United States
Department of
Agriculture

Forest Service

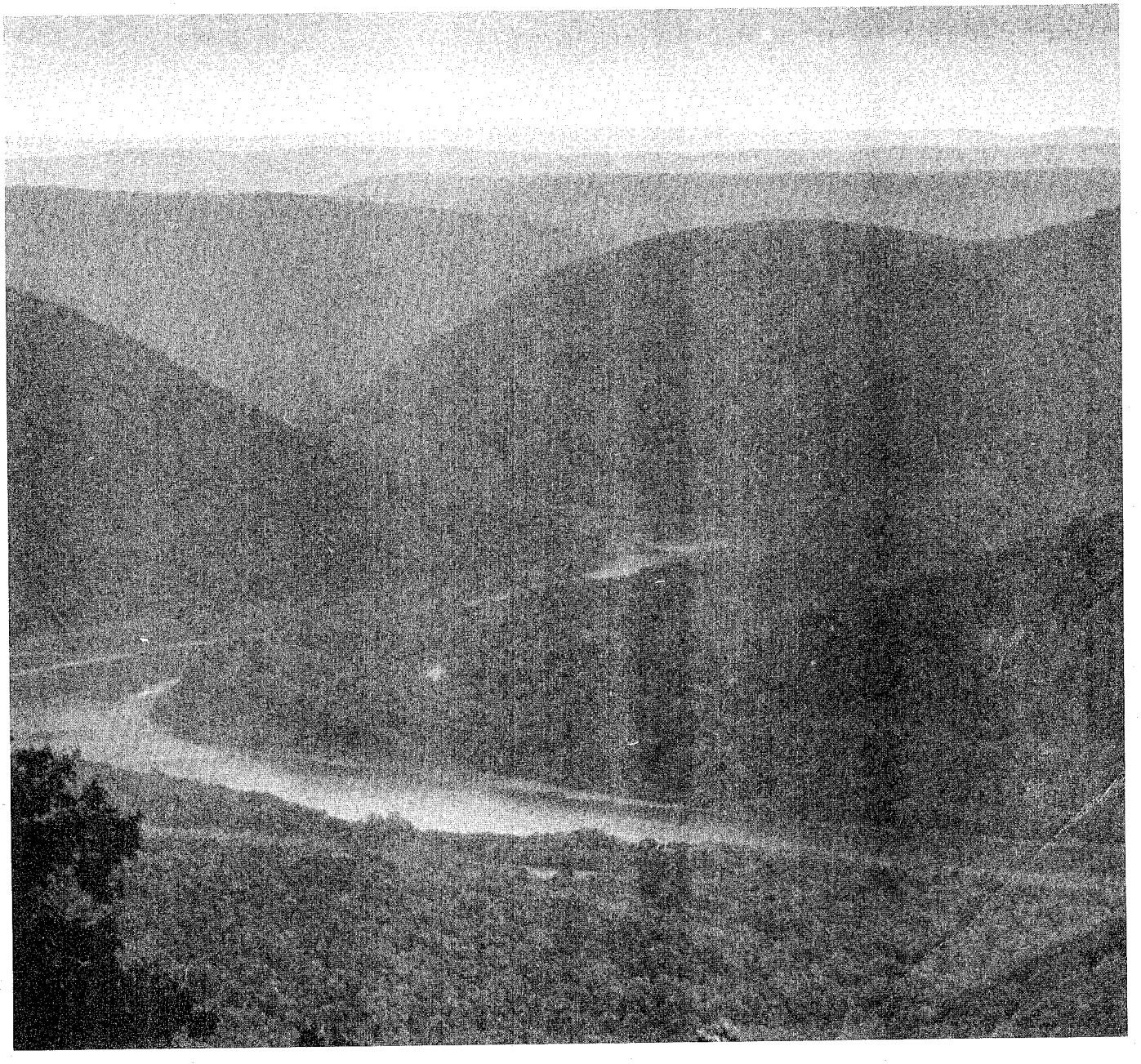
Northeastern Forest
Experiment Station

Resource Bulletin NE-69

1982

An Analysis of Pennsylvania's Forest Resources

Douglas S. Powell
Thomas J. Considine, Jr.



The Authors

Douglas S. Powell, research forester, received a B.S. degree in forestry from the University of Michigan in 1971 and an M.S. degree in forest ecology from West Virginia University in 1976. He joined the Northeastern Forest Experiment Station in July 1971, and is currently a Resource Analyst in the Northeastern Station's Resources Evaluation Unit, located in Broomall, Pa.

Thomas J. Considine, Jr., research forester, received a B.S. degree in forestry from Rutgers University in 1975 and an M.F. degree in forest economics from Duke University in 1978. He joined the Northeastern Station in June 1978, and is currently a Resource Analyst in the Station's Resources Evaluation Unit.

Abstract

This report presents an analysis of the results of the third forest survey of Pennsylvania as well as trends that have occurred since the previous surveys. Topics include forest area by ownership, stand size, and forest type; timber volume by species, location, and quality; biomass; timber products output for sawlogs, pulpwood, and fuelwood; timber's role in the state's economy; and growth and removals. Forest area, volume, and growth and removals are projected through 2008. Nontimber forest resources and uses—water, soil, minerals, fish, wildlife, and recreation—are discussed and related to each other and to the timber resource. Also identified are forest management opportunities for increasing the production of major forest resources and enhancing the benefits derived from Pennsylvania's forests.

Foreword

This analysis of Pennsylvania's forest resources draws upon the results of three forest inventories conducted by the Resources Evaluation Unit of the Northeastern Forest Experiment Station, USDA Forest Service, in cooperation with the Pennsylvania Bureau of Forestry, Department of Environmental Resources. Additional information and data, especially for nontimber forest resources, were provided by a variety of agencies and organizations including the Bureau of Resources Programming, the Bureau of State Parks, and the Bureau of Surface Mine Reclamation, Department of Environmental Resources, the Bureau of Economic Development of the Pennsylvania Department of Commerce, the Pennsylvania Governor's Office of State Planning and Development; the Pennsylvania Game Commission; the Pennsylvania Fish Commission; The Pennsylvania State University; the USDA Soil Conservation Service; the U.S. Army Corps of Engineers; the U.S. Department of Energy; the Pennsylvania Forestry Association; and the Western Pennsylvania Conservancy.

A tremendous amount of data was collected during the preparation of this report. The authors analyzed only what they believed were the most important aspects of Pennsylvania's forest resources. Much additional data are available and further analyses are possible. Should you require additional information, contact Resources Evaluation, USDA Forest Service, Northeastern Forest Experiment Station, 370 Reed Road, Broomall, PA 19008 (telephone: 215-461-3037)

Cover photo

The Allegheny Mountains and the West Branch of the Susquehanna River from Hyner View (Clinton County). Note that the ridges are similar in elevation, which is characteristic of a dissected plateau.

An Analysis of Pennsylvania's Forest Resources

Contents

Background 1
Forest Surveys of Pennsylvania . 4
Eight Geographic Units 4
Forest Area 6
Trends 8
Ownership 12
Stand Size 15
Forest Type 20
Timber Volume 22
Species 25
Geographic Units 29
Biomass 32
Sawlog Quality 33
Timber Products Output 34
Lumber and Sawlogs 37
Pulpwood 38
Fuelwood 38
Other Products 38
Timber's Role in Pennsylvania's Economy 40
Growth and Removals 41
Components of Change 41
Geographic Unit Growth and Removals 43
Trend Changes 43
Timber Outlook 44
Nontimber Forest Resources and Uses 45
Water 45
Soil 50
Minerals 52
Fish 58
Wildlife 59
Recreation 67
Forest Management Opportunities 70
Is There a Need to Manage the Forests? 70
Basic Features of Forest Sites 71
Opportunities for Enhancing Various Benefits 72
Literature Cited 81
Appendix 84
Definition of Terms 84
Planning and Designing the Survey 87
Processing the Data 88
Commercial Tree Species of Pennsylvania 89
Tables 92
Metric Equivalents 97

Highlights

This report covers many items related to the past, present, and future conditions of the many forest resources in Pennsylvania. The following are a few of the more important highlights; the reader will find more detailed discussions and analyses in the sections that follow.

- From 1965 to 1978 total forest land increased slightly while commercial forest land area decreased by about 2 percent.

- Forest industries and State agencies showed increases in commercial forest-land acreage, most of this coming from the largest ownership group—miscellaneous private—which showed a loss of more than 1 million acres.

- Pennsylvania's forests are maturing. There are more sawtimber stands and fewer poletimber stands.

- Growing-stock volume increased by 22 percent and sawtimber volume by 48 percent from 1965 to 1978. These increases are the result of a bulge of timber volume moving from smaller to larger diameter classes.

- Red maple maintained its standing as the species with the most growing-stock volume; because most of this volume is in small trees, red maple was a distant second to northern red oak in sawtimber volume.

- Sugar maple growing-stock volume rose by 60 percent between surveys, the largest percentage increase among the major species. Maples will continue to increase more than oaks.

- The aboveground green weight of all live trees 5.0-inches in diameter at breast height (dbh) and larger is 1.3 billion tons. Twenty-three percent of this is topwood and branchwood, and the utilization of this resource can be greatly expanded.

- Hardwood sawlog quality has improved. In 1965, 28 percent of the hardwood sawtimber volume was Grade 2 or better material. By 1978, this figure had risen to 37 percent. Increasing average tree size is the most important reason for the improvement.

- The total output of timber products from all sources was 212.5 million cubic feet in 1976, a 21-percent increase over 1964's output.

- Sawlogs continue to dominate timber products output, but pulpwood production accounts for an increasingly larger share of the output.

- Annual hardwood mortality increased by 60 percent between inventories, largely as a result of heightened insect and disease attacks in the oak forest types.

- Thirty-year projections (1978 to 2008) indicate a slightly declining commercial forest-land base, a slowing of the increase in growing-stock inventory, and a steadily decreasing growth-to-removals ratio.

- Forests provide valuable protection for many of Pennsylvania's watersheds.

- Forty-four percent of Pennsylvania's area is covered by soils with very good to excellent potential for growing trees.

- Increased activity in oil and gas exploration and extraction and strip mining of coal will have both negative and positive impacts on forest resources.

- Pennsylvania's streams and ponds support about 170 species of fish, most of which depend on quality water and protection provided by forest land.

- More than 230 of the bird and mammal species in Pennsylvania are at least partially dependent on forested environments.

- Much of the booming demand for outdoor recreation in Pennsylvania is satisfied by publicly owned forest land. Many millions of acres of privately owned forest land are available for some public recreation, but they are presently underutilized.

- Many forest management opportunities are available to the private Pennsylvania forest-land owner. There are opportunities for enhancing single benefits such as wood production, wildlife habitat, esthetic enjoyment, and recreational or wilderness values, and for enhancing a variety of combinations of these benefits.

Background

The history of land use and the accompanying development of forestry in Pennsylvania provides background information that is necessary for understanding the present condition and trends of the state's forest resources.

Before the first settlement of Europeans in the early 17th century, Pennsylvania was sparsely populated with Indian tribes, who cleared little land. Except for such clearings and a few natural meadows and savannahs, the area now known as Pennsylvania was covered with virgin forests. In the northern plateau areas, the forests consisted of white pine and hemlock mixed with beech and sugar maple. White oak, American chestnut, hickory, and chestnut oak were dominant in the southern areas (Braun 1950).

These magnificent stands, some believed to have contained more than 100,000 board feet per acre, were seen as obstacles to settlement. As land clearing began in the southeast corner of his province, William Penn, in 1681, directed the colonists to "leave one acre of trees for every five acres cleared." Most settlers, anxious to establish farms and develop their fertile land, paid little attention to Penn's foresighted attempt to conserve the forest resources. After all, the climate and soils were favorable, fires were rare, streams ran full and clear without dangerous flooding, and the timber stretched on seemingly forever. Why not clear all of the land? The consequences of such an attitude became painfully clear to Pennsylvanians over 200 years later.

As the population increased, the Coastal Plain and Piedmont physiographic regions, with their fertile soils, level to rolling topography, and relatively long growing seasons, could no longer support Pennsylvania's settlers. Pioneers moved up the river valleys, into the Ridge and Valley region (Fig. 1), and cleared the more level and fertile valleys. Anthracite coal was discovered in east-central Pennsylvania early in the 1760's, and forests were cleared to get at this valuable fuel. Despite such activity, the state was still 75 percent forested 200 years after the first settlers became established.

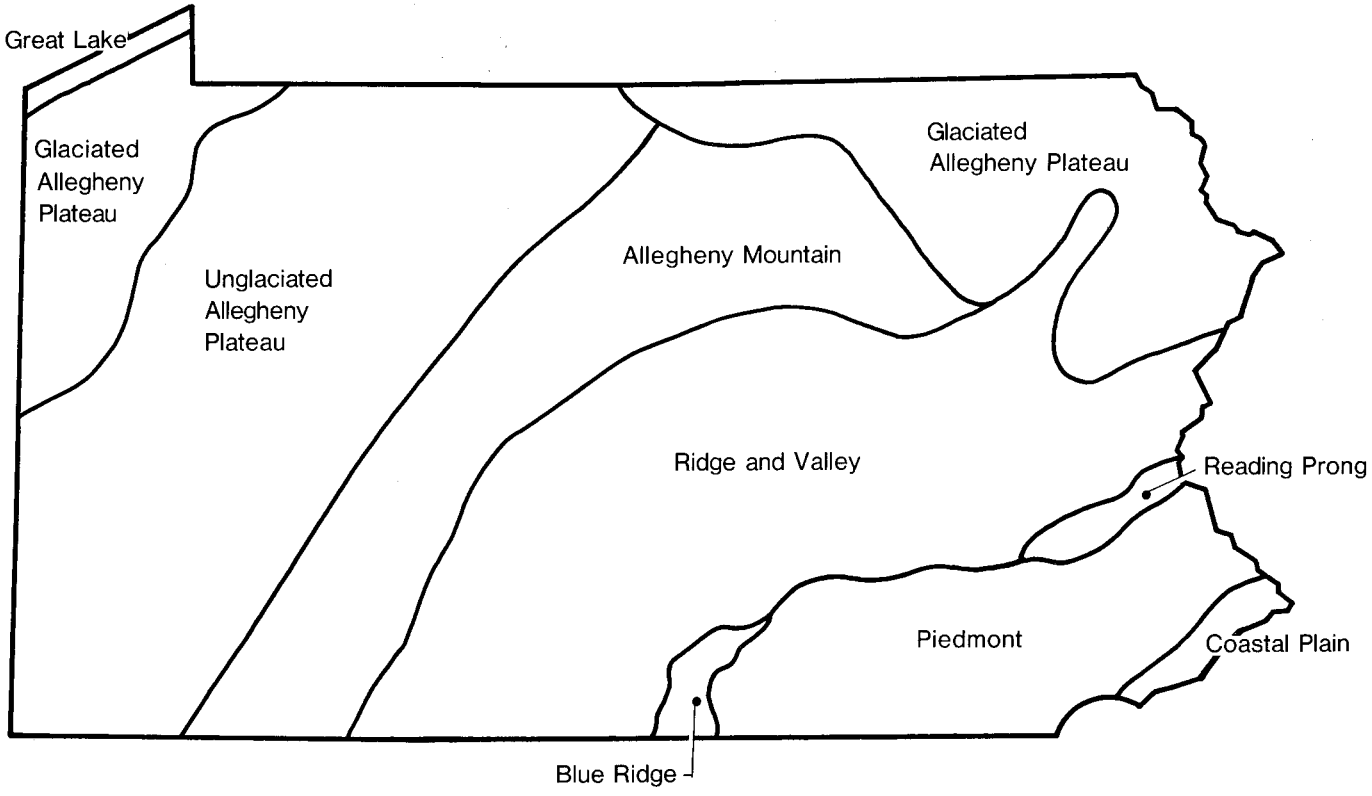


Figure 1.—The physiographic regions of Pennsylvania (adapted from Fenneman 1938).

Aerial view of the Ridge and Valley region of Centre and Clinton Counties.

Western Pennsylvania Conservancy

The Industrial Revolution led to the end of Pennsylvania's old-growth forests as the logger and farmer teamed up—the former to fell the timber, the latter to convert the land to agricultural use. The mining industry required much wood for timbers. Charcoal was needed to fire the iron furnaces. The tanning industry required tons of hemlock bark. Logs were removed for construction lumber, railroad ties, shingles, barrel staves, lath, furniture, tool handles, and other products. Timber utilization was very complete (Marquis 1975). By 1850, the center of logging in America had shifted from Maine and New York into Pennsylvania. Between 1850 and 1870, the Commonwealth led all states in sawtimber production.

During the 1800's and early 1900's, timber harvesting in Pennsylvania consisted of removing most merchantable trees from the area being logged. This uncontrolled logging ranged from high grading, where only the best trees were taken, to complete removal of all trees. The forests were exploited,

Felling trees and peeling the bark for use in tanning leather was arduous labor at the turn of the century.

Pennsylvania Bureau of Forestry

and no consideration was given to the desirability of adequate regeneration following cutting (Nelson et al. 1975).

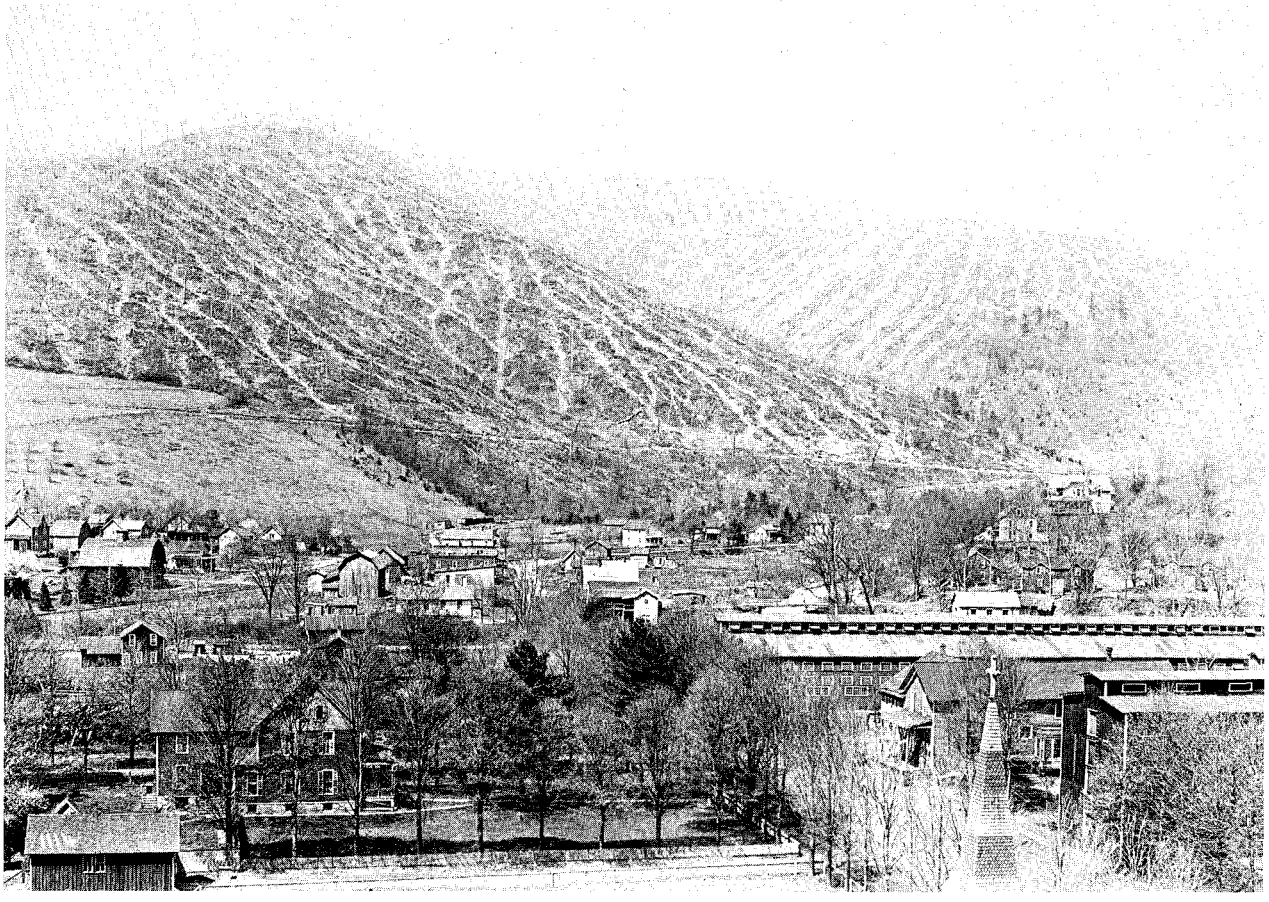
This heavy logging was followed by repeated fires, and after each one came poorer soil conditions, higher runoff, and the production of poorer quality timber. Because of the unique market for small timber used as props and lagging in mines, many of these second-growth stands, especially in the anthracite region of east-central Pennsylvania, were repeatedly cut when the trees reached pole size.

From 1850 to 1920 most of Pennsylvania's magnificent old-growth forests were reduced to areas where hillsides were bare and streams were muddy and prone to flash flooding. Some wildlife species that were once abundant became scarce, and boom towns were becoming ghost towns. An estimated 10 million acres of prime forest land were converted to other uses, primarily agriculture. Of the forest land that was left, more than 5 million acres were barren and unproductive, while many more were poorly stocked with trees. Most of the woodland areas were unproductive, unattractive, and unregulated (Illick 1923a). Common sights on the landscape were blackened snags, bramble thickets, and scrub oak barrens.

As a result, many people became concerned and organized an effort to restore the forests in some measure. In 1886, the Pennsylvania Forestry Association was founded to secure and maintain a due proportion of forest area throughout the state. In 1895, the Pennsylvania Bureau of Forestry was established primarily to put out fires but also to establish State Forest Reserves. Dr. Joseph T. Rothrock was instrumental in initiating many such programs and is most deserving of the title "Father of Pennsylvania Forestry."

As the loggers moved into West Virginia, the Lake States, and beyond, and as wildfires were

Logging, fires, and erosion left many hillsides denuded in central Pennsylvania (Costello Cut, Potter County, 1918).



Pennsylvania Bureau of Forestry

brought under control, the forests began to recover. Tax sales made thousands of acres of cutover forest land available at low cost. The State took advantage of this and in 1898 made the initial purchase of 39,277 acres of today's 2-million-acre State Forest System. In the mid-1920's, the Federal Government began buying land for the Allegheny National Forest. Forest-land acreage slowly increased as marginal cropland and pasture were abandoned, and as farmers moved to the cities where industries were gearing up for wartime production.

Pennsylvania's forests were gradually recovering and developing much better than many people had anticipated. Good stands of second-growth timber became established on most of the cutover areas (Nelson et al. 1975). Returning with the trees were more stable watersheds, abundant and varied populations of fish and wildlife, and areas ideally suited for outdoor recreation.

While the forests have made a remarkable comeback in the last 80 years, many impacts on the forest resources have been less than favorable. During the early part of the century, one of Pennsylvania's most common and valuable hardwoods, the American chestnut, was wiped out by a devastating blight. Only small trees, originating as sprouts from the old roots, can be found in Penn's Woods today. Also, during the last decade, insect pests such as the oak leafroller, oak leaftier, and the gypsy moth have defoliated millions of acres of forest land and caused extensive mortality. Coal mining, especially surface mining in the western bituminous fields, is disturbing thousands of acres of forest land annually, sometimes adversely affecting many forest resources.

Penn's Woods are continually changing. Some changes are subtle and gradual, others are obvious and occur over a short period. Without quantifying and assessing the condition of the many resources of the forest, we are unable to see where we have been, where we are, and where we are going. We need this information if we are to plan for the future. This is where forest surveys come into the picture.

