

Cull decrement. The net volume of rough or rotten trees in the previous inventory that became growing-stock trees in the current inventory (divided by the number of growing seasons between surveys to produce average annual cull decrement).

Cull tree. A rough tree or a rotten tree.

Cull increment. The net volume of growing-stock trees in the previous inventory that became rough or rotten

trees in the current inventory (divided by the number of growing seasons between surveys to produce average annual cull increment).

Diameter at breast height (d.b.h.). The diameter outside bark of a standing tree measured at 4-1/2 feet above the ground.

Dry ton. A unit of measure of dry weight equivalent to 2,000 pounds or 907.1848 kilograms.

Dry ton stand-volume class. A classification of forest land in terms of net dry weight of the aboveground components of all live trees per unit area; usually expressed in dry tons per acre.

Dry weight. The weight of wood and bark as it would be if it had been oven-dried; usually expressed in pounds or tons.

Farmer-owned lands. Lands owned by farm operators, whether part of the farmstead or not; excludes land leased by farm operators from nonfarm owners.

Federal lands. Lands (other than National Forests) administered by Federal agencies.

Forest industry lands. Lands owned by companies or individuals that operate primary wood-using plants.

Forest land. Land that is at least 10 percent stocked with trees of any size, or that formerly had such tree cover and is not currently developed for a nonforest use. The minimum area for classification of forest land is 1 acre. The components that make up forest land are timberland and all noncommercial forest land (see definitions).

Forest type. A classification of forest land based on the species that form a plurality of live-tree basal-area stocking.

Forest-type group. A combination of forest types that share closely associated species or site requirements. The many forest types in this state were combined into the following major forest-type groups (the descriptions apply to forests in this state):

a. *White/red pine*--forests in which white pine, hemlock, or red pine make up the plurality of the stocking, singly or in combination; common associates include red spruce, maple, and yellow-poplar.

b. *Spruce/fir*--forests in which red spruce, northern white-cedar, balsam fir, white spruce, black spruce, or tamarack, singly or in combination, make up a plurality of the stocking; common associates include yellow birch and red maple.

c. *Loblolly/shortleaf pine*--forests in which loblolly, shortleaf or other southern yellow pines (except longleaf or slash pine), singly or in combination, make up a plurality of the stocking; common associates include hickory and maple.

d. *Oak/pine*--forests in which northern red oak or white ash, singly or in combination, make up a plurality of the stocking and in which pines or eastern redcedar contribute 25 to 50 percent of the stocking; hemlock, maple, sweet birch, and yellow-poplar are associates.

e. *Oak/hickory*--forests in which upland oaks, red maple (when associated with central hardwoods), or hawthorn, singly or in combination, make up a plurality of the stocking and in which white pine makes up less than 25 percent of the stocking; common associates include hard pines, hemlock, maple, birch, hickory, and yellow-poplar.

f. *Elm/ash/red maple*--forests in which black ash, elm, red maple (when growing on wet sites), willow, or green ash, singly or in combination, make up a plurality of the stocking; common associates include sugar maple, hickory, yellow-poplar, and black cherry.

g. *Northern hardwoods*--forests in which sugar maple, beech, yellow birch, red maple (when associated with northern hardwoods), pin cherry, or black cherry, singly or in combination, make up a plurality of the stocking; common associates include hard pines, hemlock, hickory, ash, and yellow-poplar.

h. *Aspen/birch*--forests in which aspen, paper birch, or gray birch, singly or in combination, make up a plurality of the stocking.

Gross growth. The sum of accretion and ingrowth.

Growing-stock trees. Live trees of commercial species classified as sawtimber, poletimber, saplings, or seedlings; that is, all live trees of commercial species except rough and rotten trees.

Growing-stock volume. Net volume, in cubic feet, of growing-stock trees 5.0 inches d.b.h. and larger from a 1-foot stump to a minimum 4.0-inch top diameter outside bark of the central stem, or to the point where the central stem breaks into limbs. Net volume equals gross volume less deduction for cull.

Hardwoods. Dicotyledonous trees, usually broad-leaved and deciduous.

Ingrowth. The estimated net volume of growing-stock trees that became 5.0 inches d.b.h. or larger during the period between inventories (divided by the number of growing seasons between surveys to produce average annual ingrowth).

International 1/4-inch rule. A log rule or formula for estimating the board-foot volume of logs. The mathematical formula is:

$$(0.22D2 - 0.71D)(0.904762)$$

for 4-foot sections, where D=diameter inside bark at the small end of the log section. This rule is used as the USDA Forest Service standard log rule in the Eastern United States.