Forest Surveys of Pennsylvania

To keep abreast of current forest conditions and to monitor resource trends and project future resource supplies, Resources Evaluation (formerly Forest Survey) of the Northeastern Forest Experiment Station, USDA Forest Service, has inventoried the forest resources of Pennsylvania on three occasions. The first forest survey was conducted over a 5-year period (1949–54) and resulted in statistical data dated 1955 (Ferguson 1958). The second survey was conducted in 1963–65 with a 1965 survey date (Ferguson 1968). The most recent survey was made in 1976 and 1977 with a survey date of 1978. All of these surveys were conducted in cooperation with the Pennsylvania Bureau of Forestry.

The results of the latest survey have been published in 76 statistical tables (Considine and Powell 1980). This report is a detailed analysis of the third survey and draws heavily on much of the data presented in the statistical report. A copy of the statistical report may be useful in following the analysis more closely. Comparisons between the third survey and either of the two previous surveys forms the basis of the trend and projection analyses.

Since the first survey, demands on the forests of Pennsylvania have increased dramatically. Demand for timber products has risen, interest in game and nongame wildlife has expanded, recreational use has become heavier, and demands on the water resource, much of which is directly linked to the forests, have increased and broadened. Due to the increasing pressures on the state's forests, the forest surveys have increased in scope and complexity. This report, for instance, includes an expanded analysis of the nontimber forest resources and some of their myriad interactions.

Eight Geographic Units

To provide better quality regional information, Pennsylvania was divided into eight geographic sampling units (Fig. 2). An attempt was made to define areas with homogeneous forest conditions. Since these unit boundaries are identical to those of the 1965 survey, we can make some comparisons of inventories and analyze certain trends for comparable areas of the state. Since the number of remeasured plots was small in relation to the number of new plots established in 1978, data on growth, removals, and mortality for the remeasured plots are presented for six geographic units. The six units coincide with the eight units except that the North-Central and Allegheny Units are combined into one unit, as are the Northeastern and Pocono Units. Analysis and comparison of geographic unit data for forest area, timber volume, and growth and removals are found in those particular sections of this report.

Before getting into these analyses, a brief description of these different regions of Pennsylvania with some basic resource and population statistics may be helpful. Data for total population and population density are based on preliminary information of the 1980 census of population obtained from the Philadelphia Office of the Bureau of Census in January 1981. The source of rural population data is the U.S. Department of Commerce (1972); estimates of per capita income are from the U.S. Department of Commerce (1980).

Pennsylvania

Counties: 67
Land area: 28,778,240 acres
Commercial forest: 55 percent of land area
Net volume per acre of commercial forest land: 1,366 cubic feet
Population: 11,807,984
Rural population: 29 percent
Population density: 262.6 per square mile
Per capita income: $5,622

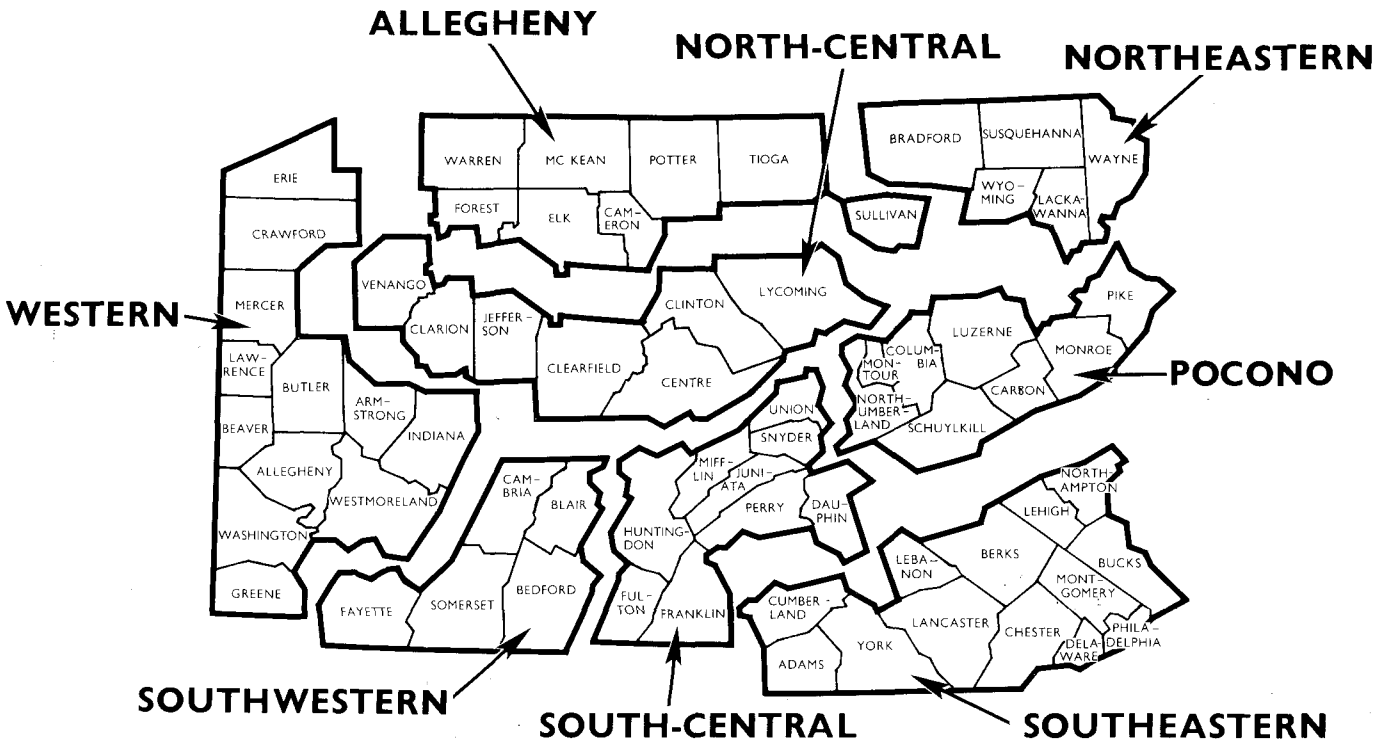


Figure 2.—The eight geographic sampling units of Pennsylvania.

Western Unit

Counties: 12
Land area: 5,606,400 acres
Commercial forest: 45 percent of land area
Net volume per acre of commercial forest land: 867 cubic feet
Population: 3,204,996
Rural population: 27 percent
Population density: 365.9 per square mile
Per capita income: $5,736

This is the largest of the eight units. Farm and forest land uses are interspersed throughout, except in the greater Pittsburgh metropolitan area. Farm land is more productive in the northern counties, which were glaciated. The volume per acre of forest land is the lowest of any unit. The Western Unit also has the greatest concentration of bituminous coal fields in the state.

Southwestern Unit

Counties: 5
Land area: 2,636,800 acres
Commercial forest: 61 percent of land area
Net volume per acre of commercial forest land: 1,206 cubic feet
Population: 606,316
Rural population: 54 percent
Population density: 147.2 per square mile
Per capita income: $4,800

This unit contains some of the most rugged mountainous terrain in the state. Mt. Davis in Somerset County, with an elevation of 3,213 feet above sea level, is the highest point in Pennsylvania. The famed Laurel Highlands are located in this unit, and forest recreation, especially skiing, is very popular.

Allegheny Unit

Counties: 8
Land area: 3,993,600 acres
Commercial forest: 82 percent of land area
Net volume per acre of commercial forest land: 1,906 cubic feet
Population: 213,233
Rural population: 69 percent
Population density: 34.2 per square mile
Per capita income: $4,582

This unit is characterized by hilly terrain, and has a relatively short growing season. It contains the Allegheny National Forest and substantial amounts of State-owned forest land. The area is famous for its black cherry production. It is the most heavily forested unit and has the highest volume per acre of all units. White-tailed deer populations are generally high throughout this

region. Total human population and density is lowest, as is per capita income. The greatest proportion of people is in rural areas.

North-Central Unit

Counties: 7
Land area: 4,028,800 acres
Commercial forest: 71 percent of land area
Net volume per acre of commercial forest land: 1,302 cubic feet
Population: 509,604
Rural population: 56 percent
Population density: 81.0 per square mile
Per capita income: $4,665

This unit is heavily forested, but has more farm and other nonforest land than the Allegheny Unit. The western half of the unit contains major bituminous coal fields, many of which are being surface mined. The forest composition is transitional, being influenced from the north by the Allegheny/northern hardwoods and from the south by the more central oak-dominated forests.

South-Central Unit

Counties: 9
Land area: 2,953,600 acres
Commercial forest: 56 percent of land area
Net volume per acre of commercial forest land: 1,447 cubic feet
Population: 570,918
Rural population: 54 percent
Population density: 123.7 per square mile
Per capita income: $5,118

The most dominating feature of this unit is the ridge and valley landform pattern, which bends around from the south to the northeast. The prominent ridges are nearly parallel and often extend unbroken for many miles. The often steep slopes are generally forested, broken occasionally by rock outcrops and barren talus-strewn areas. The valleys between the ridges are used primarily for agriculture, which highlights the contrasts in the physical features.

Northeastern Unit

Counties: 5
Land area: 2,287,360 acres
Commercial forest: 59 percent of land area
Net volume per acre of commercial forest land: 1,349 cubic feet
Population: 386,387
Rural population: 40 percent
Population density: 108.1 per square mile
Per capita income: $4,712

This rather heavily forested unit is the smallest in total land area. It lies in the glaciated part of the Allegheny Plateau, and thus has many small natural lakes, ponds, and swamps. This, plus its relatively low population density, makes it one of the prime areas for black bear in the state. Agricultural land use is also important, though Lackawanna County contains Scranton and its suburban communities as well as some disturbed anthracite mining areas.

Pocono Unit

Counties: 8
Land area: 2,748,160 acres
Commercial forest: 60 percent of land area
Net volume per acre of commercial forest land: 1,088 cubic feet
Population: 814,044
Rural population: 38 percent
Population density: 189.6 per square mile
Per capita income: $4,669

This unit contains the major anthracite coal fields of the country. The western part is more agricultural while the eastern part is more forested. This area is recovering more slowly than the remainder of the state from the repeated and heavy logging and fires during the early 1900's. The current low volume per acre reflects this slow recovery. As its name suggests, this unit contains the area commonly referred to as the Pocono Mountains. This forested region has many glacial lakes and because of its location receives heavy year-round recreation use by the more urban residents of southeastern Pennsylvania, northern New Jersey, and southeastern New York.

Southeastern Unit

Counties: 13
Land area: 4,523,520 acres
Commercial forest: 22 percent of land area
Net volume per acre of commercial forest land: 1,653 cubic feet
Population: 5,502,486
Rural population: 18 percent
Population density: 778.5 per square mile
Per capita income: $6,021

This large unit contains the least amount of forest land, both in total and as a percentage, of all eight units. Its volume per acre is high, however, attributable in part to a long history of relatively low levels of timber removals. The forests are dominated by oak cover types. Farms and built-up or urban areas cover most of the area. This part of the state has the most prime agricultural land and the highest population, population density (due primarily to Philadelphia and its influence), and per capita income. The land is generally level to gently rolling with few hills of any distinction. It has the longest growing season in the state.

Forest Area

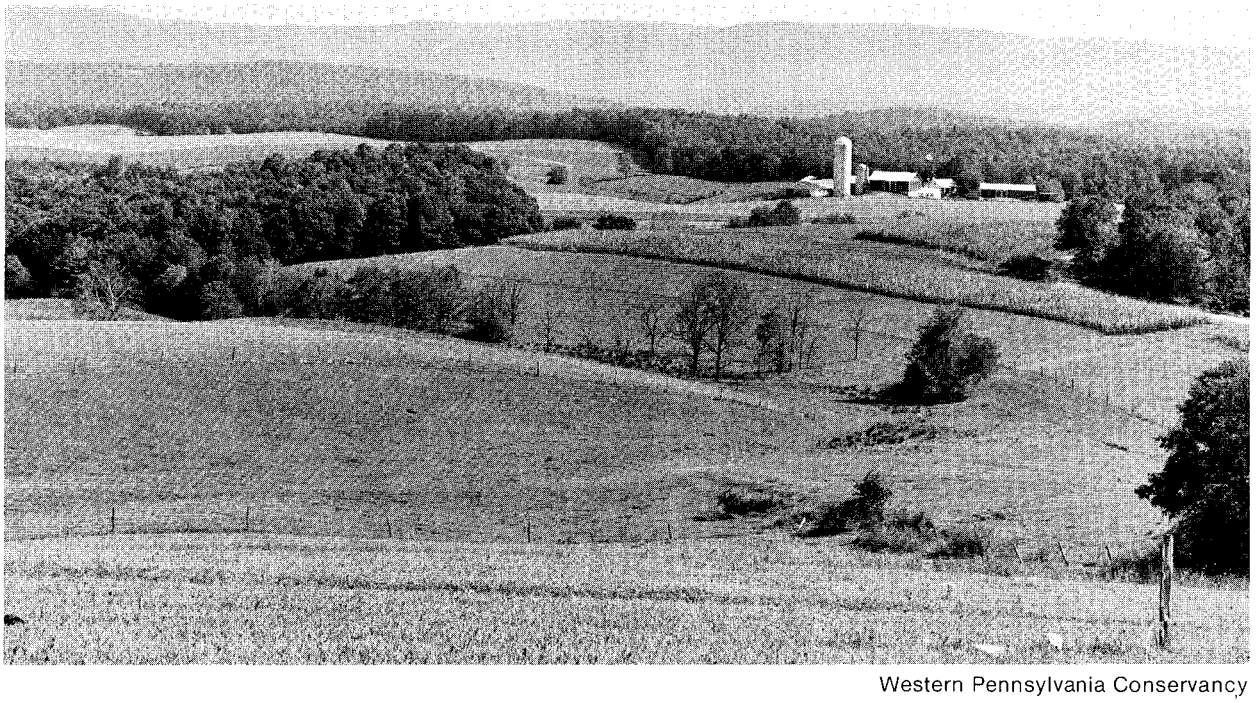
The total area of Pennsylvania is 29,013,120 acres. This makes it the 33rd largest state in the Nation, but second only to New York in the Northeast. Subtracting 234,880 acres of inland water (large lakes, reservoirs, and rivers) leaves a total land area of 28.8 million acres. Nearly 12 million acres, or 42 percent of the land area, is in nonforest land use. More than 6.4 million acres are either cropland or pasture. The remaining 5.6 million acres are in urban or built-up land, roads, rights-of-way, small bodies of water, or other nonforest use.

The most common land cover is forest, accounting for 16.8 million

Residents of Philadelphia and other urban centers depend on the outlying forests for wood products, outdoor recreation, clean air and water, and many other important benefits.

Pennsylvania State Department of Commerce

Pasture, cropland, and forest land account for 81 percent of Pennsylvania's land area. The present arrangement and distribution of these land uses in the state creates outstanding wildlife habitat, both in quantity and quality.



Western Pennsylvania Conservancy

acres or 58 percent of the state's land area. Forest land is classified as either noncommercial or commercial. Noncommercial forest land covers about 900,000 acres in Pennsylvania, and is composed of productive reserved, unproductive, and urban forest land. Urban forest land is a relatively new classification that describes land that could be considered commercial forest land except that it is surrounded by residential, commercial, or industrial developments. Noncommercial forest land, while accounting for only 3 percent of the state's land area, and from which little or no timber will be harvested, is nevertheless very important—especially to the urban and suburban residents of Pennsylvania. All publicly owned parks with forest land are considered productive reserved and, along with urban forest land, provide much of the green space that is becoming more precious for a majority of the state's population.

Commercial forest land, the land class that our survey was designed for, accounts for the remaining 15.9 million acres of forest land, and makes up 55 percent of Pennsylvania's land base. Table 1 in the Appendix includes a detailed breakdown of the forest land by county, type of forest land, and ownership.

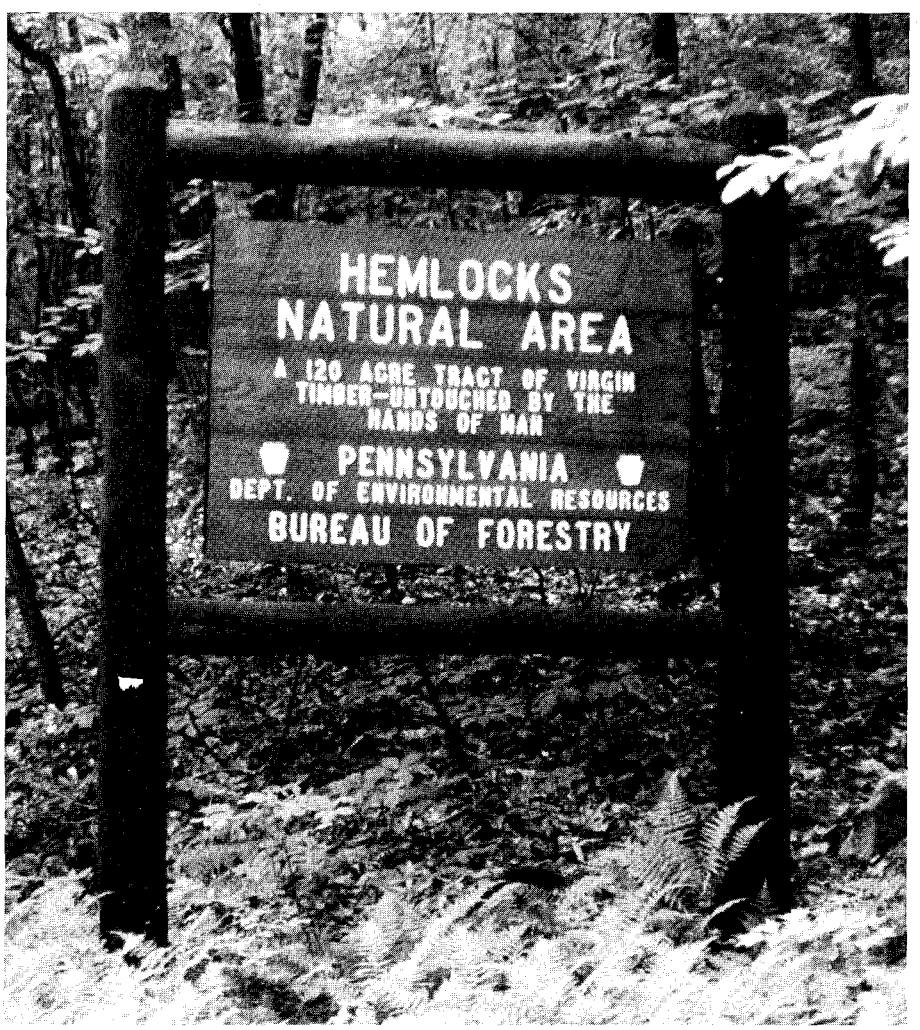
Trends

To discuss trends in forest area, we need to have the best estimates for at least two points in time. We could take the previously published estimates (for 1955 and 1965) and compare them with the 1978 estimate. However, in calculating the 1978 area estimate of commercial forest, we used a new technique that resulted in better county-level statistics. Part of this technique entailed recalculating estimates from 1955 and 1965 so that the basis for all three survey estimates was consistent. The recalculations yielded different but, we believe, better estimates of commercial forest land for 1955 and 1965. Comparable estimates of forest land for the three survey dates are:

Forest land	*1955*	*1965*	*1978*
	Acres		
Commercial	15,607,500	16,230,900	15,923,700
Noncommercial	97,000	354,000	902,200
Total	15,704,500	16,584,900	16,825,900

Forest area has changed dramatically since the time William Penn established the colony of "Penn's Woods" (Fig. 3). Historical records indicate that nearly all of the state was forested 300 years ago. As more and more settlers moved in and cleared land for farming, the forest area declined. Toward the end of the 19th century, the clearing of forest land for timber picked up momentum; by the early 20th century, forest land area was at its lowest point. Much of the logged-over land was burned over and eroded so badly that it was considered to be barren land.

Creation of Wild and Natural Areas is the major reason for the decline in commercial forest land administered by the Bureau of Forestry.



Western Pennsylvania Conservancy

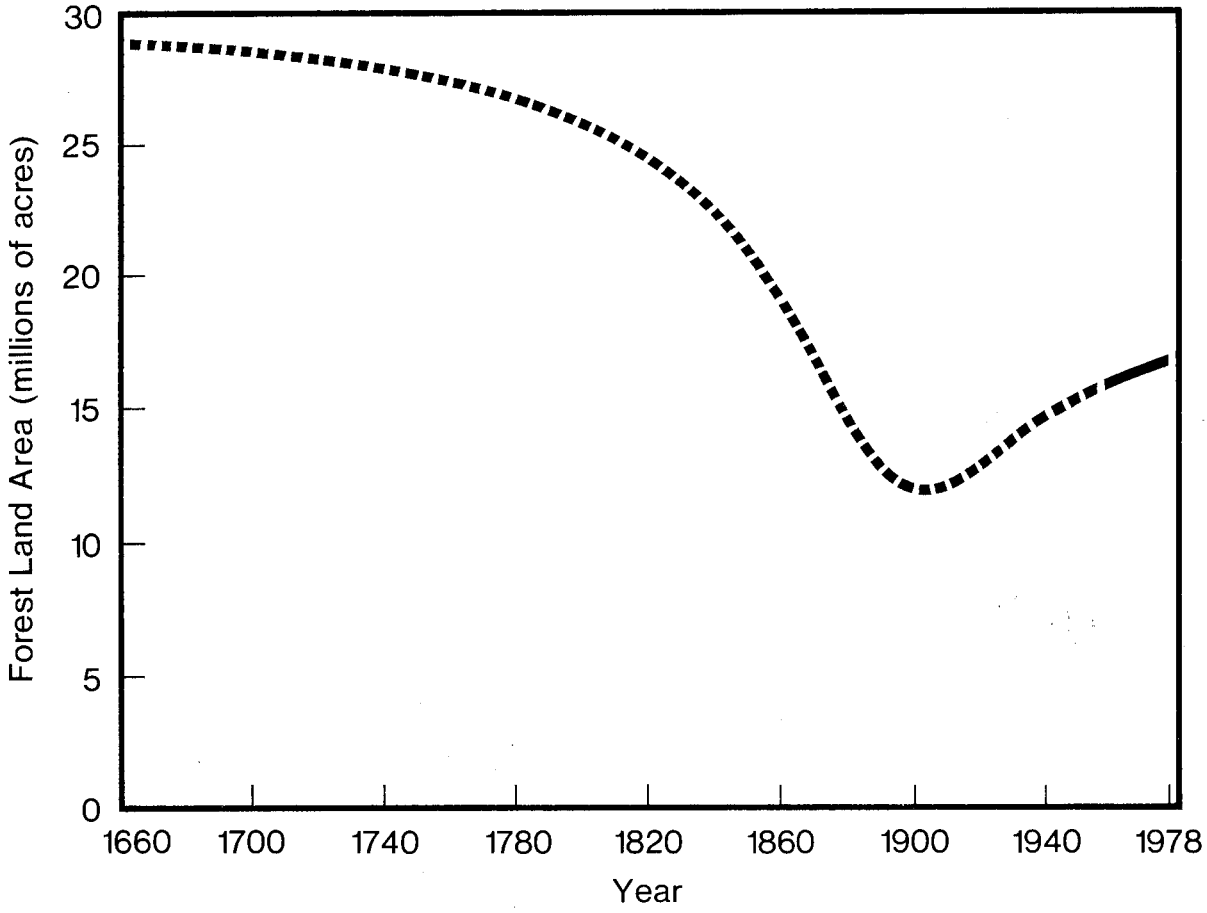


Figure 3.—Probable decline and rise of forest-land area in Pennsylvania, 1660 to 1978 (Sources: Illick 1923b; Ferguson 1958; Ferguson 1968; Considine and Powell 1980).

Then, as the last of the big trees were felled and as people had no need for additional cleared land, the area of forest land stopped declining. As nature began to reclaim the ravaged hillsides and as many marginal farms were abandoned, the area of forest land began its gradual climb to its present level.

During the period from 1965 to 1978, acreage shifted in and out of various land use classes. The net effect of these changes was that forest land increased slightly—by 241,000 acres or 1 percent. Noncommercial forest land acreage rose by 548,200 acres in the 13-year period. Much of this increase occurred on State-owned forest land where newly acquired land and previously owned land were classified as productive reserved (State parks and Wild and Natural Areas) or as unproductive forest land.

The net effect for commercial forest land, on the other hand, was a slight drop of about 300,000 acres or 2 percent between 1965 and 1978. This change is the net effect of losses to other land uses exceeding gains from other land uses (Fig. 4). Over this period, we estimate that commercial forest land gained about 300,000 acres, about three-quarters of this from agricultural land (old fields and pastures) reverting to forest. But in other areas throughout the state, about 600,000 acres of commercial forest land were being cleared, flooded, developed, or reclassified to noncommercial use. Nearly 60 percent of this land was classified as "urban and other." In a separate evaluation of land clearing in Pennsylvania between 1957 and 1971, we found that commercial forest land was converted to a number of urban and other land uses. The largest of these was rights-of-way (roads, pipelines, and powerlines) followed by housing (both single and multifamily), mining (primarily surface coal mines), industrial-commercial, public recreation, and other in that order. Nearly 25 percent of the loss (150,000 acres) was the result of public agencies reclassifying commercial forest land to a noncommercial use. Approximately 70,000 acres went into agricultural land while another 30,000 were flooded to make ponds or reservoirs.

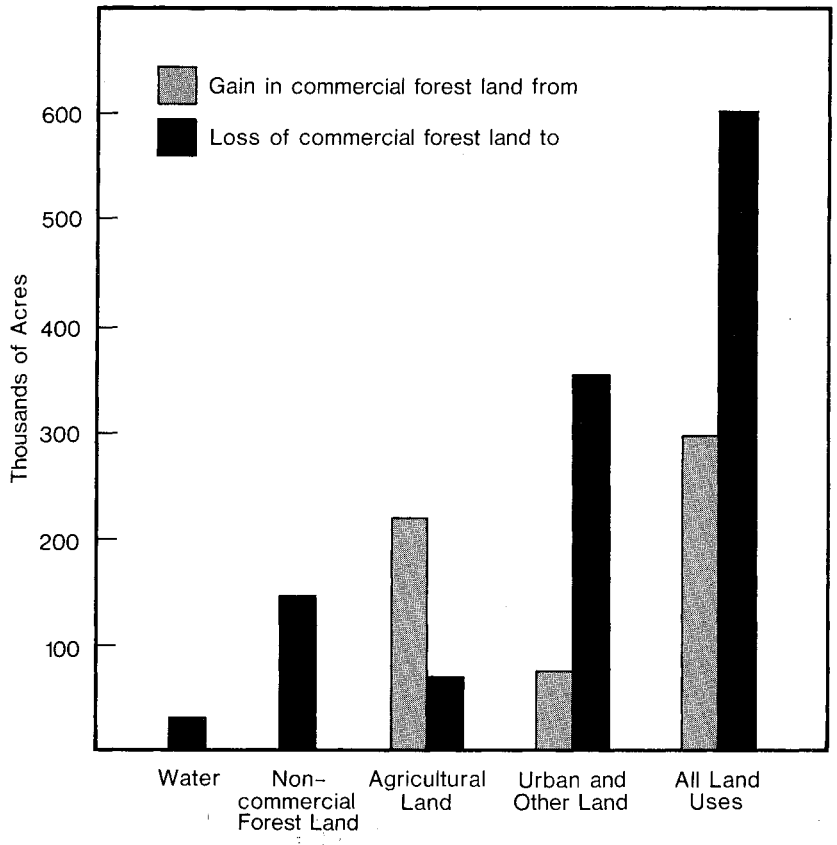


Figure 4.—Gain and loss of commercial forest land in Pennsylvania from 1965 to 1978.

Abandoned farmland is the major source of new forest land in Pennsylvania.

Western Pennsylvania Conservancy

With land use patterns varying across the state (Fig. 5), it is not surprising that the change in commercial forest acreage has varied between the geographic units:

Unit	Commercial forest land		Change
	1965	1978	
	- - - - Thousand acres - - - -		Percent
Western	2,522.6	2,534.3	+ 0.5
Southwestern	1,709.7	1,597.1	– 6.6
Allegheny	3,325.4	3,282.2	– 1.3
North-Central	2,900.6	2,859.8	– 1.4
South-Central	1,721.4	1,642.0	– 4.6
Northeastern	1,220.7	1,357.3	+ 11.2
Pocono	1,763.7	1,656.7	– 6.1
Southeastern	1,066.8	994.3	– 6.8
All units	16,230.9	15,923.7	– 1.9

The Western Unit maintained its forest area over this period. Any decrease in forest area due to expansion of urban and built-up land around Pittsburgh and other urban areas was offset by a corresponding increase in forest area from marginal farmland and reclaimed surface mines.

The Northeastern Unit showed the largest absolute and percentage change, registering the only significant gain of commercial forest acreage. Our data indicate that this was primarily due to the reversion of abandoned agricultural land.

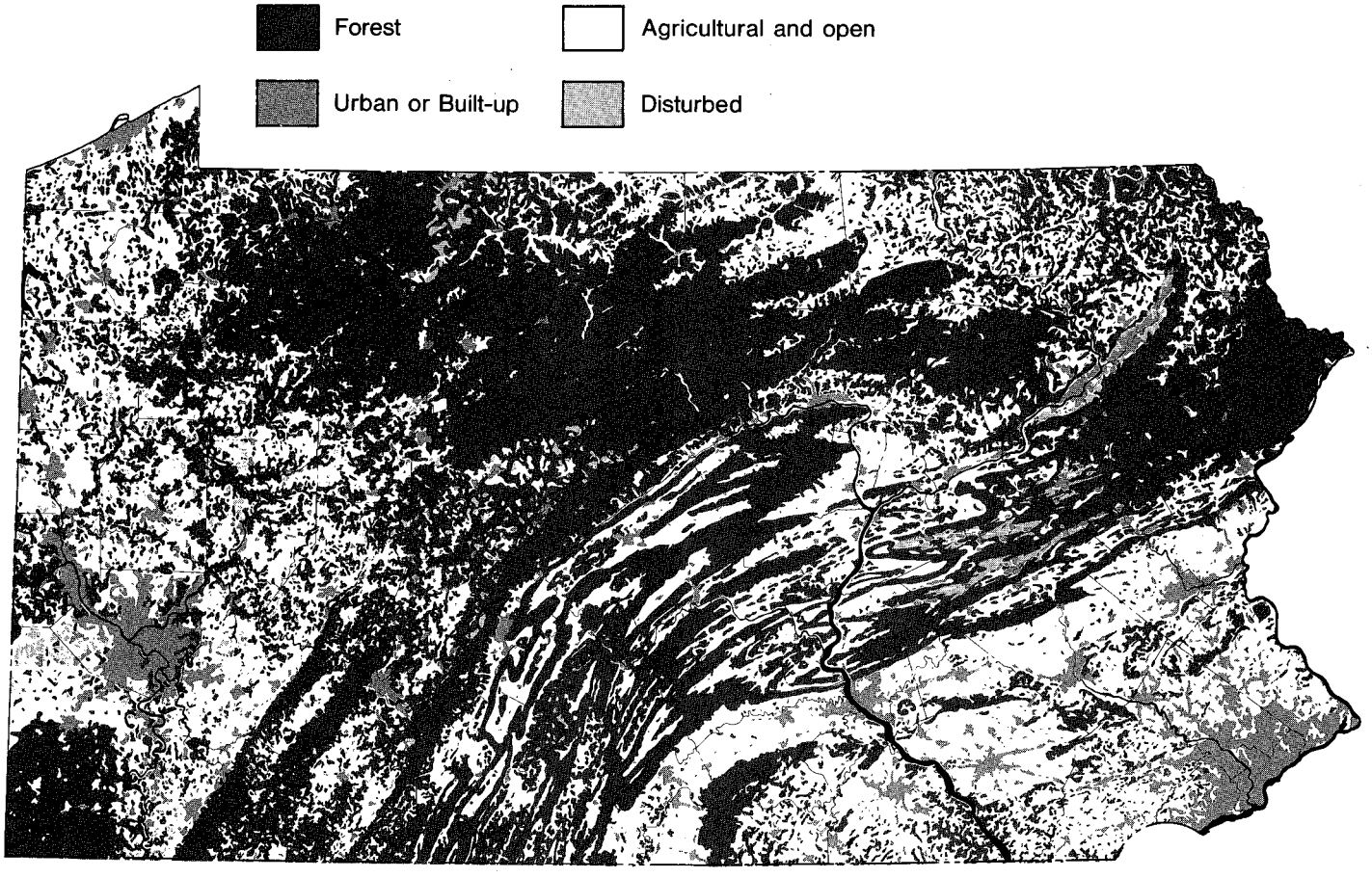


Figure 5.—Generalized land use map of Pennsylvania for the early 1970's (Source: Pennsylvania Land Policy Project 1975).

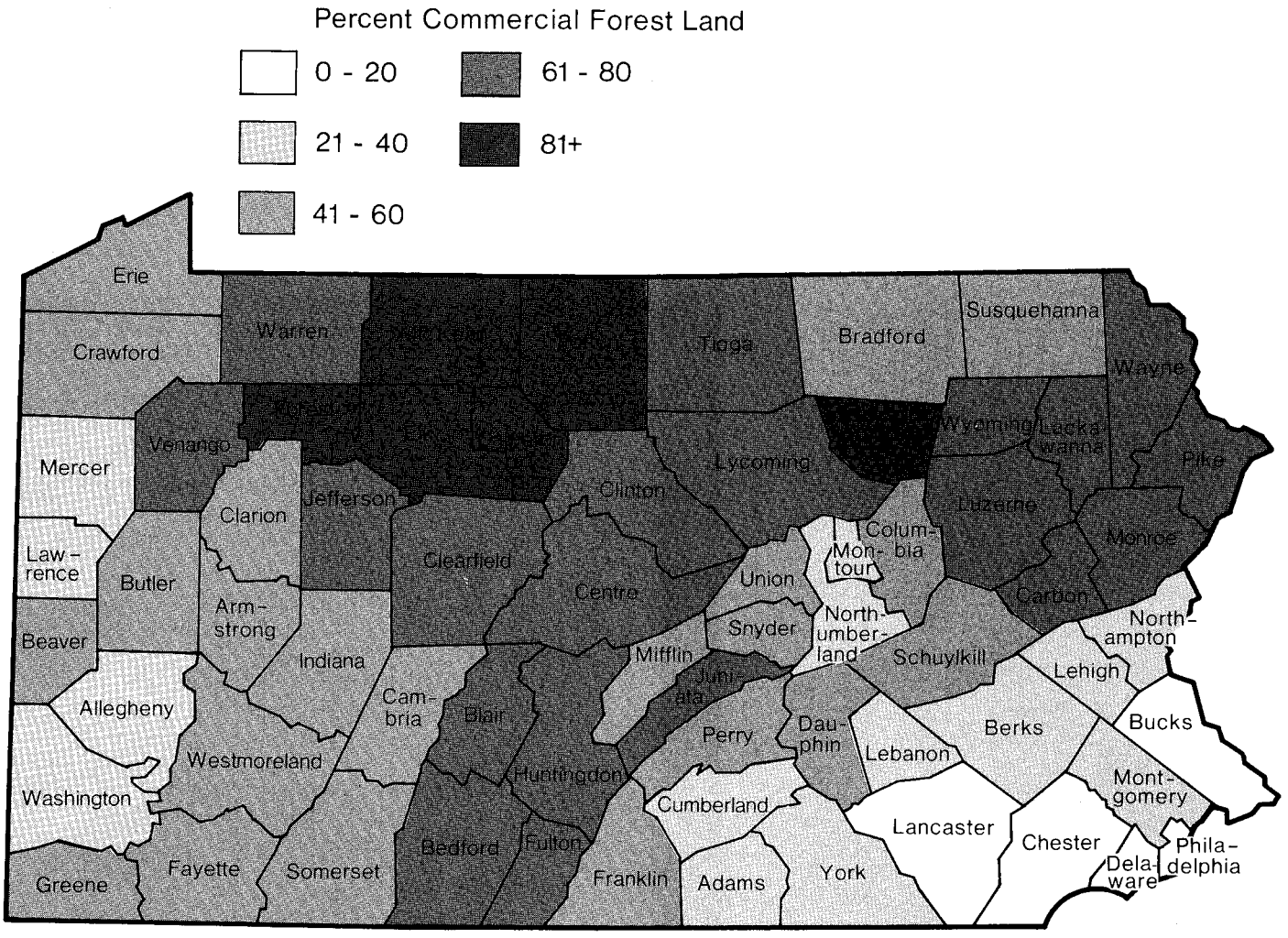


Figure 6.—Distribution of commercial forest land in Pennsylvania, 1978.

The distribution of commercial forest land by county (Fig. 6) shows the highest concentration of forests in the northern and central parts of the state. The Allegheny National Forest, most of the State Forests, and most of the State Game Lands are found in these counties. Because of the relative lack of development and the abundance of forest land with its associated resources and opportunities, the highlands of this area have received special attention. The Pennsylvania Department of Environmental Resources (DER) has developed general management guidelines for the "North Central High Mountain Area" since it is one of the few large remote forested regions remaining between the east coast megalopolis and the Chicago-Detroit-Cleveland urban complex of the Midwest. The Western Pennsylvania Conservancy has proposed a regional strategy for conserving the unique natural assets of this area while promoting needed economic development. A forum of interested parties has recently been set up to address this proposal.

The more sparsely forested counties are in southeastern and extreme western Pennsylvania (Fig. 6). These areas match the urban and agricultural counties shown in Figure 5 quite well. When used together, these two maps provide a good but general picture of the distribution and extent of the important land uses in the state.

Ownership

Fully one-fourth—4.2 million acres—of Pennsylvania's forest land is publicly owned. This is the greatest proportion and acreage in public holdings of any state in the Northeast. The Pennsylvania Bureau of Forestry manages 2 million acres of State Forests for such diverse benefits as timber products, wildlife habitat, outdoor recreation, water, and minerals. The other large multiple-use manager is the USDA Forest Service, which administers the 489,000

Certain areas of north-central Pennsylvania are covered with unbroken expanses of forests.

Western Pennsylvania Conservancy

acres of forest land in the Allegheny National Forest. The Pennsylvania Game Commission manages 1.1 million acres of forest in State Game Lands primarily to improve wildlife habitat. In this process, numerous other forest resources are enhanced. The remaining public forest land is held by diverse organizations, many of which provide forest recreation (State Parks) or plentiful fresh water (municipal watersheds).

Nearly 83 percent of the public forest land is classified as commercial forest. The remaining 17 percent is noncommercial forest land, which means that as a result of either its location, low productivity, or administrative designation, this acreage cannot provide a sustained yield of timber crops. Nearly all of the noncommercial forest land is publicly owned.

Seventy-five percent of the forest land is in private hands. Nearly 99 percent of this land, or 12.5 million acres, is commercial forest land. The heaviest concentrations of privately

Forest land, the darker shades in this aerial view, is relegated to relatively small and scattered tracts in southeastern Pennsylvania (Berks County).

Agricultural Stabilization and Conservation Service

owned commercial forest land are in the western and eastern parts of the state (Fig. 7). The private lands are held by an estimated 490,100 owners. In an ownership study conducted in conjunction with this forest survey, the characteristics and attitudes of these diverse owners were assessed and analyzed (Birch and Dennis 1980). This study showed that 86 percent of the private landowners are individuals (as opposed to partnerships, corporations, clubs, etc.), most of whom live within a mile of their woodland. The average size holding of individual owners is 20.3 acres. Only a little more than one-half of the private landowners have held their land for more than 10 years. Benefits other than timber production are more important to most landowners; 75 percent have never harvested timber from their land. The average forest holding of these owners is only 16.1 acres. About one-half of the private owners, holding about one-fifth of the private commercial forest land, indicate that they never plan to harvest timber from their woodland. Slightly more than one-half allow some form of recreational use of their land by the public.

The trends in ownership of commercial forest land are shown in Figure 8. Most of the changes have occurred since 1965. Farmer, State, Federal, and County and Municipal ownership have been relatively constant over the 23-year period. State Forests and State Game Lands have been expanding as a result of active land acquisition policies, but the rise in commercial forest acreage has been slight since 1965 due to the reclassification of forest land to noncommercial forest land by the Pennsylvania Bureau of Forestry. Forest industry holdings have more than

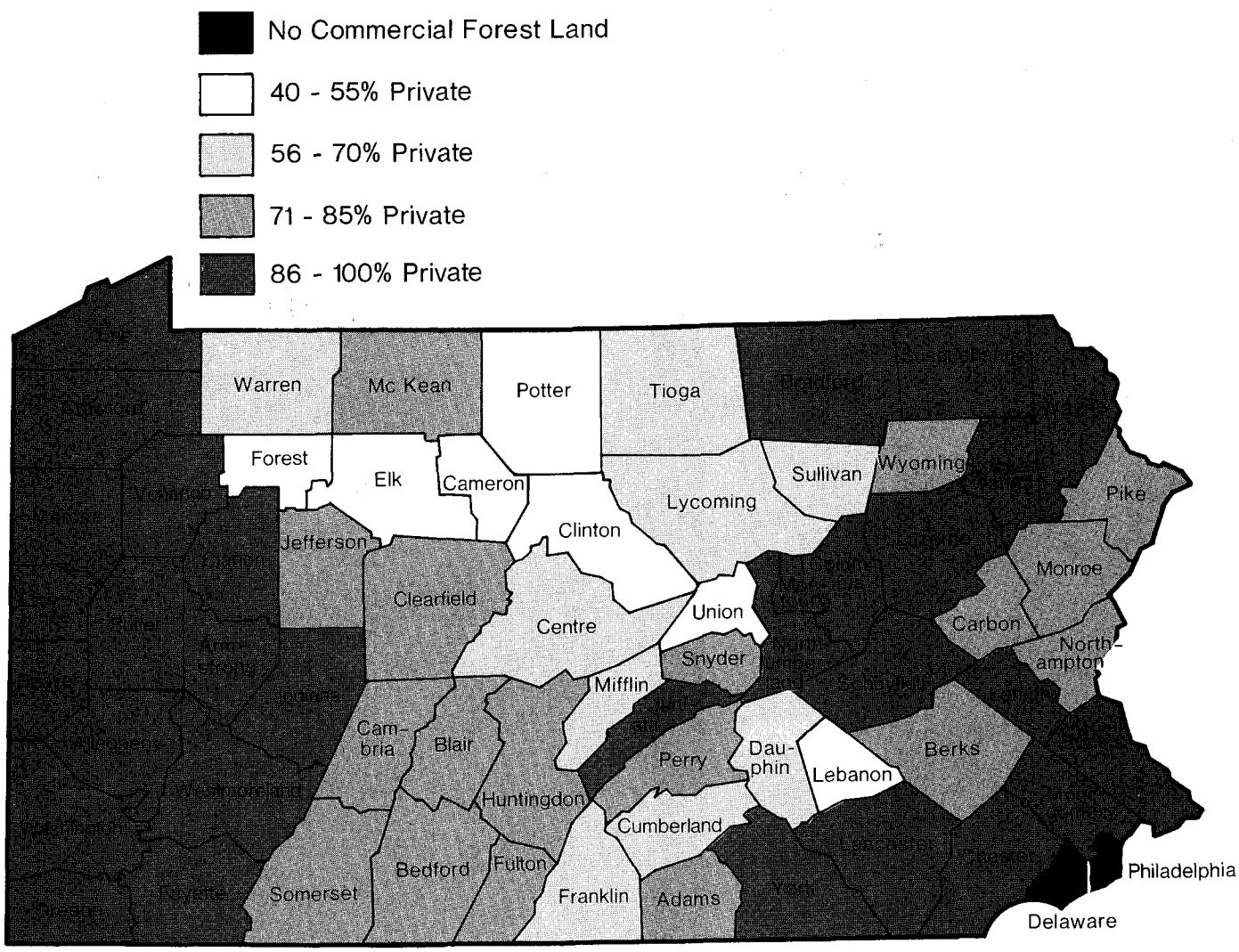


Figure 7.—Distribution of privately owned commercial forest land, by county.

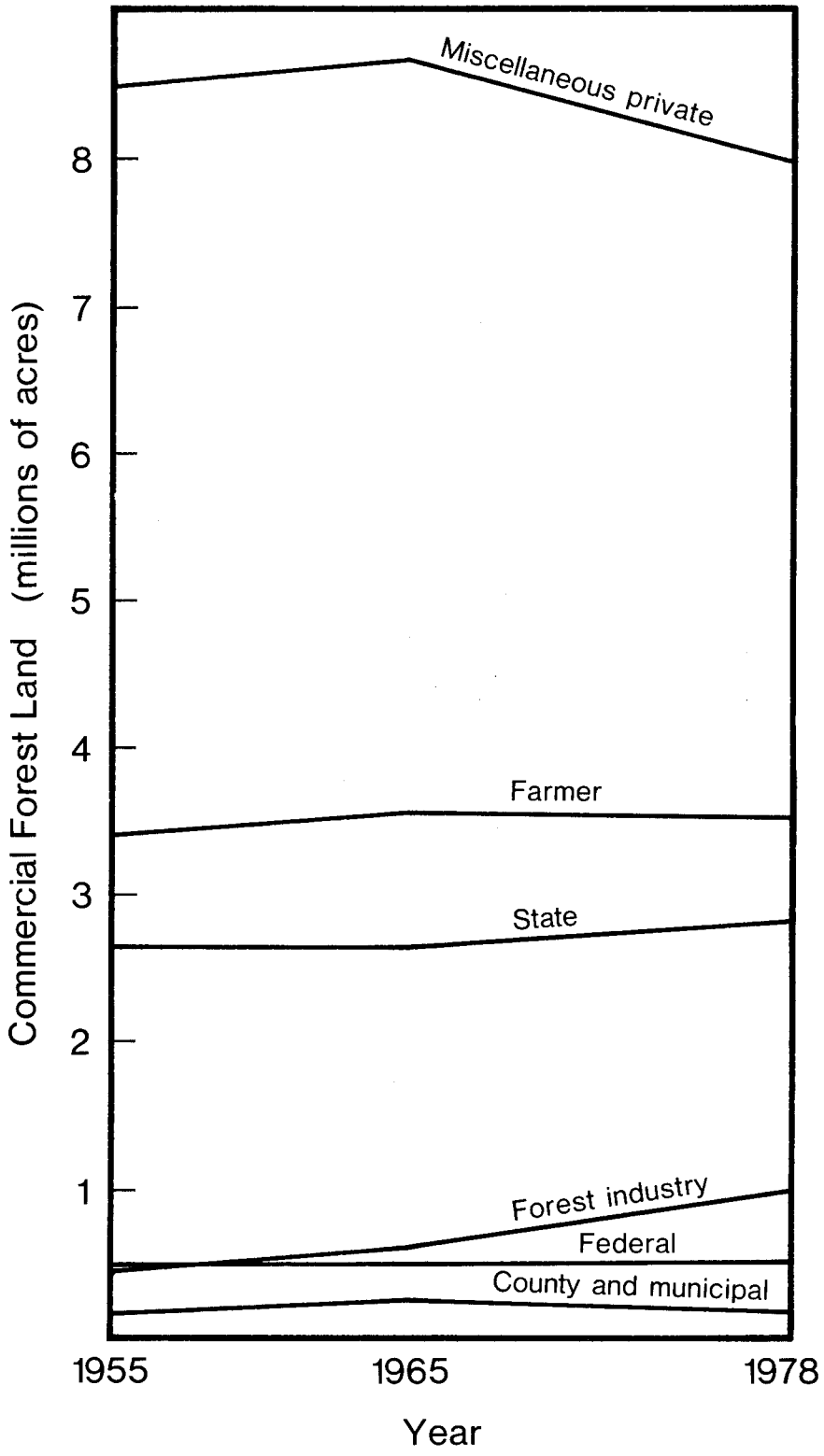


Figure 8.—Trends in ownership of commercial forest land.

doubled since 1955. These industries are consolidating their holdings as well as expanding to obtain a more productive and reliable timber base. Nearly all of the increases in State and forest industry holdings have been at the expense of the miscellaneous private landowner category. This category, while still far and away the most dominant, is the only one that showed a substantial decrease since 1965. In addition to purchases by State agencies and forest industries, the miscellaneous private landowners are the ones most likely to lose commercial forest land to such nonforest uses as highways, rights-of-way, shopping centers, and housing developments.