Land area. (a) Bureau of Census: The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river flood plains; streams, sloughs, estuaries, and canals less than 1/8 statute mile wide; and lakes, reservoirs, and ponds less than 40 acres in area. (b) Forest Inventory and Analysis: same as (a) except that the minimum width of streams, etc. is 120 feet, and the minimum size of lakes, etc. is 1 acre.

Merchantable stem. The main stem of the tree between a 1-foot stump height and a 4-inch top diameter (outside the bark), including the wood and bark.

Mortality. The estimated net volume of growing-stock trees at the previous inventory that died from natural causes before the current inventory (divided by the number of growing seasons between surveys to produce average annual mortality) .

National Forest lands. Federal lands legally designated as National Forests or purchase units and other lands administered as part of the National Forest System by the USDA Forest Service.

Net change. The difference between the current and previous inventory estimates of growing-stock volume (divided by the number of growing seasons between surveys to produce average annual net change). Components of net change are ingrowth plus accretion, minus mortality, minus cull increment, plus cull decrement, minus removals.

Net dry weight. The dry weight of woody material less the weight of all unsound (rotten) material.

Net growth. The change, resulting from natural causes, in growing-stock volume during the period between surveys (divided by the number of growing seasons to produce average annual net growth). Components of net growth are ingrowth plus accretion, minus mortality, minus cull increment, plus cull decrement.

Noncommercial forest land. Reserved timberland, Christmas tree plantations, other forest land, and other reserved forest land (see definitions).

Noncommercial species. Tree species of typically small size, poor form, or inferior quality that normally do not develop into trees suitable for industrial wood products.

Nonforest land. Land that has never supported forests, or land formerly forested but now in nonforest use such as cropland, pasture, residential areas, or highways.

Nonstocked area. A stand-size class of forest land that is stocked with less than 10 percent of minimum full stocking with live trees.

Other forest land. Forest land that is incapable of producing 20 cubic feet per acre per year of industrial wood under natural conditions, because of adverse site conditions (formerly known as unproductive forest land).

Other reserved forest land. Forest land that is incapable of producing 20 cubic feet per acre per year of industrial wood under natural conditions, because of adverse site conditions, and is protected through statute or administrative designation.

Ownership class. A classification of forest land based on ownership and nature of business or control of decisionmaking for the land. It encompasses all types of legal entities having ownership interest in the land, whether public or private.

Pasture land. Includes any pasture land other than cropland and woodland pasture. Can include lands that had lime fertilizer or seed applied, or that had been improved by irrigation, drainage, or control of weeds and brush.

Poletimber tree. A live tree of commercial species meeting regional specifications of soundness and form and at least 5.0 inches in d.b.h., but smaller than a sawtimber tree.

Removals. The net growing-stock volume harvested or killed in logging, cultural operations (such as timber stand improvement) or land clearing, and the net growing-stock volume neither harvested nor killed but growing on land that was reclassified from timberland to noncommercial forest land or nonforest land during the period between surveys. This volume is divided by thenumber of growing seasons to produce average annual removals.

Reserved timberland. Forest land sufficiently productive to qualify as timberland but withdrawn from timber utilization through statute or administrative designation; land exclusively used for Christmas tree production (formerly known as productive reserved forest land).

Rotten tree. A live tree of commercial species that does not contain at least one 12-foot sawlog or two noncontiguous sawlogs, each 8 feet or longer, now or prospectively, and does not meet regional specifications for freedom from defect primarily because of rot; that is, more than 50 percent of the cull volume in the tree is rotten.

Rough tree. (a) The same as a rotten tree except that a rough tree does not meet regional specifications for freedom from defect primarily because of roughness or poor form; also (b) a live tree of noncommercial species.

Sampling error. A measure of the reliability of an estimate, expressed as a percentage of the estimate. The sampling errors given in this report correspond to one standard deviation and are calculated as the square root of the variance, divided by the estimate, and multiplied by 100.

Saplings. Live trees 1.0 through 4.9 inches d.b.h.

Sapling-seedling stand. A stand-size class of forest land that is stocked with at least 10 percent of minimum full stocking with live trees with half or more of such stocking in saplings or seedlings or both.

Sawlog. A log meeting regional standards of diameter, length, and freedom from defect, including a minimum 8-foot length and a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods.

Sawlog portion. That part of the bole of a sawtimber tree between the stump and the sawlog top; that is, the merchantable height.