Stand Size

Over the 13-year period from 1965 to 1978, the stand-size composition (i.e., sawtimber stands, poletimber stands, sapling-seedling stands, and nonstocked areas) has shifted toward a more mature distribution (Fig. 9). The 1965 inventory showed that sawtimber stands dominated with 44 percent, followed by poletimber stands (35 percent), sapling-seedling stands (19 percent), and nonstocked areas (2 percent). By 1978, the gap between the sawtimber and poletimber proportions had widened. Many poletimber stands had matured into sawtimber stands to more than offset any change in sawtimber stands to smaller stand sizes.

The share of the commercial forest base in sapling-seedling stands has changed little over the 13 years, remaining at or near 20 percent. These stands usually originate from abandoned agricultural land that has reverted to forest, or from forest land that was extensively cut over, regenerated naturally, and is now in an early stage of development. The stability of sapling-seedling stand's percentage indicates that as much land is coming into this class by the previously mentioned processes as is moving out into the poletimber-size class. This stability suggests that the combined effect of agricultural reversion and clearcutting intensity has remained relatively constant over this period for the state as a whole.

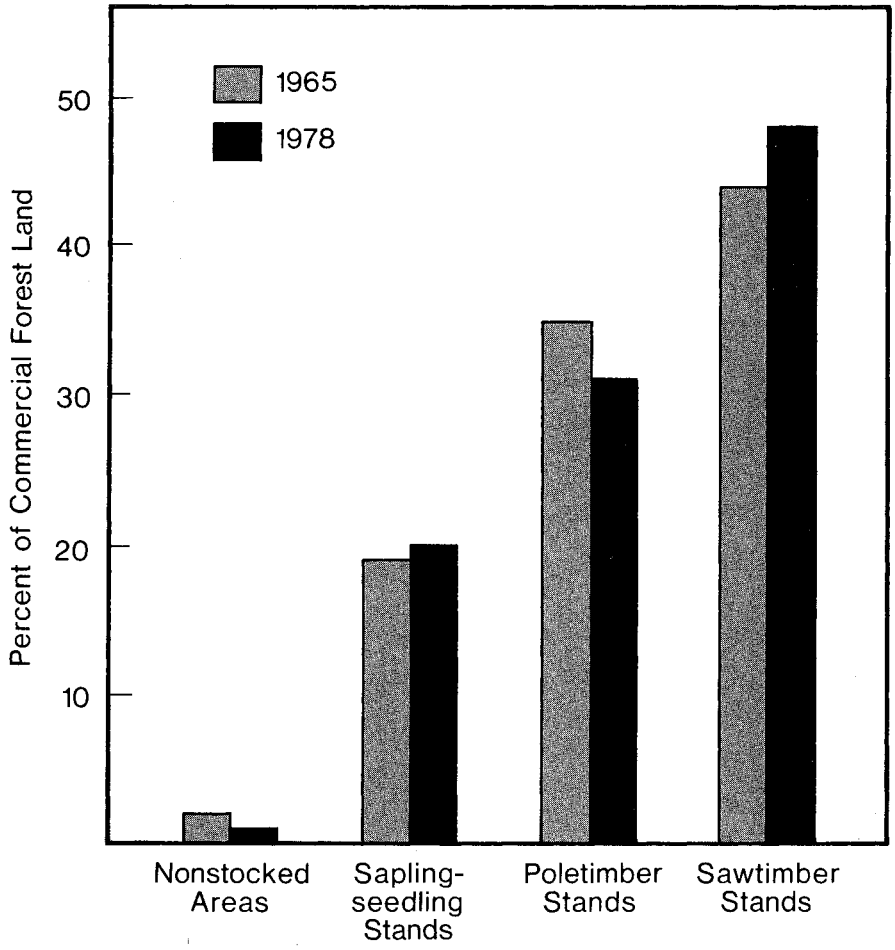


Figure 9.—Trends in stand-size class of commercial forest land.

Over the last 60 years or so, the acreage of nonstocked areas has been declining, and by 1978 was about 200,000 acres. This low figure attests to the fact that cleared land in Pennsylvania does not remain barren for long. Seedlings, seedling sprouts, and stump sprouts, responding to abundant water, nutrients, and light, usually reclaim the land within a couple of years.

In a regulated hardwood forest, that is, an intensively managed forest that produces a steady and continual supply of sawlogs, one suggested optimum distribution of stand sizes is 50 percent in sawtimber, 30 percent in poletimber, and 20 percent in sapling-seedling stands (Liscinsky 1978). On a statewide basis, these percentages are now at 48, 31, and 19 respectively, indicating a favorable situation for the hardwood timber resource, and one that favors many wildlife species as well. This stand-size distribution has not, however, resulted from intensive forest management—only a small fraction of Pennsylvania's forests have received such treatment. The current situation is the result of a combination of arbitrary cuttings, abandonment of farmland, and natural forces. These have occurred in the absence of any concerted and unified effort by the forest-land owners of the state. The decline of wildfires, due largely to fire control efforts of the Bureau of Forestry, also has contributed to this maturing stand-size distribution.

However, among the geographic units there is considerable variation in stand-size distribution, reflecting the past cutting histories and markets for the forests in these areas. As shown in Figure 10, the proportion of commercial forest land in sawtimber stands ranged from 32 percent in the Pocono Unit to 69 percent in the Southeastern Unit. Poletimber stands ranged from 14 percent in the Southeastern Unit to 40 percent in the Northeastern Unit, and sapling-seedling stands and nonstocked areas ranged from only 9 percent in the Allegheny Unit to 33 percent in the Western Unit.

For an explanation of how past management has affected the stand-size distribution, let's look at two adjacent but very different units—Pocono and Southeastern. The Pocono Unit has the lowest concentration of sawtimber stands in the state and, consequently, relatively high proportions of poletimber and other stands. At the turn of the 19th century, iron ore was discovered in this region, and furnaces were built to process the ore into iron. These furnaces initially required steady supplies of charcoal to fuel them, and this charcoal came from the abundant hardwood (mainly oak) resource. Heavy and frequent cuttings were made through the early 19th century. Then anthracite coal was recognized as the better fuel. The forests, however, were still cut frequently as they now supplied the thousands of mine timbers needed for the construction and expansion of the underground mines. This heavy cutting through the 19th century and early into the 20th century left the forests with few sawtimber stands but many sapling-seedling and poletimber stands. As the demand for charcoal and mine timbers dropped and was eventually replaced by a less intense demand for sawlogs and pulpwood, the resource began to recover and mature. Recent trends indicate the proportion of sapling-seedling stands is decreasing and that sawtimber stands are increasing. But with poletimber stands still dominating, the resource is still several decades away from a distribution more favorable for sustained timber yield.

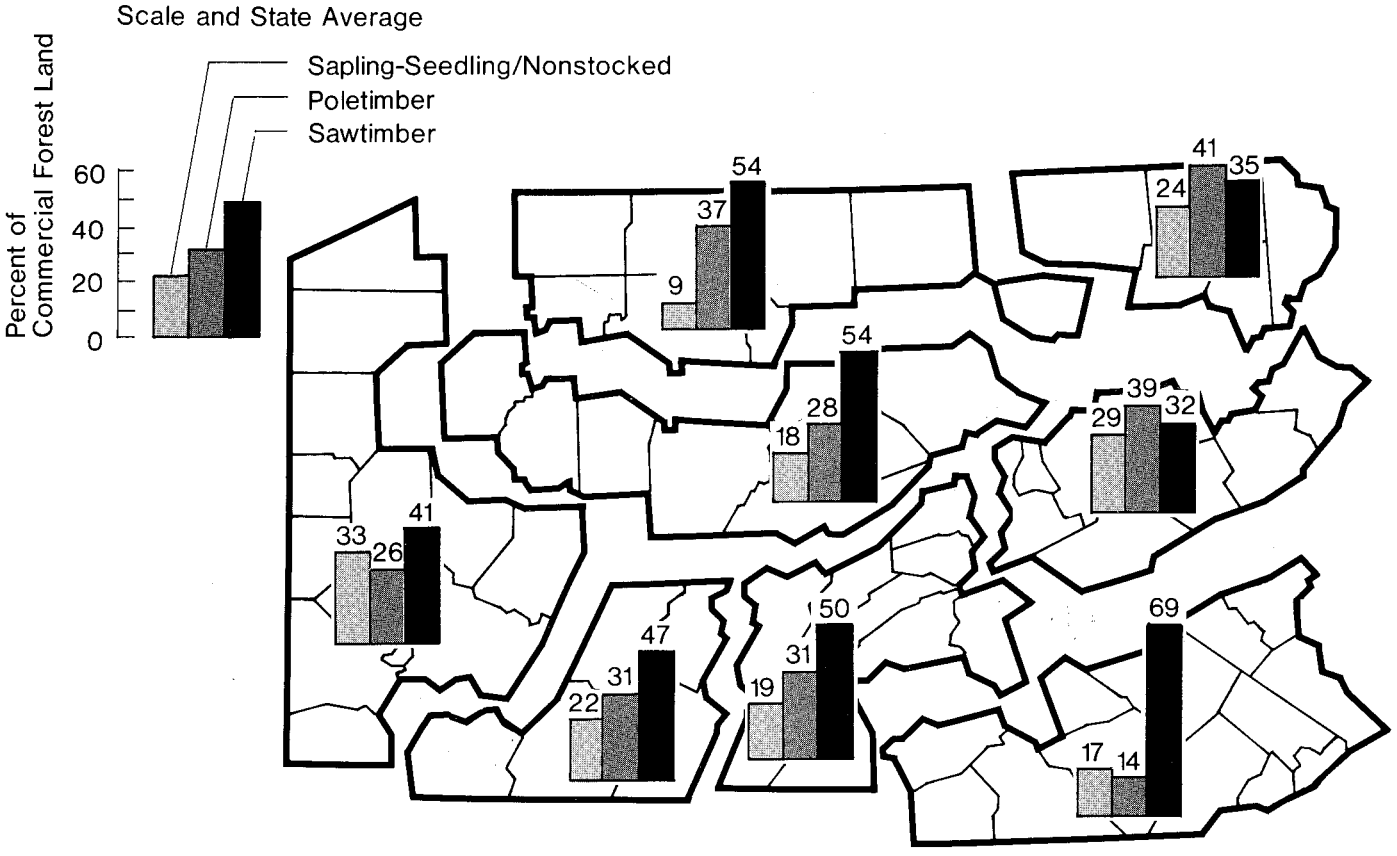


Figure 10.—Stand-size distribution, by geographic unit, 1978.

The Southeastern Unit, just to the south, has a much different stand-size distribution (Fig. 10). Here, sawtimber stands account for nearly 70 percent of the commercial forest land, with the remainder divided relatively evenly between poletimber and other stands. This region was the first area in the state to be settled. The old-growth timber stands were cleared for farming, and by the early 19th century most of the best agricultural lands had been identified and were in pasture or cropland. A relatively small fraction of the land was left in a forested condition, so forest industries turned their attention to the more northern and western areas, where timber was cheaper and more plentiful. In this region, 86 percent of the commercial forest land is in private hands, and the average private holding is only 11 acres (Birch and Dennis 1980). Under such circumstances, heavy cutting often is not desired by the landowner. This is especially true of clearcutting, which would create sapling-seedling stands. These are some of the reasons why sawtimber stands have dominated the southeastern forests for many decades, and trends indicate that the proportion of poletimber and other stands is continuing to decline.

Since sawtimber stands have special significance in that they provide a variety of benefits to forest users, it is useful to know which counties have especially high concentrations of this resource. While north-central counties such as Lycoming, Centre, and McKean have the greatest areas of sawtimber

Oak-hickory sawtimber stands account for about 4 million acres of forest land in Pennsylvania.

Western Pennsylvania Conservancy

stands, it is in counties such as Adams, Cumberland, and York where sawtimber stands dominate the commercial forest land (Fig. 11). These three southern counties combined have 276,600 acres of sawtimber stands, but sawtimber stands account for 78 percent of the commercial forest in these counties. Centre County, on the other hand, has 283,500 acres of sawtimber stands, but these stands represent only 56 percent of the county's commercial forest land. As a comparison of Figures 6 and 11 shows, a county need not be heavily forested to contain a high concentration of sawtimber stands. This has significance for buyers of large hardwood sawlogs, recreation planners seeking older growth forests for parks, and birdwatchers looking for screech owls, Carolina chickadees, or hairy woodpeckers, which dwell in mature oak forests.

The five large ownership classes in Pennsylvania show some interesting differences in stand-size distribution (Fig. 12). The Allegheny National Forest has the greatest proportion of poletimber (40 percent) and a low proportion of sapling-seedling and nonstocked areas (5 percent). Since the USDA Forest Service began to manage this land, 250,000 to 300,000 acres have received some sort of management treatment. Of these treatments, the ratio of thinnings to regeneration cuts has been roughly 5 to 1 (personal communication, Joel Hockinson, Allegheny National Forest). Regeneration cuts, which would produce sapling-seedling stands, are occurring at an annual rate of 1,000 acres. These management activities, as well as multiple-use policies, have favored retaining a heavy proportion of the Forest in poletimber and sawtimber stands. Since most of the stands are 50 to 70 years old, future inventories of the Forest will probably show a sizable shift of poletimber stands into sawtimber stands.

The State Forest distribution shows the greatest percentage in sawtimber stands (74) and the lowest percentages of poletimber (23) and other (3) stands. Much State Forest land is similar to Allegheny National Forest land, especially as regards past history and current management. Part of the explanation for the difference between the National Forest and the State Forest distribution is that State Forest lands contain a higher proportion of oak types than the National Forest. The oak types in Pennsylvania generally were cut earlier than the northern hardwoods types, and are therefore more mature. This leads to more sawtimber stands in the oak areas than in the northern hardwood areas.

The other public group is dominated (83 percent) by State Game Lands. The management goal on these lands is to enhance the habitat for all species of wildlife. To achieve this goal, the Pennsylvania Game Commission is increasing the diversity of habitats through a judicious use of cutting. While sawtimber stands still dominate, poletimber stands are a close second (Fig. 12). Also, the Game Commission often acquires lands that have been logged and that may be in a smaller stand-size condition. This also helps explain why over one-half of the Game Commission's forest land is in poletimber stands, sapling-seedling stands, or nonstocked areas.

Forest industry is an ownership group that uses varied approaches to woodland management. Some indus-

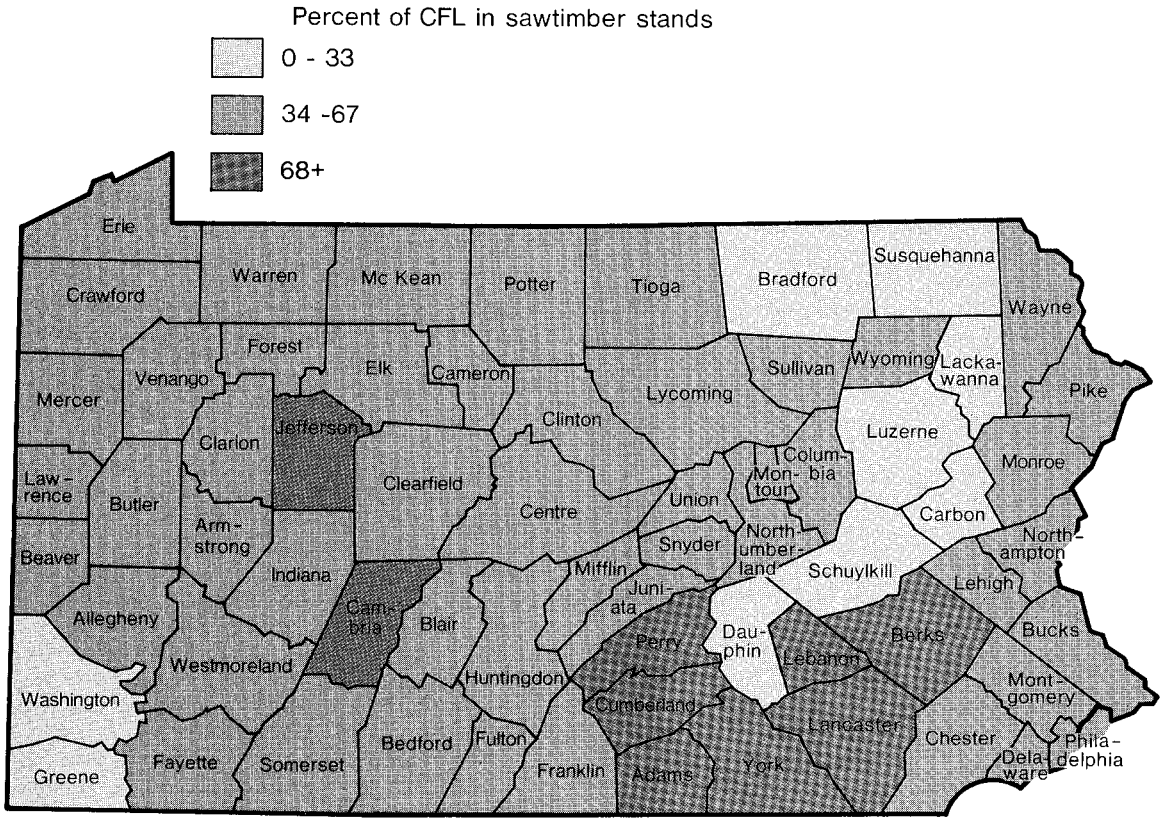
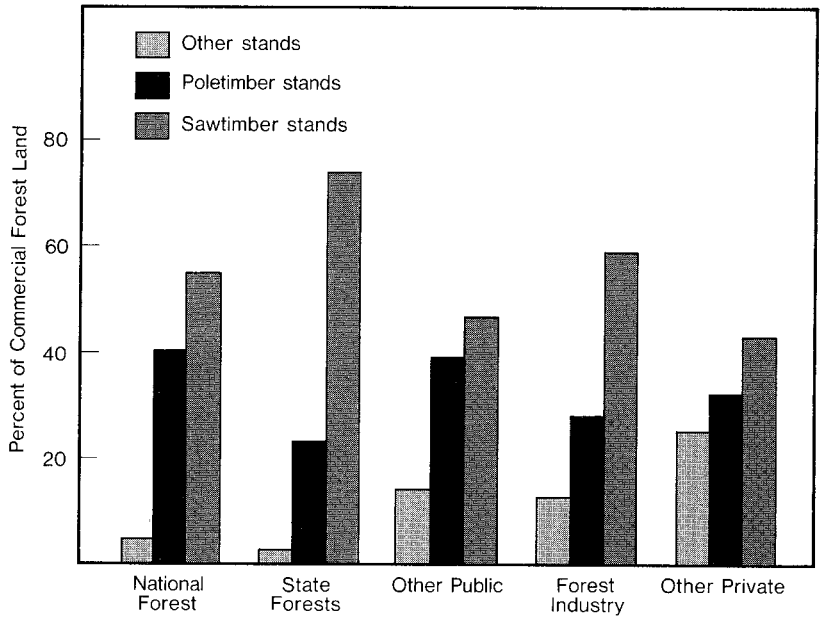


Figure 11.—Sawtimber stand-size distribution, by county, 1978.

Figure 12.—Stand-size distribution, by ownership class.



tries manage their forest land intensively to produce large quantities of timber products. Management and harvesting practices vary according to the product needed. Other industries rely on private forests for their timber. They may practice only low-cost, extensive management on their own lands, keeping them in timber for insurance or investment purposes, or both. These varied approaches have resulted in sawtimber stands accounting for nearly 60 percent and poletimber stands accounting for 28 percent of forest industry forest land. The dominance of sawtimber stands is not surprising since they are the most valuable stands and provide the many timber products that Pennsylvania's forest industries need.

The other private landowners have a hodgepodge of management plans, ranging from no plan at all, to one that is kept in the back of the owner's mind, to one that is formalized in writing. Looking at these diverse lands from a statewide perspective, the proportion of sawtimber stands is the lowest while the proportion of sapling-seedling stands and nonstocked areas is the highest (Fig. 12). This condition may be attributable to more reversion of nonforest land to forest land, heavier cutting of sawtimber stands, and/or more prolonged regeneration periods compared with those of other ownership groups. Few other private landowners manage their land primarily for timber products, but many have cut timber because they believed it was mature or they needed the money and were offered a good price (Birch and Dennis 1980). Many landowners, when they feel that their timber is large enough to have any commercial value, will cut their woodlands without giving much thought to regenerating these stands. In certain areas where the deer populations are so high that they prevent adequate regeneration, new stands may stay in a nonstocked or seedling condition for an abnormally long period. In fact, the other private group not only has the highest percentage of other stands but also has more than 200,000 acres (nearly 100 percent of the state's total) of nonstocked areas.

Looking at the stand-size distribution, we can gain some insight into the impact forest-land ownership on Pennsylvania's forest resources. Stand-size has some obvious implications for timber products, but also is an important indicator of the forest's ability to provide wildlife habitat and recreation opportunities, and to protect soil and water resources. Different owners and/or managers have different perspectives on the mix of these values that forests should produce. This variety of approaches to forest management has contributed largely to the diverse stand-size distributions (Fig. 12) and to the rich mixture of conditions and opportunities that characterize the commercial forest land of Pennsylvania.

Forest Type

Pennsylvania's commercial forest land is composed of 33 forest types, based on plurality of species stocking. Twenty-one of these are relatively uncommon, accounting for only 11 percent of the total commercial forest area. Seventy-eight percent of this forest land base is in 10 types. Individually, these range from 5 to 15 percent of the forest area.

To simplify the discussion, the 33 types can be assigned to 9 forest-type groups. Two of these groups—oak/hickory and northern hardwoods—dominate Pennsylvania's forests, so much so that the other seven groups together only account for 13.2 percent of the commercial forest land (Fig. 13).

The geographic location of Pennsylvania is the primary reason why these two forest-type groups dominate. Oak/hickory forests prevail throughout the Midwest and the Mid-Atlantic regions in moderately dry to moist temperate climates. The soils generally are well-drained and unglaciated. The northern hardwoods (maple/beech/birch) prevail in glaciated regions such as New England, New York, and the Great Lake States. They tolerate cooler and moister conditions than oaks. Pennsylvania encompasses conditions that favor either forest-type group and a broad and ill-defined transition zone where there is considerable mixing and interspersion of the forest types that make up these two groups. The average number of days without a killing frost seems important in separating these groups, and in Pennsylvania the boundary approximates the 140-day lines highlighted in Figure 14, with oaks generally dominating in

Top Ten Forest Types

	Thousand acres	*Percent of total*
1. Sugar maple/beech/yellow birch	2,413	15
2. Chestnut oak	1,817	11
3. Black cherry	1,394	9
4. Red maple/northern hardwoods	1,324	8
5. Mixed northern hardwoods	1,180	7
6. Northern red oak	943	6
7. Mixed central hardwoods	941	6
8. Red maple/central hardwoods	869	6
9. White oak/red oak/hickory	856	5
10. Post, black, or bear oak	772	5
Total	12,509	78

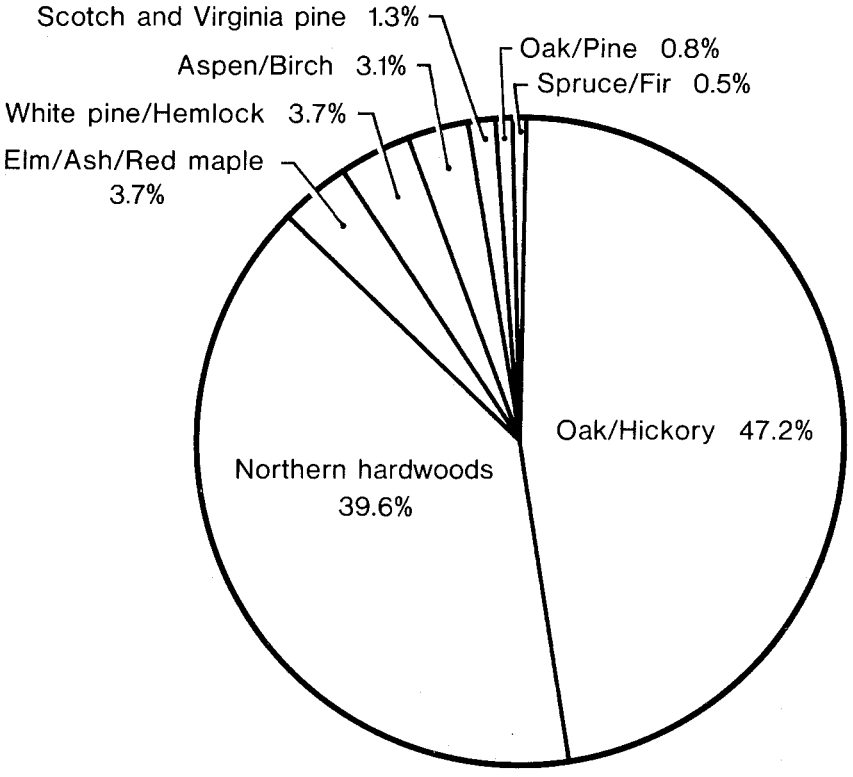


Figure 13.—Percentage of commercial forest-land area, by major forest-type group, Pennsylvania, 1978 (the oak/gum group amounts to less than 0.1 percent).

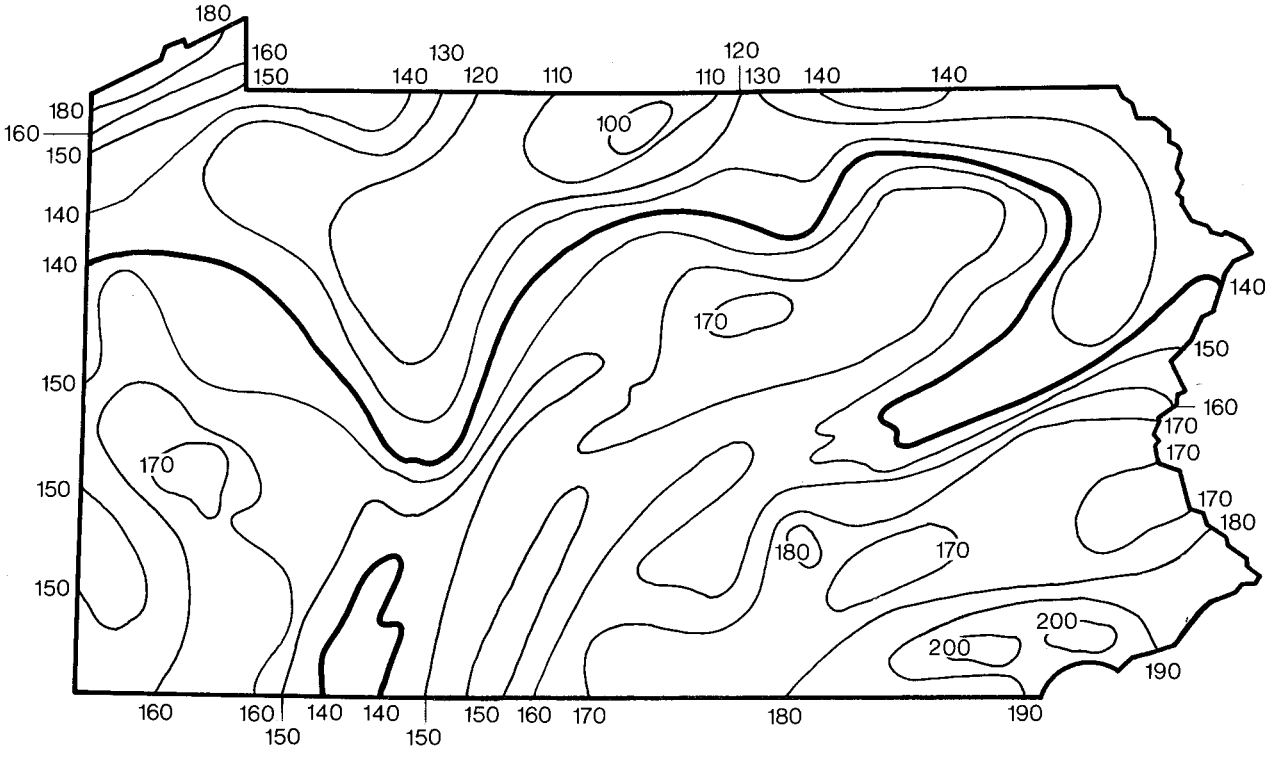


Figure 14.—The average number of days without a killing frost (Source: Cunningham et al. 1977).

areas with more frost-free days. The cutting practices and fires earlier in this century did not favor the reestablishment of softwood stands (especially white pine and hemlock), and lowland conditions that would support elm/ash/red maple or oak/gum stands are uncommon.

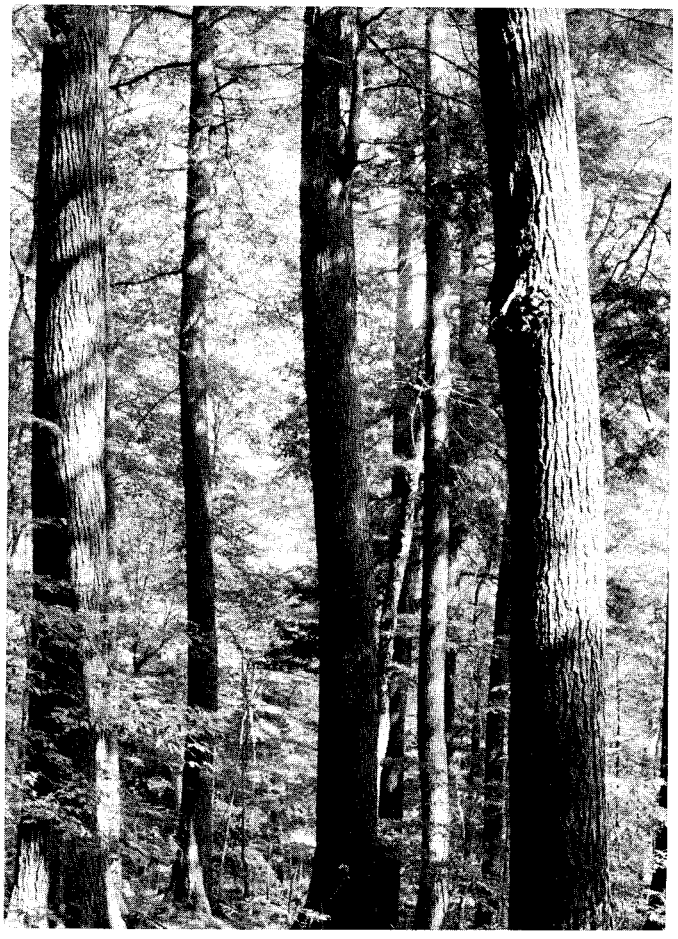
The most abundant type group is oak/hickory. This group accounts for the majority of the commercial forest acreage in the North-Central (54 percent) and the Southwestern (58 percent) Units, and dominates the South-Central, Pocono, and Southeastern Units (72 percent). The nine oak/hickory types account for 7.5 million acres of commercial forest land. Within this type group, the most common type is chestnut oak with 1.8 million acres. Sawtimber stands dominate the group with 53 percent while poletimber stands are next with 30 percent, followed by other stands with 17 percent. Besides the white pine and hemlock type group, oak/hickory has the highest percentage of sawtimber stands, an indication that this is one of the more mature forest-type groups in the state.

The other major forest-type group, northern hardwoods, accounts for 6.3 million acres and dominates the forests of the Allegheny (69 percent), Northeastern (64 percent), and Western (44 percent) Units. The sugar maple/beech/yellow birch forest type is most prevalent with 2.4 million acres. The black cherry type accounts for 1.4 million acres and, from a timber perspective, is the most valuable type in Pennsylvania. The stand-size distribution of the northern hardwoods type group is similar to the statewide average, with 46 percent in sawtimber stands. Two ownership classes, National Forest and forest industry, are dominated (70 and 55 percent, respectively) by northern hardwoods. This is expected since all of the Allegheny National Forest and over half of the forest industry woodlands are located in the Allegheny Unit.

The other forest-type groups, while accounting for only 13 percent (2.1 million acres) of the commercial forest land area, are important in enriching the variety of forest conditions in Pennsylvania. The evergreen hemlock, pine, and spruce stands provide both a welcome contrast to an otherwise drab winter landscape and valuable wildlife cover for a variety of species. Where markets exist, these types also provide valuable timber products.

Since the last survey (Ferguson 1968), the definition of our forest types has changed so significantly that comparisons of the 1978 data presented here or in the statistical report (Considine and Powell 1980) with those from previous surveys are not valid and should not be attempted.

Old-growth hemlock stands are rare in Penn's Woods today (Tionesta Scenic Area, McKean County).



Timber Volume

Although Pennsylvania's commercial forest-land base decreased slightly since the last survey, timber volumes have generally increased. Between 1965 and 1978, growing-stock volume increased from 17.9 to 21.8 billion cubic feet, a gain of nearly 22 percent. Similar increases were also reported in recent surveys of West Virginia (Bones 1978) and Kentucky (Kingsley and Powell 1978), where the forests that were cut over during the early part of the century continue to grow back.

Pennsylvania forests also experienced a sizeable increase in sawtimber volume, from 31.3 to 46.4 billion board feet—a 48-percent increase. The magnitude of the sawtimber volume increase is larger than those observed in the neighboring states, in part because Pennsylvania was logged over before those states.

There are a number of factors that help explain the sizeable growing-stock and proportionately larger sawtimber increase, the most important of which is that Penn's Woods are maturing. A significant portion of the trees have reached large poletimber or small sawtimber size—a time in the life of trees when annual growth rates are high. While the amount of timber volume grown in a given year is influenced by a host of favorable and unfavorable factors, the annual trend since the last survey has been for successively larger amounts of volume to be added to the growing-stock inventory (see Growth and Removals).

The maturation of the forests may be easily seen in Figures 15 and 16. In Figure 15, the distribution of numbers of growing-stock trees by diameter class, shows proportionately more trees in the 10-inch class and above and proportionately fewer trees in the 6- and 8-inch classes in 1978 than in 1965. Figure 16 shows the growing-stock volumes by diameter class for the two surveys. In essence, a bulge of timber volume which entered the growing stock inventory probably around the time of the first survey in the early 1950's is passing through the diameter classes. This bulge originated in the early decades of this century when most of Pennsylvania's forest lands were logged, often repeatedly. About the same time, large acreages of farmland, mostly of marginal productivity, were abandoned. People were leaving the farms for jobs in the state's rapidly expanding industrial cities. As a result, large blocks of land reverted to woodland within a relatively short time (Fig. 3). It is interesting to note that while the majority of Pennsylvania's volume is in hardwood species, a similarly shaped bulge of pine volume has been observed in some southeastern states (Boyce et al. 1975).

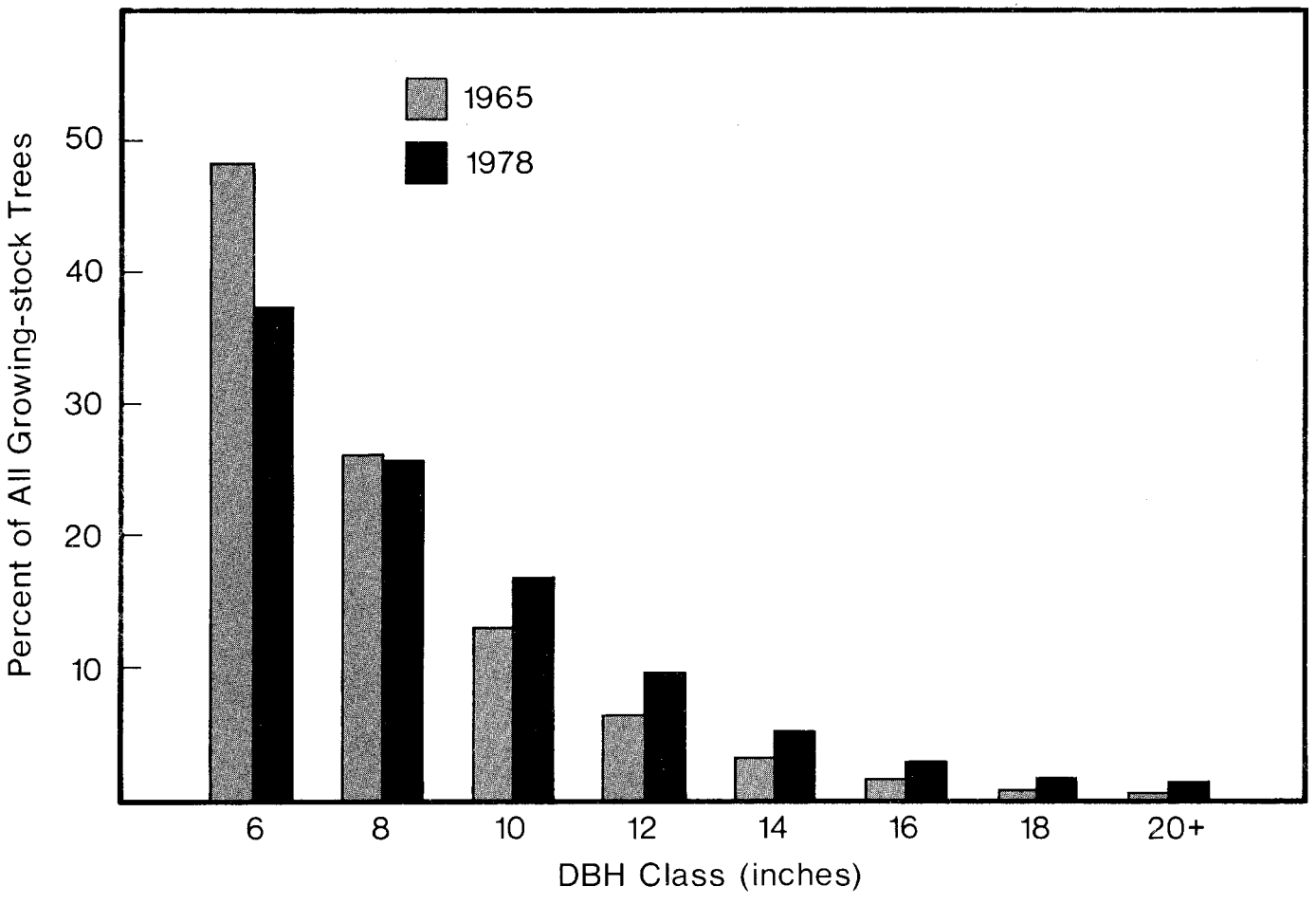


Figure 15.—Distribution of growing-stock trees, by diameter class, Pennsylvania, 1965 and 1978.

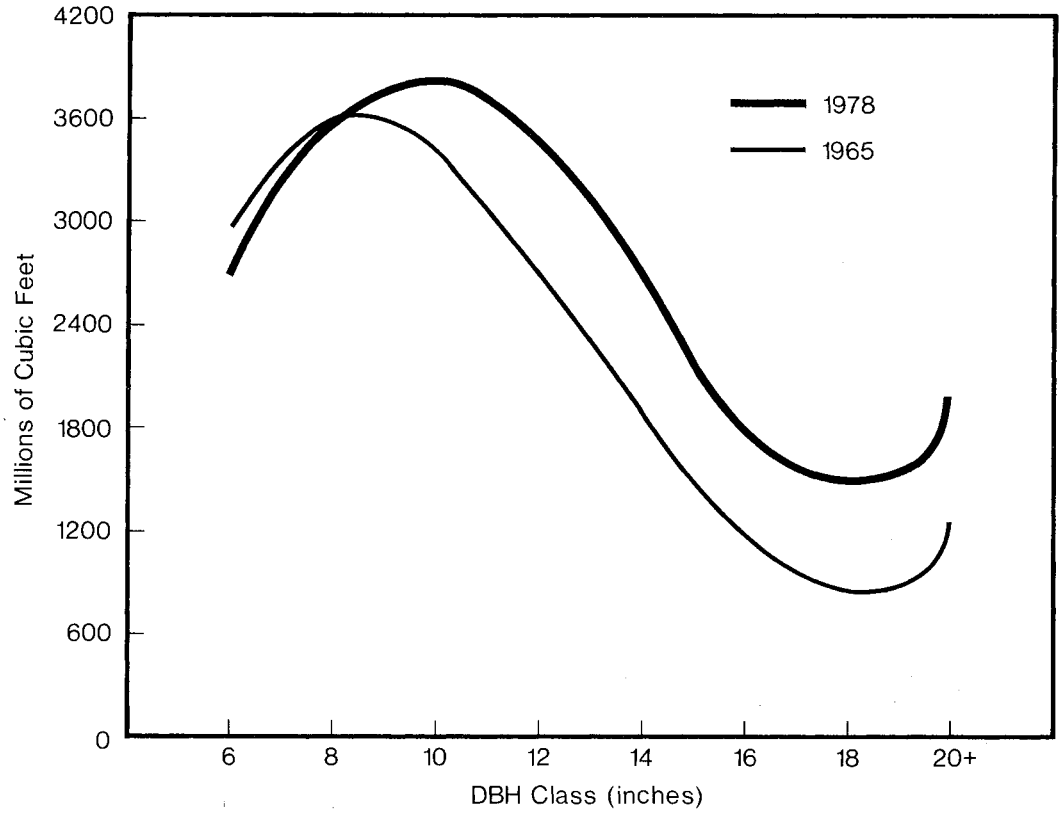


Figure 16.—Net volume of growing stock, by diameter class, Pennsylvania, 1965 and 1978.

Because of the slight decline in commercial forest land while timber volumes were building, the per-acre inventory changes are even more dramatic, especially when examined by ownership classes.

On public lands, growing-stock volume per acre jumped by 53 percent between surveys—from 1,184 to 1,808 cubic feet. The private owners had a much more modest 15-percent increase—from 1,078 to 1,243 cubic feet. The trend in stand-size distribution of commercial forest land for these two ownership groups offers an explanation for the differential volume increases:

Stand size	*Public*		*Private*	
	1965	*1978*	*1965*	*1978*
	Percent			
Sawtimber	44	61	44	44
Poletimber	45	32	32	31
Sapling-seedling	10	7	22	23
Nonstocked areas	1	—	2	2
Total	100	100	100	100

Private ownerships had and have a much larger portion of their land in sapling-seedling and nonstocked stands. These low-volume stands have pulled down overall averages. Also, the stand-size distribution on the surface has changed little over 13 years. But what the balance really means is that the harvesting and other losses of sawtimber stands kept pace with the ingrowth from pole to sawtimber. Harvesting of these sawtimber stands reduced volume buildups.

The stand-size distribution on public lands is different from private lands. Harvesting did not keep up with the maturing stands. This allowed a sizeable increase in sawtimber stands and a resulting higher increase in volume. The increase of

sawtimber stands on public lands should not be a surprise. Public lands usually are managed for a variety of uses, timber being one of many. Timber management is usually for high-quality sawtimber, which requires long rotations. This means that compared with private lands, proportionately fewer sawtimber stands were cut on public lands. However, we anticipate higher harvesting levels on public lands over the next few decades. Volume per acre increases should be smaller, reflecting this rise in removals.

Pennsylvania's Top Ten

Species	Million cubic feet	Percent of total
1. Red maple	3,370	15
2. Northern red oak	2,598	12
3. Chestnut oak	2,058	10
4. Sugar maple	1,991	9
5. Black cherry	1,892	9
6. White oak	1,368	6
7. Beech	901	4
8. Black oak	890	4
9. White ash	880	4
10. Hemlock	872	4
Total	16,820	77

Species

Pennsylvania is dominated by hardwoods. In fact, Pennsylvania has more hardwood growing-stock volume than any other state in the country (USDA For. Serv. 1980c). Pennsylvania's growing-stock volume is 92 percent hardwood—20 billion cubic feet—and 8 percent softwood—1.8 billion cubic feet. These proportions have not changed since the 1965 survey, though their totals increased by 22 and 24 percent, respectively.

Not all species within these two groups performed equally. In order to discuss species' changes in more detail, we grouped the 64 commercial tree species encountered in our survey into nine groups. Each group has at least 1 billion cubic feet of growing-stock volume. Eight of these groups, with relatively few species in each, will be discussed in decreasing order of dominance: red maples, northern red oak, chestnut oak, sugar maple, black cherry, softwoods, select white oaks, and other oaks. The ninth group, other hardwoods, will be discussed last, even though it has the most volume.

Red maples. This group includes red and silver maple. Red maple accounts for over 99 percent of this group's growing-stock volume. Red maple has the largest volume of any species in the state (see box), a position it also held in 1965. It has 15 percent of the growing-stock volume, but 19 percent of all growing-stock trees. This indicates that most of the volume is in smaller trees. Seventy-one percent of red maple trees are less than 9 inches in dbh. This is why it is a distant second to northern red oak in sawtimber volume. The following shows the percentage of growing-stock trees on commercial forest land in 1978, by species and diameter class.

Species	Diameter class (inches at breast height)										
	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9	15.0–16.9	17.0–18.9	19.0–20.9	21.0–28.9	29.0+	All classes
White and red pines	41	24	17	8	3	3	2	1	1	W	100
Hemlock	43	24	12	10	5	3	1	1	1	W	100
Select white oaks	33	26	18	10	6	3	2	1	1	W	100
Northern red oak	25	21	19	14	8	6	3	2	2	W	100
Other oaks	23	22	19	14	10	5	4	1	2	W	100
Chestnut oak	33	29	18	10	5	3	1	1	W	W	100
Sugar maple	38	29	15	9	5	2	1	1	W	W	100
Red maples	45	26	15	8	4	1	1	W	W	W	100
Beech	39	23	16	9	6	3	2	1	1	W	100
White ash	36	22	18	11	6	4	2	1	W	W	100
Black cherry	29	26	20	12	6	4	2	1	W	W	100
Aspen	43	30	18	6	2	1	W	W	W	W	100
All species	37	26	17	9	5	3	1	1	1	W	100

W—Less than 0.5 percent

Red maple is one of the few species that has growing-stock volume in all nine of Pennsylvania's forest-type groups (see Table 2 in the Appendix). Red maple is the most voluminous species in the elm/ash/red maple and northern hardwoods type groups. One-third of red maple's volume is in the oak/hickory type group, where its volume is almost as high as the select white oaks and other oak species groups. In the white pine and hemlock and oak/pine type groups, red maple is the most voluminous hardwood species. All of this attests to the wide variety of sites that red maple grows on and the wide variety of species associated with it.

Between surveys, red maple's volume increased by about one-third. A number of factors helped red maple hold its top position in growing-stock volume and even increase its lead over red oak. The species is opportunistic and aggressive (Powell and Erdmann 1980). American elm, which used to be the dominant species in the elm/ash/red maple type group, has been decimated by the rapid spread of Dutch elm disease. Red maple replaced many of the dead elms, and is now the dominant species in this wet-site type group.