Sawlog top. The point on the bole of a sawtimber tree above which a sawlog cannot be produced. The minimum sawlog top is 7.0 inches diameter outside bark (d.o.b.) for softwoods and 9.0 inches d.o.b. for hardwoods.

Sawtimber stand. A stand-size class of forest land that is stocked with at least 10 percent of minimum full stocking with all live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber.

Sawtimber tree. A live tree of commercial species at least 9.0 inches d.b.h. for softwoods or 11.0 inches for hardwoods, containing at least one 12-foot sawlog or two noncontiguous 8-foot sawlogs, and meeting regional specifications for freedom from defect.

Sawtimber volume. Net volume in board feet, by the International 1/4-inch rule, of sawlogs in sawtimber trees. Net volume equals gross volume less deductions for rot, sweep, and other defects that affect use for lumber.

Seedling. A live tree less than 1.0 inch d.b.h. and at least 1 foot tall.

Snag. Standing dead tree with most or all of its bark missing that is at least 5.0 inches d.b.h. and at least 10 feet tall (does not include salvable dead).

Soft hardwoods. Hardwood species with an average specific gravity greater than 0.50.

Stand. A group of forest trees growing on forest land.

Stand-size class. A classification of forest land based on the size class (that is, seedlings, saplings, poletimber, or sawtimber) of all live trees in the area.

Standard cord. A unit of measure for stacked bolts of wood, encompassing 128 cubic feet of wood, bark, and air space. Fuelwood cord estimates can be derived from cubic-foot estimates of growing stock by applying an average factor of 80 cubic feet of solid wood per cord. For pulpwood, a conversion of 85 cubic feet of solid wood per cord is used because pulpwood is more uniform.

Standard-lumber log grade. A classification of sawtimber quality based on standard sawlog grades for hardwoods, white pine, and southern pine.

State lands. Lands owned by the state or leased to the state for 50 years or more.

Stocking. The degree of occupancy of land by trees, measured by basal area and number of trees in a stand compared to the upper limit of basal area and number of trees required for optimal growth. In this report factors were used to account for differences in growth characteristics of individual species.

Stump. The main stem of a tree from ground level to 1 foot above ground level, cluding the wood and bark.

Timberland. Forest land producing or capable of producing crops of industrial wood (more than 20 cubic

feet per acre per year) and not withdrawn from timber utilization (formerly known as commercial forest land).

Timber products. Roundwood (round timber) products and manufacturing plant by-products harvested from growing-stock trees on timberland; from other sources, such as cull trees, salvable dead trees, limbs, tops, and saplings; and from trees on noncommercial forest and nonforest lands.

Timber removals. The growing-stock or sawtimber volume of trees removed from the inventory for roundwood products, plus logging residues, volume destroyed during land clearing, and volume of standing trees on land that was reclassified from timberland to noncommercial forest land .

Tree class. A classification of the quality or condition of trees for sawlog production. Tree class for sawtimber trees is based on their current condition. Tree class for poletimber trees is a prospective determination--a forecast of their potential quality when they reach sawtimber size (11.0 inches d.b.h. for hardwoods, 9.0 inches d.b.h. for softwoods).

Tree grade. A classification of sawtimber quality based on guidelines for tree grades for hardwoods, white pine, and southern pine.

Trees. Woody plants that have well-developed stems and that usually are more than 12 feet tall at maturity.

Unproductive forest land. See "Other forest land".

Upper-stem portion. That part of the main stem or fork of a sawtimber tree above the sawlog top to a diameter of 4.0 inches outside bark, or to the point where the main stem or fork breaks into limbs.

Urban forest land. Forest land sufficiently productive to qualify as timberland that is completely surrounded by or nearly surrounded by urban development (not parks), whether commercial, industrial, or residential.

Veneer log or bolt. A roundwood product from which veneer is sliced or sawn that usually meets certain minimum standards of diameter, length, and defect.

Volume suitable for pulpwood. The sound volume (only rotten cull excluded) of growing-stock and rough trees.

Widmann, Richard H. 1995. **Forest resources of Pennsylvania** Resour. Bull NE-131. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 41 p.

This report presents an analysis of the results of the 1989 forest inventory of Pennsylvania as well as trends that have occurred since the previous survey. Major topics include changes in forest land by ownership, forest type, and timberland component; stand structure is charaterized by stand size, understory woody vegetation, dead trees, and changes in relative stocking; and harvesting by distribution of cut, species composition, and growth to removals ratios.

Keywords: Forest survey, timberland, timber supply, growing-stock volume, stand structure species composition, stocking, area, volume, growth, removals

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