In the northern hardwood type group, red maple has done well for several reasons. First, it grows rapidly in Pennsylvania's northern region. Second, though it has recently become a preferred timber species, red maple for many years was not as preferred as black cherry, yellow birch, and sugar maple. This allowed timber volumes to build. Finally, and probably most important, since many of the forest stands in the northern counties originated about the same time, we are seeing a discernible successional trend. After the original harvesting, fast-growing, shade-intolerant species like black cherry grew rapidly. Red maple, which is more shade tolerant and slower growing, did not do as well initially but is now gaining on cherry. Since the red maple resource is not yet mature, it is likely to show sizeable increases for several decades, but coming on strong is an even more shade-tolerant species—sugar maple (personal communication, Dave Marquis, USDA Forest Service).

In the oak/hickory type group, heavy oak mortality from several insect pests created openings in the stands that red maple exploited. Other opportunities for red maple's expansion were created from harvesting the more desirable oaks for sawtimber and pulpwood.

Although red maple occurs in every county in the state, it is concentrated in the northern counties. With 40 percent of its growing-stock volume in the Allegheny Unit, 18 percent in the North-Central Unit, and 12 percent in the Northeastern Unit, red maple has 70 percent of its volume in 20 northern and northeastern counties.

Ten percent of all live red maple trees are cull—twice the proportion found in the select oaks. There are by far more rotten red maple trees than rotten trees of any other species, and rough trees outnumber rotten trees by about 25 percent.

Northern red oak. This valuable species has the second highest growing-stock and highest sawtimber volume in the state. Red oak has 12 percent of the total growing-stock volume and 8 percent of the growing-stock trees, indicating that more of its volume is in larger trees.

In fact, the distribution of growing-stock trees by diameter class points out interesting differences between red oak and several other species, notably red maple and aspen. Red oak has a much lower proportion of trees in the 5.0- to 6.9-inch diameter class than maple and aspen. This seems to indicate a future problem for red oak. While red oak is longer lived than many species and may need fewer small trees to sustain a given sawtimber level (Merritt 1979), there is concern about the long-term prospect for the oak resource. Regeneration failures have been documented and efforts to stimulate regeneration generally have been successful (Marquis et al. 1976).

The short-term prospect for the resource is good. Growing-stock volume increased by 11 percent between surveys. Although this was a lower percentage increase than the maples and cherry showed, the inventory still increased by 264 million cubic feet.

Northern red oak is the most voluminous species in the oak/hickory type group (Table 2). Eighty-four percent of its volume is in this type group. It is also the oak most often associated with the northern hardwoods, aspen/birch, and white pine and hemlock type groups. These type groups are most common in areas north of central Pennsylvania.

Red oak growing-stock volume is concentrated in the central portions of the state. Forty percent of the volume is in the North-Central and Allegheny Units, while another 30 percent is split between the Southwestern and South-Central Units.

For the state as a whole, 5 percent of all live northern red oak trees are cull. There are about 1½ times as many rough as rotten trees.

Chestnut oak. This species currently has 10 percent of the state's growing-stock volume and ranks third among all species. This volume represents a gain of 8 percent since 1965. Chestnut oak is concentrated mostly in the ridge and valley physiographic region (Fig. 1). Over 40 percent of its volume is in the South-Central and Pocono Units. Befitting its reputation as a species of generally low quality, chestnut oak has proportionately nearly twice as many cull trees as do the select white oaks and northern red oak. Rough trees outnumbered rotten trees by two to one.

The following shows the percent distribution of growing-stock volume in 1978, by species, across the geographic units of Pennsylvania.

Species	Western	Southwestern	Allegheny	North-Central	South-Central	Northeastern	Pocono	Southeastern	All units
				Percent					
White pine	4	4	10	30[a]	18	18	11	5	100
Hemlock	5	6	30[a]	26	5	17	10	1	100
Select white oaks	12	8	10	26[a]	15	4	16	9	100
Northern red oak	9	15	17	24[a]	15	7	7	6	100
Chestnut oak	1	14	8	18	25[a]	3	17	14	100
Black oak	9	11	6	16	21	2	11	24[a]	100
Sugar maple	11	7	54[a]	10	2	13	3	W	100
Red maples	8	7	40[a]	18	4	12	8	3	100
Beech	9	5	52[a]	9	1	15	6	3	100
White ash	12	5	30[a]	11	14	9	5	14	100
Yellow-poplar	23	8	11	9	12	W	6	31[a]	100
Black cherry	18	9	53[a]	10	1	6	2	1	100
All species	10	9	29[a]	17	11	8	8	8	100

[a] Unit where largest species volume occurred.
W—Less than 0.5 percent.

Sugar maple. The volume of sugar maple rose by about 60 percent between inventories, the largest percentage increase among the major species. Sugar maple ranks fourth in the state with 9 percent of the growing-stock volume. It also has 9 percent of the growing-stock trees. Unlike red maple, sugar maple's volume is almost wholly concentrated in the northern hardwood type group. About 7 percent of all live trees are cull, with the number of rough and rotten trees nearly equal.

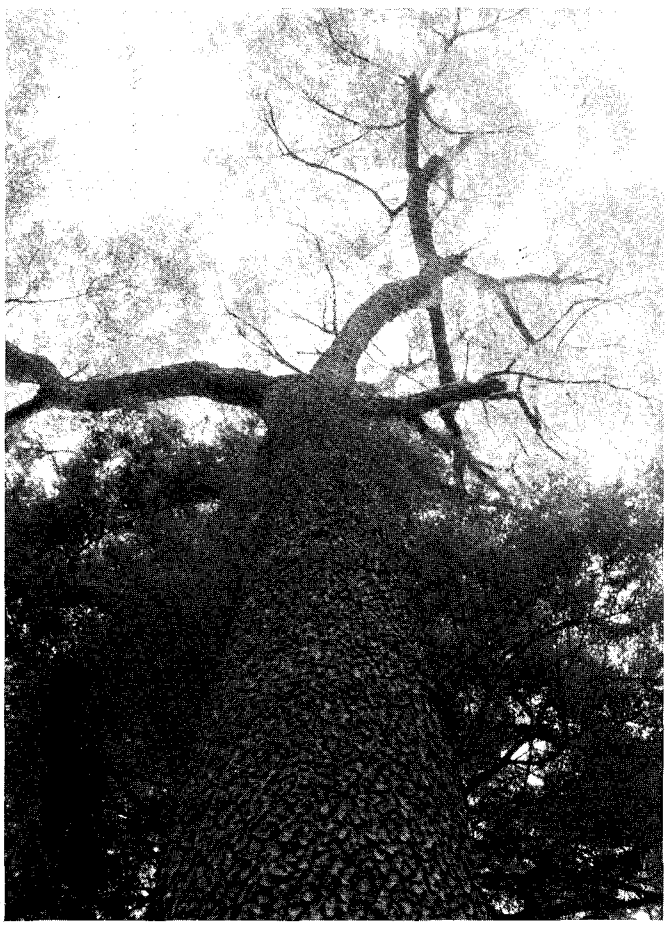
The dramatic increase in sugar maple volume is related directly to the progression of forest succession in the state. Over half of sugar maple's volume is in the Allegheny Unit and over half of its volume increase occurred there. Therefore, a discussion of the trends in this unit will highlight the reasons for the statewide increase. Many forests in this unit are second growth and originated from heavy cutting 50 to 90 years ago. Since that time, the natural progression of stand development has dictated which species would grow fastest and predominate.[1] Fast-growing, shade-intolerant species like black cherry had the first growth spurts and big increases in volume. Cherry had more volume than sugar maple during the first and second inventories—a situation that is now reversed.

Sugar maple is slower growing than cherry and red maple and was overtopped by their growth. Development of sugar maple's timber volumes has taken longer because of its slower growth and has been helped because timber harvesting has been light relative to timber inventory. Sugar maple's development under undisturbed conditions has also been observed in upland stands in other states (Schlesinger 1976). In those stands that are not heavily disturbed, sugar maple will continue to show significant increases for several decades.

Black cherry. Pennsylvania is the center of the black cherry supply for the world. A valuable sawtimber and veneer species, black cherry ranks fifth in the state for growing-stock volume and third for sawtimber. It has 9 percent of the growing-stock volume and seven percent of the growing-stock trees, indicating, as with red oak, that its volume tends to be on larger trees.

[1] Marquis, David A. The effect of past cutting history on the structure, species composition, and development of present-day Allegheny hardwood forests. USDA For. Serv., Northeast. For. Exp. Stn., Broomall, PA (Manuscript submitted to Forest Science).

A superlative old-growth black cherry in Tionesta Scenic Area (McKean County).



Eighty-five percent of cherry's volume is in the northern-hardwood type group, though some volume is found in all the other type groups. While black cherry's geographic range includes all of Pennsylvania, most of its volume is in counties situated within the Allegheny Plateau (Fig. 1). The Allegheny Unit covers a portion of the Plateau, and this is where cherry reaches its optimum development. Over half of its growing-stock volume and nearly 60 percent of its sawtimber volume are found there.

Black cherry was rare in the virgin forests of Pennsylvania, even on the Plateau (Hough and Forbes 1943). Logging and burning of the woods around the early part of this century created the openings that species like cherry needed to grow rapidly and become more abundant. So cherry became a major component of many second-growth forests.

As the Allegheny Plateau forests have matured, the species composition has shifted. Fifty to ninety years of growth has allowed species that grow slower than cherry, like red and sugar maple, to increase substantially in volume. The cherry resource is more mature and has more sawtimber in the Allegheny Unit than the two maples, even though the maples have more growing-stock volume.

Softwoods. In this hardwood-dominated state, softwoods are a minor timber resource. Hemlock is the most abundant softwood, accounting for nearly half of all the softwood growing-stock volume, yet representing only 4 percent of the total growing-stock volume. It is the only softwood among the 10 major timber species. Nearly three-quarters of hemlock's volume is concentrated in the Allegheny, North-Central, and Northeastern Units where cool, moist growing conditions favor its presence. Hemlock volumes rose by more than 20 percent between inventories.

White pine is the second most abundant softwood, accounting for about one-third of the volume. Two thirds of the white pine volume is concentrated in the North-Central, Northeastern, and South-Central Units.

Although softwoods accounted for about three-quarters of Pennsylvania's lumber production around the turn of this century, they made up nowhere near that proportion of the State's timber inventory. Heavy cutting and fires depleted the softwood resource early in the century, and in some areas white pine and hemlock were virtually eliminated from the forests (Marquis 1975).

With fire protection and the forest's natural regrowth, the softwood volume is gradually increasing. As recently as the period between 1955 and 1965, increases in hardwood volume (on a percentage basis) exceeded softwood increases. Between 1965 and 1978, however, softwoods had a higher percentage increase in growing-stock volume (24 percent) than hardwoods (22 percent). Ingrowth of softwoods into growing stock was an important component of this recent increase. Many softwood plantations established in the 1930's and 1940's have developed to the stage where they could be considered merchantable. The relatively low demand for timber products from softwood and the absence of insect and disease attacks in recent years also contributed to the increase.

As with the hardwood species, softwoods are not restricted to a particular forest-type group. One should not assume that all or nearly all of the white pine and hemlock growing-stock volume is in the white pine and hemlock type group. The names of the type groups generally indicate species with a plurality of stocking

(see the definitions of forest types in the Appendix). In the case of white pine, half of its growing-stock volume is in the white pine and hemlock type group. Hemlock, however, has only 28 percent of its volume in that group. White pine and hemlock are by far the major species in that type group, but they are also common associates in other type groups. In fact, 60 percent of all softwood growing-stock volume is in hardwood type groups.

Several softwoods are found in Pennsylvania, predominantly in the Pocono and Northeastern Units, which are of little economic value due to their very limited occurrence but are of high interest ecologically. These species—spruce, balsam fir, and larch—are characteristic of the boreal forest, usually found far to the north in Maine and Canada. Now in Pennsylvania they cover only a fraction of the area they once did. They are stands typical perhaps of an era when Pennsylvania's climate was colder and glaciers covered portions of the state. Boreal species were once more common than many of the species prevalent today.

Select white oaks. In Pennsylvania, this commercially valuable group includes three species: white, swamp white, and bur oaks. Nearly all the volume in this group is in white oak. This group ranks sixth in growing-stock volume. Over one-quarter of the volume in this group is in the North-Central Unit, with another one-third split between the Pocono and South-Central Units. This was the only major species or species group to show a decline in volume between inventories. The decline was not significant and was not evenly spread across all units; in fact, some units gained in volume. The largest declines were in the North-Central and Allegheny Units. During the period between inventories portions of these units were hit very hard by a number of insect and disease attacks. The select white oaks in these units seem to have suffered greatly as their mortality and cull increment were very high in relation to their gross growth. For the state as a whole, about 5 percent of all live select white oak trees are cull, evenly split between the rough and rotten categories.

Other oaks. Seven oaks (black, scarlet, pin, shingle, southern red, post, and willow) make up this diverse group, though black and scarlet oaks dominate the growing-stock volume (98 percent). Black oak alone ranks eighth in the state with 4 percent of the volume. Almost one-quarter of the volume in this group is located in the South-Central Unit. Growing-stock volume is up 7 percent since the last inventory.

Other hardwoods. This diverse group accounts for the remainder of the hardwood volume—5.4 million cubic feet. It includes beech, white ash, yellow-poplar, sweet birch, hickory, and aspen. On the whole, they are distributed around the state, though certain species tend to be concentrated in particular units. For example, nearly one-third of the yellow-poplar volume is in the Southeastern Unit, and over one-half of the beech volume is in the Allegheny Unit.

Geographic Units

The quantity and quality of the timber resources in Pennsylvania's eight geographic units are quite variable. A brief look at each unit, ranked by their average cubic foot volume per acre, will highlight their unique characteristics (Fig. 17).

Allegheny Unit. This unit is Pennsylvania's premier forested area. It is 84 percent forested. In 1965 and 1978 it had the highest growing-stock total and per acre volumes of any unit (Fig. 17). Per acre growing-stock volumes are 15 percent above the next highest unit and 120 percent over the lowest unit. This is an area of active forest management by the forest industries and public agencies, who own nearly 60 percent of the commercial forest land.

The following shows the percent distribution of growing-stock volume in 1978, by species, within each geographic unit in Pennsylvania. Note that red maple, sugar maple, and black cherry account for 55 percent of the inventory in the Allegheny Unit.

Species	Western	Southwestern	Allegheny	North-central	South-Central	Northeastern	Pocono	Southeastern	All units
					Percent				
White pine	1	1	1	4	4	5	3	2	2
Hemlock	2	3	4	6	2	8	5	W	4
Other softwoods	4	1	1	2	2	2	4	2	2
Select white oaks	8	6	2	10	9	3	12	8	6
Northern red oak	10	20 [a]	7	16 [a]	17	10	11	9	12
Chestnut oak	1	15	3	10	21 [a]	4	19 [a]	18 [a]	9
Black oak	4	5	1	4	8	1	5	13	4
Sugar maple	10	7	17	5	2	14	4	W	9
Red maples	12	13	22 [a]	16 [a]	6	21 [a]	15	7	16
Beech	4	2	7	2	W	8	3	2	4
White ash	5	2	4	3	5	4	2	7	4
Yellow-poplar	6	2	1	1	3	W	2	11	3
Black cherry	15 [a]	9	16	5	1	6	2	1	9
Other hardwoods	18	14	14	16	20	14	13	20	16
All species	100	100	100	100	100	100	100	100	100

[a] Species with largest volume in unit.
W—Less than 0.5 percent.

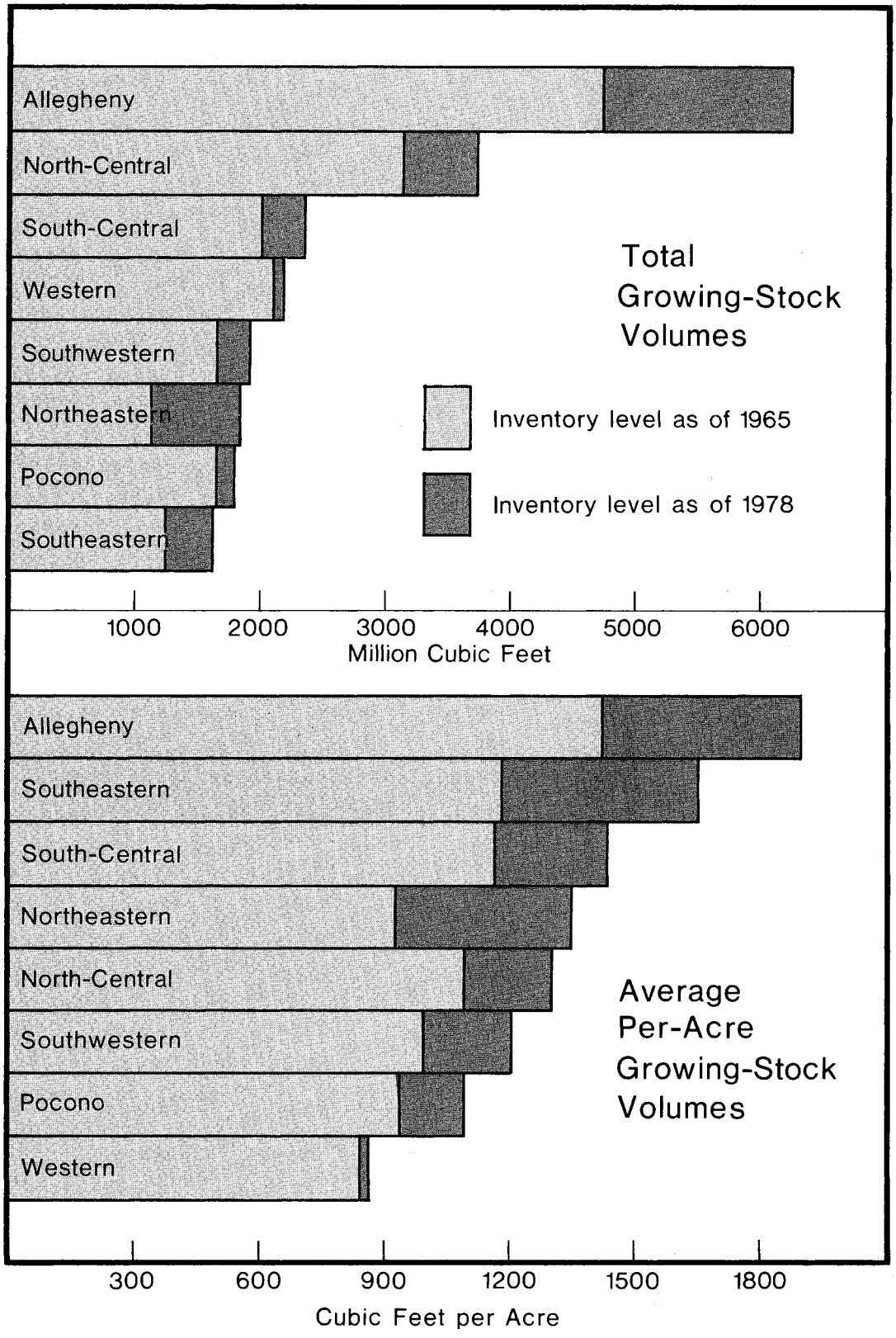


Figure 17.—Total and average per-acre growing-stock volumes by geographic unit, Pennsylvania, 1965 and 1978.

Six major species (hemlock, sugar maple, red maple, beech, white ash, and black cherry) have more volume in this unit than in any other (see page 27).

Southeastern Unit. This unit ranks second in volume per acre, a position it also held during the previous survey. At first glance this is surprising since this unit is the least forested and most densely populated. These factors influence the volume total, which is the lowest among all units. But there is plenty of volume on the acres that are forested. Nearly 70 percent of the commercial forest land is in sawtimber-size stands. The great majority of the forest land is privately held and in small parcels. Timber harvesting pressure is relatively light. This allowed timber volumes to climb rapidly. Since these increases were on a declining land base, the per acre changes were much more substantial than total volume changes.

Timber volumes are more evenly distributed among species in this unit than in the Allegheny Unit. A variety of oaks, notably chestnut and black oak, account for over 50 percent of the volume. Black oak and yellow-poplar reach their maximum volume here.

South-Central Unit. This unit ranks third in both volume per acre and total volume. In 1965 the unit held the same position in volume per acre but was one notch lower in total volume. Its percentage gains in per-acre and total volume were in the middle of the range established by the units.

As in the Southeastern Unit, oaks are the largest species group for timber volume. Chestnut oak and northern red oak are the principals in this group, which accounts for over 55 percent of the volume. Chestnut oak's maximum volume is in this unit.

Northeastern Unit. This unit is fourth in volume per acre and sixth in total volume, but had the largest percentage gains of any unit for both categories. In 1965 this unit ranked seventh in per-acre volume and last in total volume. In contrast to nearly all the other units, the total volume percentage gain was larger than the per-acre change because this unit had a significant increase in its commercial forest-land base. Since additions to the forest land base had to be sapling-seedling stands with low volume, the overall per-acre average was pulled down.

Much like the Allegheny Unit, the major species in the Northeastern Unit are northern hardwoods. Red and sugar maples account for over one-third of the volume. Beech, black cherry, and white ash make up another one-fifth. Proportionately, the Northeastern Unit has more softwood than the other units.

North-Central Unit. This unit ranks fifth in volume per acre but second in total volume. This low per-acre average is in sharp contrast to the Allegheny Unit, its northern neighbor. Several factors seem to explain this difference. First, the species composition of the two units is quite different. Four oaks account for over 40 percent of the North-Central's volume, while in the Allegheny Unit they account for only 13 percent. The insect and disease attacks that occurred in the North-Central Unit were directed mostly against oaks. Undoubtedly, these attacks contributed to lower volumes on many acres, lowering overall per-acre volume.

Second, the black cherry component of the resource is much lower in the North-Central Unit than the Allegheny Unit—5 versus 16 percent. Other factors being equal, stands with a significant component of black cherry have much higher volumes per acre than others. Thus, the Allegheny Unit, with its higher concentrations of black cherry, is expected to have higher per-acre volumes.

Third, the stand-size distribution of the North-Central Unit is such that it has twice as many acres of sapling-seedling stands as the Allegheny Unit. Strip mining has recently been heavy in the western half of this unit. Reclaimed strip mines that have been planted with trees or have reverted to forest are usually still in an early stage of development. These sapling-seedling stands have low volumes in relation to poletimber and sawtimber stands and, like the insect-ravaged stands, tend to lower the average per acre volume.

Southwestern Unit. This unit ranks sixth in per-acre volume and fifth in total volume. Its percentage increases were below almost all the other units. The most probable cause for the low increases is the heavy timber harvesting pressure the unit receives. Based on its timber inventory, this unit was cut more heavily for sawlogs and pulpwood than any other. This means the growth rate, which was near the state average, was not large enough to allow timber volumes to accumulate very much.

The South-Central Unit is the only unit that has more sawmills per million board feet of sawtimber inventory than the Southwestern Unit. But the Southwestern Unit has proportionately more large sawmills than any other unit. Nearly 40 percent of its sawmills have an annual production capability of more than 1 million board feet. Sawtimber harvest has been heavy in part because of concentrations of valuable species like red oak. Pulpwood harvest has been heavy because a number of pulpmills either were or are located in or near this unit. Currently, only one pulpmill is active in the unit but several more are close by in neighboring counties or in Maryland. In the 1960's there were three pulpmills in this unit alone.

The species mix of this unit is interesting. Both oaks and northern hardwoods are well distributed. Oaks, with northern red oak dominating, account for about one-half of the growing-stock volume. Northern hardwoods make up another one-third. This high percentage of northern hardwoods does not occur in the neighboring South-Central Unit. The Southwestern Unit with its higher elevations provides a more suitable environment for the northern species. This unit serves as a bridge connecting the northern units of Pennsylvania and the mountains of West Virginia where northern species dominate.

Pocono Unit. This unit ranks seventh in per-acre and total volume. It has had repeated heavy timber cutting and many fires (see Forest Area). Its forests have been recovering, but the commercial forest-land base and its timber volumes are currently being reduced by recreational developments. Nearly 30 percent of the commercial forest land is in sapling-seedling stands, and it is only one of two units that have less area in sawtimber-size stands than poletimber. Oaks and red maples account for about two-thirds of the timber volume.

Western Unit. This unit sits at the bottom of the per-acre volume scale. It ranks fourth in total volume, but this is only because of its relatively large forest-land base. Fully one-third of its commercial forest land, the highest proportion of any unit, is in sapling-seedling stands or in nonstocked areas. These are very low-volume conditions. This unit also has the highest proportion of cull trees among all live ones; more than one in five is rough or rotten. These cull trees contribute nothing to growing-stock volumes but occupy valuable growing space. The following shows the numbers of cull, growing-stock, and live trees in each geographic unit that are more than 5 inches in dbh (1978).

Total and per-acre volume increases in the Western Unit were negligible. This unit is not particularly active for timber removals, though there is quite a bit of strip mining.

This unit has a high degree of species diversity. Oaks and maples each account for about one-fifth of the volume. Black cherry has the highest volume in the unit (see page 29), but as an indication of the unit's timber quality, over one-half of the state's cull black cherry trees are found here.

Biomass

Most of the discussion of timber volumes in this report concerns net growing-stock and sawtimber volumes. However, these volumes are by no means the state's total wood resource. Rather, they represent a segment of the wood resource bounded by specific size, species, merchantability, and locational characteristics. In light of the potential energy and nontimber benefits from the woods, it is worthwhile to examine some of the other components of total timber volume.

It was not practical for Resources Evaluation to estimate Pennsylvania's total timber volume. To do so would have required calculating timber volumes on nonforest and noncommercial forest land in addition to commercial forest land. While we estimated the area in these land classes, we were not charged with developing timber volume estimates for nonforest and noncommercial forest land.

On commercial forest land, volumes were not calculated for trees less than 5 inches in dbh or for noncommercial species. The commercial species above 5 inches in dbh were segregated into growing stock, rough, and rotten categories based on form and soundness. For these trees, estimates of gross and net cubic- and board-foot volume were developed.

The gross growing-stock volume for all live trees above 5 inches in dbh to a 4-inch top, on commercial forest land, is estimated at 25.6 billion cubic feet. The estimated net volume for all commercial species is 23.6 billion cubic feet. This includes the net volume in rough and rotten trees—1.8 billion cubic feet. When the net volume in cull trees is deducted, the net volume in growing-stock trees is 21.8 billion cubic feet. So the net growing-stock volume is 85 percent of the gross volume in all live trees. Fifteen percent of the gross all live volume on commercial forest land is

Geographic unit	*Cull*	*Growing stock*	*All live*	*Proportion in cull trees*
	Thousands of trees			*Percent*
Western	64,178	248,626	312,804	21
Southwestern	43,718	191,451	235,169	19
Allegheny	81,613	540,607	622,220	13
North-Central	46,409	365,088	411,497	11
South-Central	26,853	200,774	227,627	12
Northeastern	29,177	189,115	218,292	13
Pocono	31,240	225,258	256,498	12
Southeastern	19,318	128,552	147,870	13
All units	342,506	2,089,471	2,431,977	14

in noncommercial species and the unmerchantable portion of growing-stock and cull trees.

Another way of examining the relationship between the growing-stock and cull portions of the inventory is to use the number of trees on Pennsylvania's commercial forest land. Fourteen percent of all live trees 5 inches in dbh and larger are classified as rough and rotten. One in seven hardwoods is cull, while only 1 in 10 softwoods is cull. Compared with 1965, this shows a reduction in the proportion of culls.

Pennsylvania is better off than nearly all of its northeastern neighbors in the proportion of cull trees in the timber resource. Only three northeastern states—Connecticut, Delaware, and New Jersey—have lower proportions of cull trees than Pennsylvania, while 10 others have a higher proportion. Two states—Vermont and New York—have, proportionately, about twice as much cull as Pennsylvania. Fire, insect and disease attacks, and timber harvesting systems where only the best trees are removed have been historically linked with increasing cull proportions in the woods. In recent times, increased protection from fires and pests, and the use of more sound silvicultural practices, have helped bring about an increase in the quality and vigor of the woods. Ways to further improve the quality of the state's forests are discussed later in this report (see Forest Management Opportunities).

The foregoing discussions of growing-stock and cull volumes exclude an increasingly important component of the timber base—the portion of a tree other than the main stem. Until recently, the merchantable bole (or main stem) was the source of nearly all forest products. Generally decreasing tree size and increases in extraction and processing costs have prompted many wood-using firms to consider using more of the aboveground portion of the tree. It has been shown that tree crowns and small trees can be used for domestic and industrial fuel, chips or particles in composite board products, fiber for pulp and paper products, mulch in agriculture, and as a bulking agent in municipal sludge composting.

As part of a national effort to quantify the aboveground biomass on commercial forest land, estimates of live green weight were developed for Pennsylvania's trees. The results are shown in Table 3. The estimates are not complete in several respects. No data are included for the Allegheny National Forest, and estimates for seedlings and saplings do not include State Forest lands.

Despite these limitations, several interesting findings emerge from the data. Most significant is the amount of wood contained in tops and branchwood and in seedlings and saplings. There are an estimated 962.1 million tons of wood in the merchantable bole of growing-stock and cull trees. Tops and branches from these trees have 294 million tons of wood, 31 percent of the merchantable bole total. Growing-stock trees, being of better form and vigor, usually have proportionately less biomass in tops and branches than cull trees.

Certain species yield proportionately more biomass from tops and branches than others. Age-class distributions, stocking levels, and branching characteristics strongly influence a particular species' top and branchwood production. For growing-stock trees, top and branchwood weight as a proportion of merchantable stem weight ranges from 13 percent for basswood and yellow-poplar to 28 percent for northern red oak. Shade-tolerant species like sugar maple, beech, and hemlock generally have proportions closer to that of northern red oak (between 24 and 27 percent). Shade-intolerant species like black locust, white ash, and black cherry tend to have proportions closer to those of yellow-poplar and basswood (16 and 17 percent, respectively).

Our estimate of seedling and sapling biomass is 192.9 million tons (Table 3). This is a conservative estimate because it does not include seedlings and saplings on State Forest land (these data were not available). But even this conservative estimate exceeds the weight of all cull trees by 68 percent and is 20 percent of the merchantable bole total for growing-stock and cull trees.

The feasibility of using these different sources of biomass varies. The merchantable bole is the portion most intensively utilized, now, and this is likely to continue. The amount of wood in seedlings and saplings approaches the amount in top and branchwood but might be harder to utilize because of high extraction costs and the desirability of protecting young stands. We can be certain of two things: (1) there is much more wood in the forest than we report as commercial timber volume, and (2) more of this wood will be utilized in coming years.

Sawlog Quality

In assessing the sawtimber resource, sawlog quality is very important. Pennsylvania has an estimated 4.3 billion board feet of softwood sawtimber. Only 2.1 billion board feet, the pines, were graded into standard-lumber grades. Of the graded volume, only 4 percent was Grade 1, and 13 percent was Grade 2. The remainder, 1.7 billion board feet, was in Grade 3. Yellow pines were of slightly better quality than the white and red pines, mostly due to the fact that yellow pines are allowed lower diameter limits for grade classification.

Pennsylvania's hardwood sawtimber volume of 42.1 billion board feet dwarfs the softwood resource by nearly a 10 to 1 ratio. Hardwood quality is not comparable with softwood quality because standards differ. Fifteen percent of the hardwood volume is Grade 1, 21 percent in Grade 2, 48 percent in Grade 3, and 16 percent in tie and timber. This is an improvement over 1965 when Grade 1 was 9 percent and Grade 2 was 19 percent.

An important contributor to the improvement in hardwood quality is, again, the maturing of forests. To become Grade 1 material a hardwood tree must attain a minimum dbh of

about 15.5 inches. Young, small sawtimber trees may qualify in every way but diameter, so the maturing process is important. Currently, 51 percent of the hardwood sawtimber volume is in trees over 15 inches in dbh—an improvement over 1965 when only 45 percent was over 15 inches. Perhaps more important than this increase for all hardwoods is the increase in commercially valued species. Red oak currently has 61 percent of its sawtimber volume in trees over 15 inches, up from 55 percent, and black cherry has 52 percent of its volume in trees over 15 inches, up from 42 percent.

Besides this natural process, a much smaller contribution to this increase in sawlog quality might be attributable to the efforts of forest managers and landowners who are managing their forests for high-quality sawtimber. More activity of this nature is probably occurring on lands owned by forest industries or administered by public agencies than on lands in the miscellaneous private sector.

Timber Products Output

Data on the output of timber products in Pennsylvania were collected in a primary timber industry survey in 1976. The data reflect the production for this particular point in time, and thus may not correspond directly to average annual removals for the period between surveys (see Growth and Removals). Additional information can be found in Tables 27 through 29 in "Forest Statistics for Pennsylvania—1978" (Considine and Powell 1980) and in "Pennsylvania Timber Industries—A Periodic Assessment of Timber Output" (Bones and Sherwood 1979).

The total output of timber products from all sources was 212.5 million cubic feet in 1976. This is a 21-percent increase over 1964's output, but was less than the high of 215.1 million in 1962 (Fig. 18). Since 1952, the output of sawlogs and pulpwood has increased while the output of other products has declined. The output of fuelwood generally declined from 1952 until the mid-1970's when it began to climb in response to rising prices for fossil fuels. In 1952, 36 percent of the total output was sawlogs and 16 percent was pulpwood. In 1976, sawlogs and pulpwood were 49 and 36 percent of the output, respectively, showing the decline of most products other than sawlogs and pulpwood.

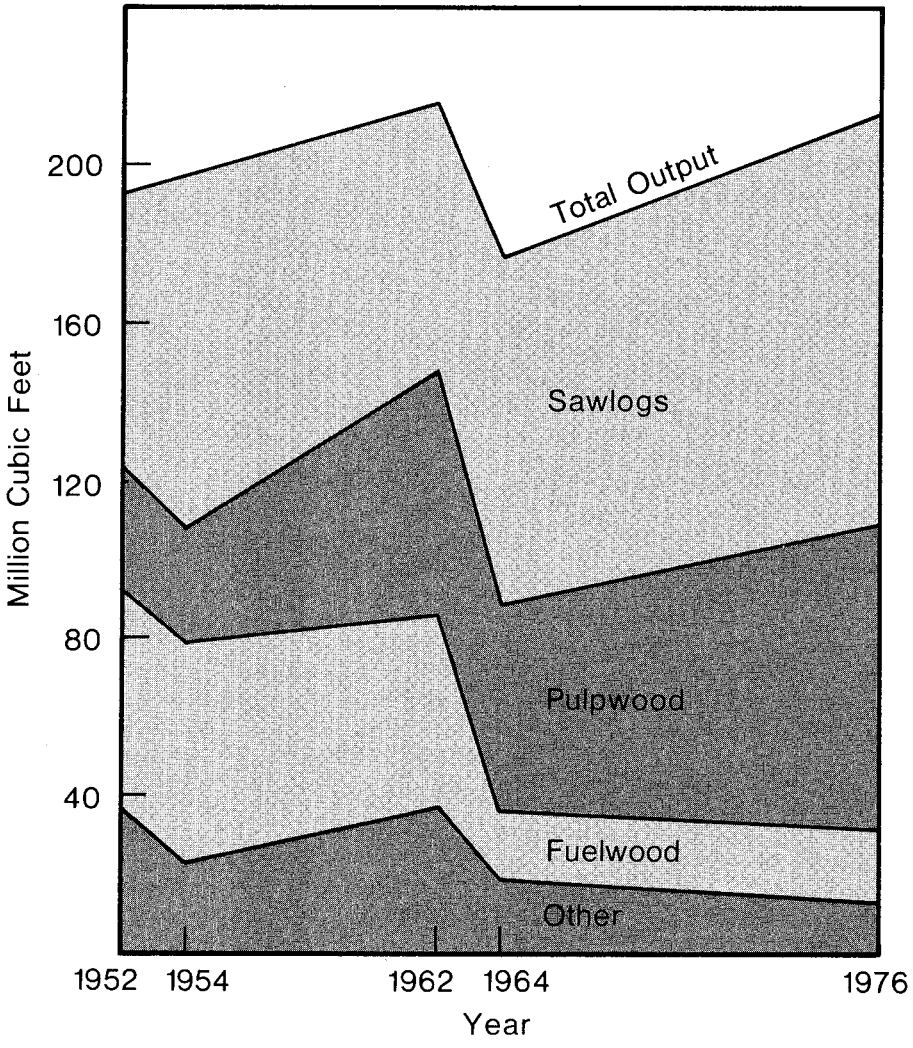


Figure 18.—Timber products output from all sources in Pennsylvania, by selected products and years.

The total output for 1976 can be classified as follows:

Source	*Million cubic feet*	*Percent*
Softwood growing stock	11.3	5
Hardwood growing stock	159.2	75
Total growing stock	170.5	80
Other roundwood sources	5.9	3
Total roundwood output	176.4	83
Manufacturing residues	36.1	17
All Sources	212.5	100

The other roundwood sources mentioned include rough and rotten trees, salvable dead trees, trees less than 5 inches in dbh, tree tops and limbs from commercial forest areas, or material from noncommercial forest land or material from nonforest land such as fence rows and suburban areas.

Output from roundwood has increased only by 9 percent since 1964, but output from manufacturing residues increased substantially. In 1964, residues used for timber products amounted to 13.4 million cublic feet, or 8 percent of the total output. In 1976, residues totaled 36.1 million cubic feet—an increase of 169 percent—and accounted for 17 percent of the total output. These figures along with repeated utilization studies (Wharton and Bones 1980) indicate that the recovery of timber for products is improving. In 1966, 79 percent of the growing-stock volume of a harvested tree was recovered for product. By 1977, the recovery rate had increased to 95 percent. Also, more biomass is now being recovered from nongrowing-stock trees and logging residues as these operations have become increasingly profitable. We expect this trend to continue as timber supplies become tighter or as utilization technology improves.

Output from hardwood species was 198.1 million cubic feet in 1976 or 93 percent of the total. This is not surprising in a state that is so dominated by hardwood trees—they account for 92 percent of the total growing-stock volume. This output increased by 36.4 million cubic feet—22 percent—since 1964. Most of this increase—28.7 million cubic feet—was in pulpwood. The output from softwoods in 1976 was 14.5 million cubic feet. Overall, this was only a 2-percent increase from 1964. Within this species group, however, sawlog output rose by 47 percent while pulpwood output dropped by 38 percent. The following tabulation shows the output in 1976, by product.

Product	*From roundwood*		*From residues*		*Total*	
	Million cubic feet	*Percent*	*Million cubic feet*	*Percent*	*Million cubic feet*	*Percent*
Sawlogs	103.7	59	—	—	103.7	49
Pulpwood	53.1	30	24.2	67	77.3	36
Fuelwood	10.4	6	9.4	26	19.8	9
Other	9.2	5	2.5	7	11.7	6
Total	176.4	100	36.1	100	212.5	100

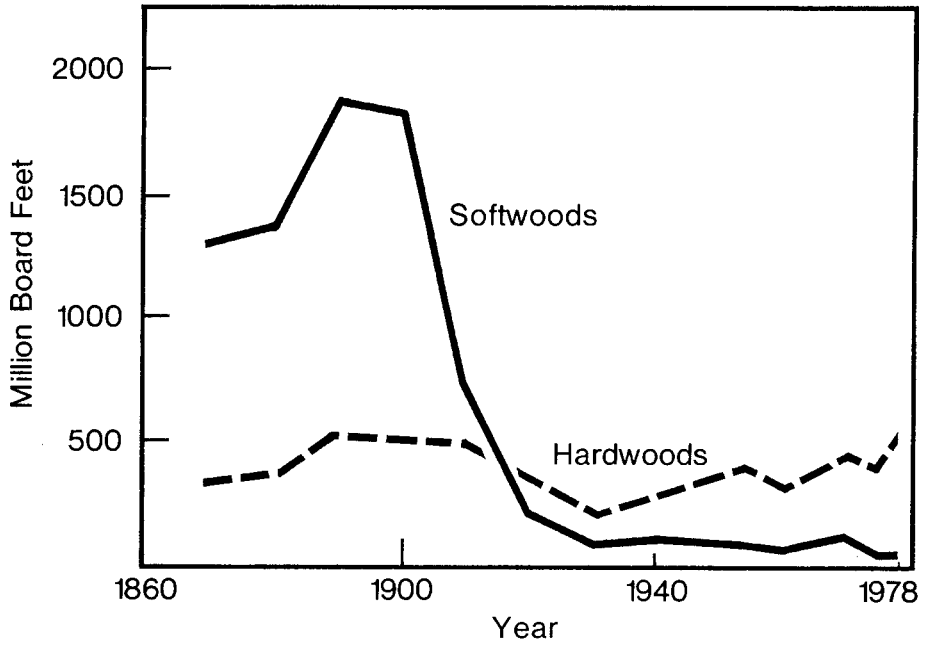
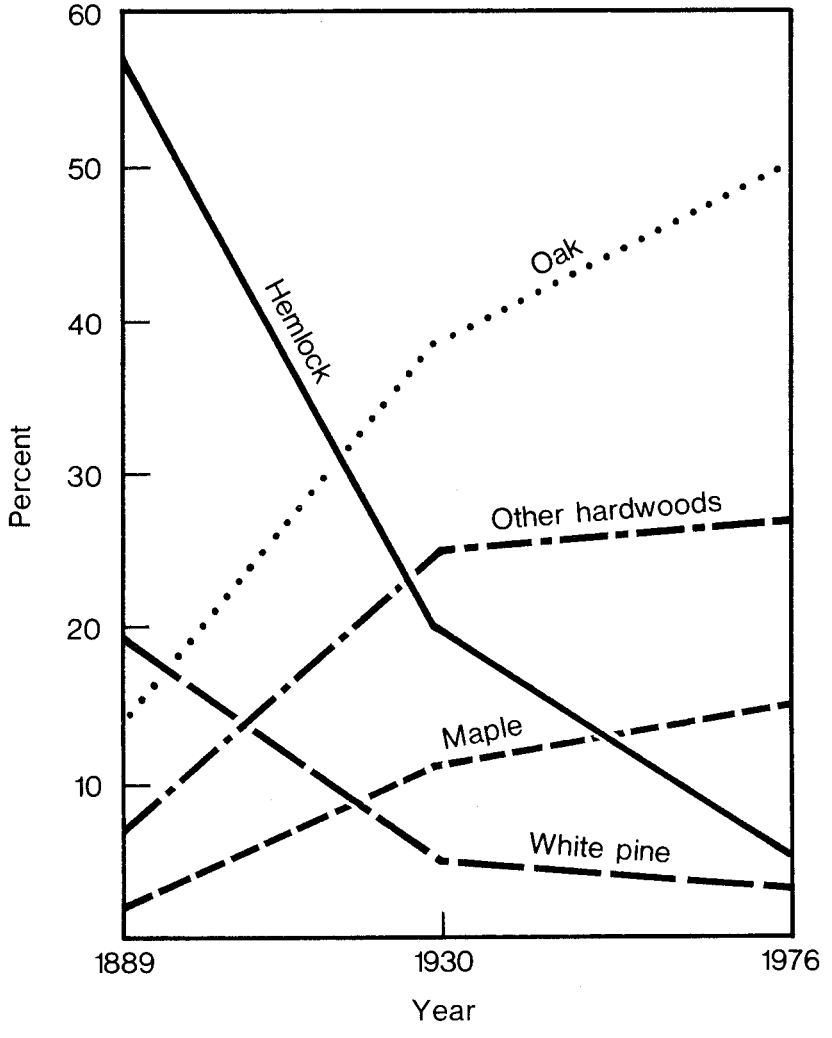


Figure 19.—Lumber production in Pennsylvania for selected years between 1869 and 1978.

Figure 20.—Lumber production for major species groups in Pennsylvania for 1889, 1930, and 1976, in percent.



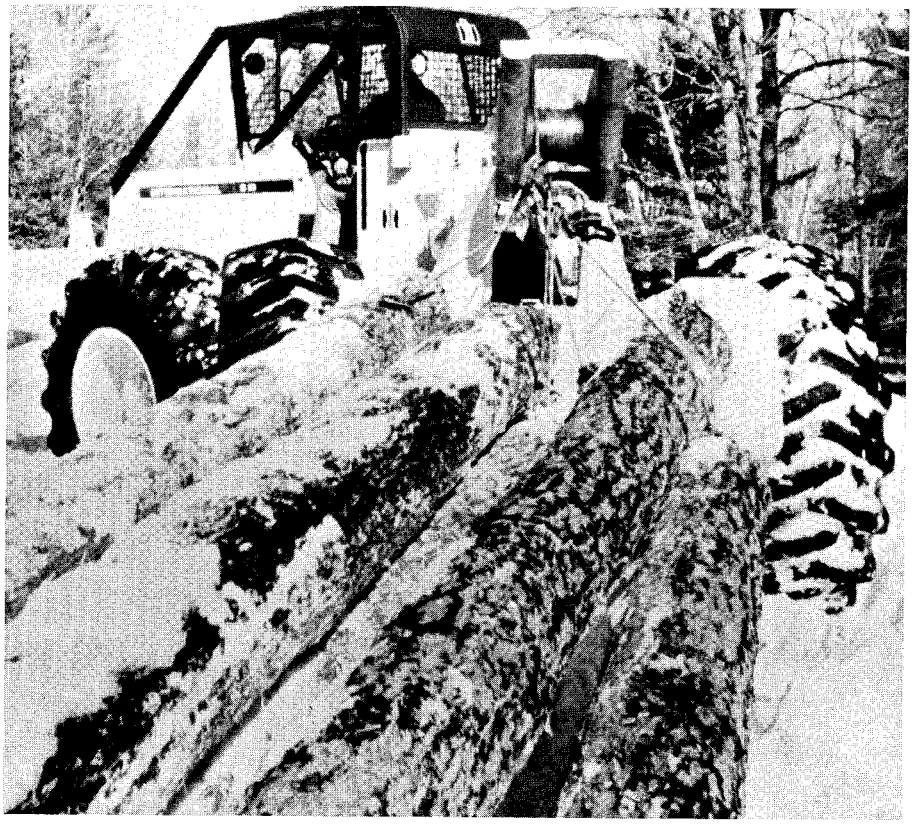
Lumber and Sawlogs

Sawlogs, which are manufactured into lumber and other sawed products, have dominated the volume of timber harvested for products since the first stand was logged over 300 years ago. By 1860 Pennsylvania led the Nation in lumber production, a position it held through 1870. During these 10 years, annual output was about 2 billion board feet, approximately one-sixth of the Nation's total. Production continued to climb until it reached a peak of 2.5 billion board feet in 1889. By the early 1900's it had dropped to about 300 million board feet, and since then has generally increased to its current level of about 500 million board feet.

Softwoods dominated the industry until about 1910 (Fig. 19). Softwood production then declined until the mid-1920's when it leveled off at about 85 million board feet. Figure 20 shows the trends, in percent, of major species groups from the time of peak production to 1976. In the 1800's, hemlock and white pine were the major species cut for lumber since they were the species with the largest and best trees and since they had established markets. Now there is little softwood volume in the state, so hardwoods naturally dominate lumber production. Various oak species account for 50 percent of the production. Most of this lumber is going into furniture, for which oak has recently established itself as a featured species. Cherry, ash, and maple also are valuable hardwood species, and they account for most of the remaining production.

The number of sawmills continues to decline. In 1947 the number of mills operating in the state stood at a record 2,745 (Bones and Sherwood 1979). By 1954 the number had dropped to 2,379, and by 1964 there were 999 mills. The industry survey showed that there were 740 operating sawmills during 1976. This trend does not indicate a decrease in production, however, since the average production of sawmills has been steadily increasing. Low-production, portable, part-time mills are closing while high-production, stationary, full-time mills are filling the gap (Bones and Sherwood 1979).

Sawlog production still ranks first in Pennsylvania. . .



International Harvester Co.

. . .but pulpwood production is increasing its share of the state's timber product output.

Keway Manufacturing Company

Pulpwood

Pulpwood production occupies an increasingly larger share of the timber products output of the state (Fig. 18). Pulpwood production increased from 534,400 cords in 1963 to 955,400 cords in 1979—a 79-percent gain. Pulpwood production is made up of output from roundwood and output from manufacturing residues. In 1979, roundwood accounted for 67 percent—636,600 cords. Ninety-five percent of this was from hardwood species. Aspen and yellow-poplar produced 36,600 cords; oak and hickory yielded 277,600 cords; and other hardwoods, mainly maples, beech, and birch, accounted for 288,400 cords. Pine dominated the softwood production, though some hemlock was cut for pulpwood. Since 1963, roundwood output has increased by 26 percent, with hardwood gaining 51 percent and softwoods losing 70 percent.

Of the 318,800 cord-equivalents produced from manufacturing residues in 1979, 94 percent were hardwood. Even though residues made up only 33 percent of the pulpwood production in 1978, this was much greater than the 4 percent share in 1963. During this period they increased over thirteenfold. Improved use of these byproducts by the pulp industry has substituted for the removal of thousands of cords of standing, live timber. Figure 21 shows the trends in pulpwood production over this period for these components.

Between 1963 and 1979, a total of 15 counties in Pennsylvania produced more than 15,000 cords of pulpwood annually. The top 10 counties and their average roundwood production (in cords) for this period are:

1	Clearfield	51,300
2	Bedford	43,400
3	Huntingdon	35,900
4	McKean	32,200
5	Centre	32,000
6	Elk	28,700
7	Clinton	25,000
8	Warren	22,700
9	Lycoming	22,200
10	Susquehanna	19,900

These counties produced more than 5.3 million cords of roundwood from 1963 to 1979, which amounts to 52 percent of the state total.

Fuelwood

Fuelwood is not considered an industrial product, but it ranks third in Pennsylvania as a timber product. Since 1952, when more than 56 million cubic feet of fuelwood were produced, the trend until the mid-1970's was down. A low of 18.2 million was reached in 1964, and by 1976 production was up slightly to 19.8 million cubic feet or 247,175 cords. Hardwoods have dominated, and in 1976 accounted for 97 percent of the state's fuelwood output.

While we do not have statewide data on fuelwood production since 1976, we do know that this production has increased dramatically. Activity on State Forest land may be indicative of what has happened throughout the state. In 1976, 14,000 cords of fuelwood were sold from State Forests, and by 1979 70,000 cords were sold.

As with pulpwood, fuelwood production comes from both roundwood and manufacturing residues. In 1976, 53 percent, or 130,000 cords, was from roundwood sources. The bulk of this went into household heating and cooking. The remaining 47 percent, or 117,175 cords, came from slabs, edgings, and other manufacturing byproducts. Most of this was used by wood-based industries to generate heat and electricity for their operations.

The outlook for fuelwood production seems very good (see Forest Management Opportunities). With the rapidly rising prices of natural gas and oil, individuals and businesses are giving greater attention to wood for energy. Hardwoods generally provide more heat per volume unit of wood than softwoods, indicating that Pennsylvania's hardwood-dominated forests can satisfy much of this increased demand.

Other Products

In 1976, output of other industrial products amounted to 11,768,000 cubic feet or 6 percent of the total timber products output. This represents a decline of 36 percent since 1964 and a drop of 49 percent since 1954. In 1964, other products output was 11 percent of the total, and in 1954 its share was 12 percent. So besides declining absolutely, its small fraction of the total timber products output is getting smaller.

The most important product in this group is mine timbers, which represented 39 percent of other products output in 1976. In general, output of this product is declining in Pennsylvania as strip mining increases and deep mining (where the timbers are used) decreases. Also, in the deep mines, timbers are being replaced to some extent by roof bolts, which also serve to support the roofs of the mines.

The next largest component of this group is an assortment of many minor products called miscellaneous products. These include wood fiber products; hewn ties; charcoal and chemical wood; handle and bat stock; and excelsior, shingle, and

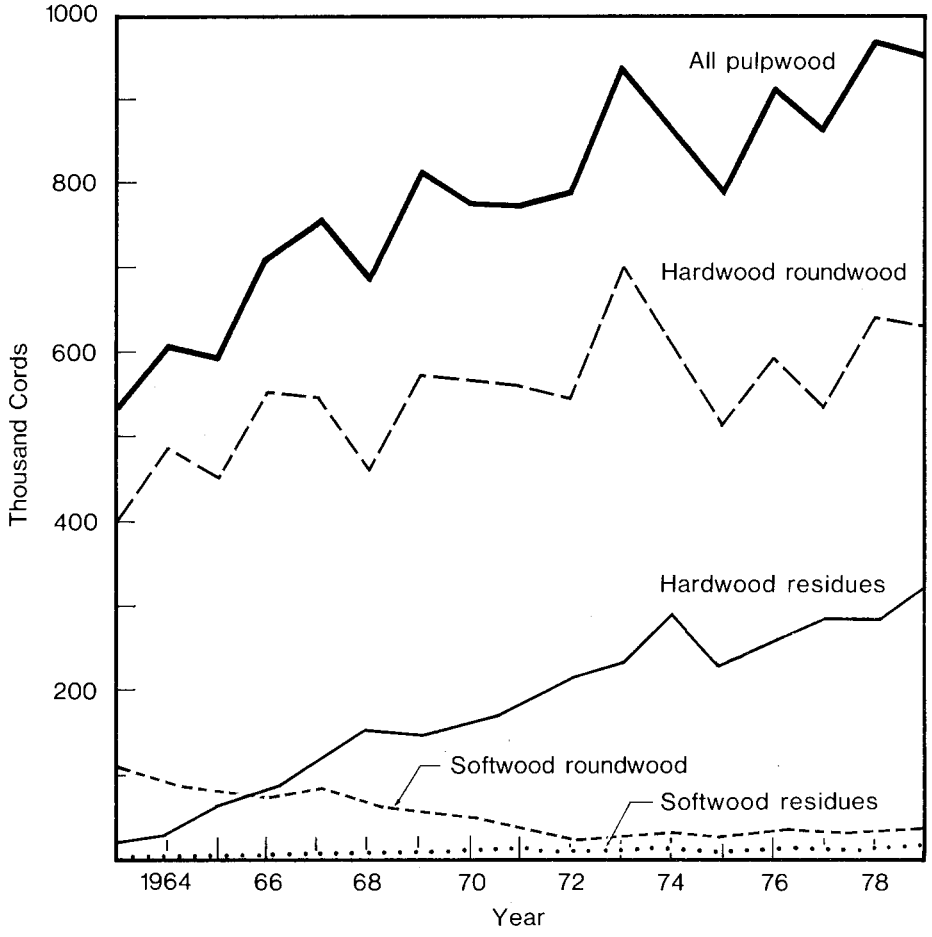
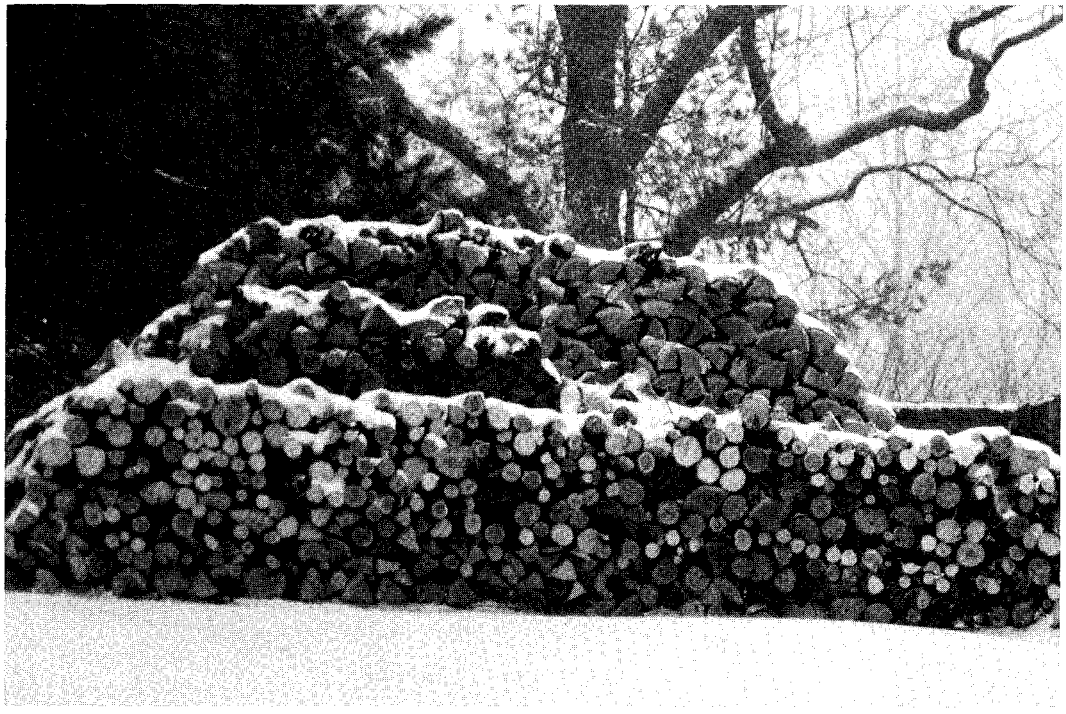


Figure 21.—Pulpwood production in Pennsylvania, by source, 1963-79.

Many Pennsylvanians spend several days a year collecting firewood, often with just a chainsaw and a pickup truck.

Pennsylvania Bureau of Forestry

Large firewood piles are not uncommon backyard sights, especially in rural Pennsylvania.



Western Pennsylvania Conservancy

turnery bolts. In 1976, their output totaled 4.4 million cubic feet or 37 percent of the total for other products.

In 1976, veneer log output was 2.1 million cubic feet (14.7 million board feet) or 18 percent of the other products total. This figure put Pennsylvania in fourth place among the 14 northeastern states, behind Maine, Maryland, and New York (Bones and Dickson 1978). At that time there were four veneer plants operating in the state—three commercial or face veneer plants and one basket veneer plant. Northern red oak led all species, accounting for 54 percent of the production; black cherry was second with 22 percent.

Cooperage and post production make up the remaining other products. In 1976 they accounted for 538,000 (4 percent) and 231,000 (2 percent) cubic feet, respectively. The output of these products has remained relatively stable since 1964. White oak is the premier tight cooperage species since it holds liquids very well. Most of the posts produced in Pennsylvania are from black locust, because this species is very durable and resistant to decay.

Timber's Role in Pennsylvania's Economy

Pennsylvania has a varied group of wood-based industries. Proportionately, these industries are not the major contributors to the state's economy that steel and some other industries are. On a local basis, however, these industries can be very important. And in terms of actual contributions (number of employees, payroll, and value added), Pennsylvania's forest industries compare favorably with or even exceed the contributions of forest industries in states like Maine where these industries are very important.

In 1977, Pennsylvania wood-processing plants produced nearly $4.7 billion worth of products—nearly 6 percent of the state total (U.S. Dep. Commer., Bur. Census 1979). This figure is somewhat conservative because some furniture and fixture industries, which use wood, were not included in the analysis. It was difficult to distinguish the portion of the product value that was attributable to timber.

Of the 18,781 manufacturing establishments reported by the 1977 Census of Manufactures, about 10 percent were wood-based industries. Slightly more than a third of these firms were primary processors such as sawmills, veneer mills, and pulpmills. The remaining two-thirds were classed as secondary processors. They are a diverse group producing items such as flooring, furniture, paneling, pallets, and paper.

Total employment in wood-based industries represented slightly more than 4 percent of the state's total manufacturing employment. In

terms of employment, many wood-based industries were small. Over two-thirds of the firms employed fewer than 20 people. Primary firms usually employed fewer people than secondary firms. Payroll for the wood-based industries was in excess of $800 million for 1977, nearly 5 percent of the state's total manufacturing payroll.

In terms of benefits to local communities and to the state, it is important that two-thirds of Pennsylvania's wood-based industries are secondary industries. The additional processing of the wood resource by secondary industries generally creates more value added by production than does processing by primary industries. Value added is the difference between the cost of goods, fuel, and energy used by the firm and the value of the product it sells. For secondary industries, higher levels of value added mean more money is available for wages, salaries, profits, taxes, and depreciation. In short, value added generates funds to help maintain local and regional economies. In 1977, wood-based industries generated almost 6 percent of the state's total value added by manufacture.

Over time, consumer tastes change, economic forces evolve, and the mix and balance of a state's industries adjust to the new demands. Since the second forest survey in 1965, the performance of Pennsylvania's forest industries has been mixed in terms of number of firms, number of employees, real payroll, and real value added (Table 4).

Trend analysis is made difficult because the Bureau of the Census in 1972 reclassified some industries into different groups. Pennsylvania's wood users fall into one of three broad industry groups: Lumber and Wood Products (SIC 24), Furniture and Fixtures (SIC 25), and Paper and Allied Products (SIC 26). SIC is an acronym for Standard Industrial Classification, and represents a grouping of similarly based firms.

The Paper and Allied Products group did better than the other two and is important to the health of Pennsylvania's forest economy. Between 1967 and 1977, this group grew in real dollars (1967 = 100) by more than 9 percent in payroll per employee, and more than 30 percent in value added. In 1977, the Paper and Allied Products group paid more in payroll and generated more value added than the other two groups combined.

Two industries within this group, Papermills and Miscellaneous Converted Paper Products, were responsible for most of the increases in payroll and value added. Paperboard mills and especially paperboard containers and boxes were industries that somewhat offset the sizeable increases of the other firms by their decline in real terms for payroll and value added.

Extensive reclassification of the industries within the Lumber and Wood Products group prevents analysis before 1972 except for the Logging Camps, Log Contractors, and Sawmill industries. The Lumber and Wood Products group includes many of Pennsylvania's primary wood processors, which collectively represent about half of the number of establishments in the group. In terms of employment, the primary processors are small; less than 10 percent employ more than 20 people. While the number of logging camps and log contractors fluctuated widely between 1967 and 1977, the number of sawmills and planing mills declined. During the period the number of larger sawmills increased, which means the loss of smaller mills was higher than the figure of net change show. The decline of smaller mills is a trend seen across much of the Nation.

A secondary processing industry that did well between 1972 and 1977 was Wood Containers. Composed mostly of pallet-making firms, this industry increased in number of establishments by nearly 75 percent, in number of employees by 36 percent, and in value added by 30 percent. There is no doubt that an important factor in the recent success of this industry is its ability to use lower quality hardwoods as a raw material over a range of diameter classes. This is a resource that has been increasing in supply in Pennsylvania since the last forest survey.

The recent success of the pallet industry and portions of the paper industry would seem to be an indication for the future of Pennsylvania's forest industries. Industries that can use a variety of species of different quality will have a greater potential supply of raw material. Many other factors decide whether or not an industry will be successful but, given the projected wood resource outlook for Pennsylvania, those industries that can process a wider selection of trees from Penn's Woods will have a key advantage.

Growth and Removals

Components of Change

There has been a sizeable increase in Pennsylvania's timber volumes between the second and third surveys. To better understand this change, it is necessary to examine the components of inventory change. The difference between average annual net growth and removals is the average amount added to the inventory for each year between the surveys.

Between 1964 and 1977, average annual growing-stock net growth for all species was 555 million cubic feet; average annual removals totaled 255 million cubic feet. This was a growth-removals ratio of nearly 2.2 to 1. The difference between growth and removals was 300 million cubic feet. The ending inventory level is calculated by taking this annual inventory change, multiplying it by the number of years between surveys, and adding the product to the beginning inventory level. For growing stock, the calculation (in million cubic feet) is: (300 X 13) + 17,852 = 21,756. Hardwoods accounted for 90 percent of the growing-stock growth and removals—just about their proportion of the inventory.

Net growth is itself the sum of several components. Net growth is the result of accretion (growth on the

initial inventory), plus ingrowth (growth on trees that become 5 inches in dbh and larger), minus mortality and cull increment (the volume that became rough or rotten). Accretion plus ingrowth is termed gross growth.

Gross growth averaged 700 million cubic feet per year. Three-quarters of gross growth, 520 million cubic feet, was accretion, and the remaining quarter, 180 million cubic feet, was ingrowth. As was discussed in the section on timber volume, Penn's Woods are maturing, long enough that accretion would be expected to exceed ingrowth. Since the state's timber is dominated by hardwoods, it follows that hardwood gross growth was mostly accretion—501 of 641 million cubic feet.

Growing-stock gross growth was reduced by an average of 21 percent annually from mortality and cull increment. While this percentage seems high, it is still better than about half of the 13 other northeastern states. Hardwoods suffered proportionally higher losses of gross growth than softwoods, 22 versus 8 percent. For both hardwoods and softwoods, mortality was more significant than cull increment. Of the average 145 million cubic feet of lost annual hardwood gross growth, 105 were attributable to mortality.

Comparisons of certain published components of net growth estimates between the second and third surveys cannot be made. In the second survey, cull increment was subtracted directly from accretion. This directly affected the estimates of gross growth. In the third survey, estimates of cull increment were developed separately and then subtracted from gross growth, along with mortality, to yield net growth. These two computation methods invalidate comparisons between the estimates of accretion, gross growth, and cull increment.

We can, however, compare estimates for net growth and mortality. Total net growth is currently 60 million cubic feet lower than the estimate from the previous survey. Softwood net growth increased, but hardwood growth declined. Since hardwoods dominate the resource, overall growth declined.

This Clinton County hillside suffered heavy mortality from the oak leaf-roller and was subsequently clearcut to salvage the timber.

A major contributor to the decline in net growth was mortality. Increased mortality levels for hardwoods, primarily due to insect and disease attacks on oaks, accounted for about two-thirds of the decline in net growth.

Timber removals are, by Resources Evaluation definition, more than timber cut for products (Fig. 22). In 1976, timber product removals (sawlogs, pulpwood, and other products) were about two-thirds of all removals. This proportion is lower than the estimate of 76 percent from the last survey because the total now includes estimates of timber volume lost to land clearing and reclassification of commercial forest land.

Timber lost as logging residues is a significant type of removal. Since the last survey the proportion of timber lost to this cause declined from 24 to 20 percent of the total. Increased stumpage and energy prices and new harvesting technology were important factors in the improved timber utilization trend (Wharton and Bones 1980). Despite the improved utilization, more wood is lost as residues than is cut for pulpwood, so there is room for improvement.

Timber destroyed during land clearing and timber removed from the inventory due to the reclassification of commercial forest land to noncommercial accounted for the remaining removals. Timber lost to reclassification was quite high between surveys, higher than we expect it will be in the future.

While net growth declined, average annual removals increased by 25 percent, from 204 to 255 million cubic feet. This trend was expected. Timber inventories have been rising since the first inventory and forest industries reacted to take advantage of the situation. On a statewide basis, the woods are not in danger of being

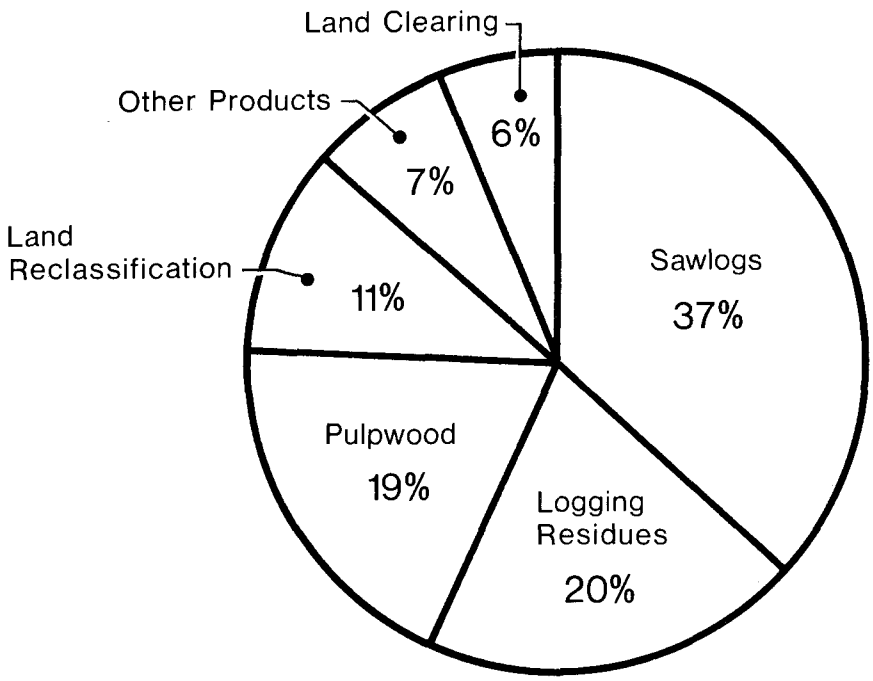


Figure 22.—Distribution of growing-stock removals, by source, Pennsylvania, 1976.

overcut anytime in the near future since the ratio of growth to removals is greater than 2 to 1.

Geographic Unit Growth and Removals

The following shows the average annual growth and removals for Pennsylvania's units for 1964-77. Due to the distribution of remeasured plots, the Allegheny and North-Central Units were combined into one, as were the Northeastern and Pocono Units.

For all units except the Western Unit, the growth rate is much higher than the removal rate. The Western Unit's growth is the lowest of any unit and barely exceeded removals. The large acreage of sapling-seedling stands and nonstocked areas and the high amount of cull trees kept net growth low. At the other end of the state, the Southeastern Unit, with its low removals pressure and large acreage of sawtimber stands, had the highest growth per acre.

Unit	*Net growth*	*Removals*
	- - - - - Million cubic feet - - - - -	
Western	39	34
North-Central	255	98
Southwestern	56	38
Northeastern	95	32
Southeastern	50	21
South-Central	60	32

Trend Changes

Trend-level estimates are another type of growth and removals calculation. They differ from average annual estimates in that they represent growth, removals, and mortality for the last full year of the period between inventories. This is the reason trend-level estimates are often the basis for projections. Additionally, average annual change is based on a simple straight line between the two inventories, while trend change (trend growth minus trend removals) is developed from a compound change function.

When inventories increase between surveys, trend-level change is higher than average annual change. Trend-level net growth of growing-stock for 1977 was 607 million cubic feet versus 555 for average annual. Trend-level removals were 279 million cubic feet versus 255 million cubic feet.

Oaks and maples dominated timber volumes, but had different relationships between growth and removals. Oaks had proportionately low growth and high removals and mortality levels. This resulted in only a slight increase in the oak inventory. In fact, the trend change for oak was only 0.5 percent of its 1978 volume. Northern red oak did somewhat better than the average for all oak, but select white oaks did much worse. They were the only major species or species group among all species that had removals exceeding growth.

In contrast to the oaks, maples had proportionately high growth and low removals and mortality. These proportions left plenty of room for inventory increases; the trend change was 2.5 percent of 1978 timber levels. Sugar maple had the widest margin between growth and removals of any species, 71 million cubic feet.

Black cherry's situation bodes well for the near future. Growth is over three times removals, and the trend change is 2.0 percent of 1978 inventory levels.

Direct comparisons between the current trend level and the previous average annual estimates of species growth and removals are not valid because of the different methods of calculation. However, certain patterns are evident. The most important one as far as species are concerned is that maples are accounting for more of the hardwood growth while the oaks are accounting for less.

Among ownership classes, Pennsylvania's public lands had the highest growth-removals ratio—4.3 to 1. These lands are actively managed but often for nontimber purposes, so timber volumes have been able to accumulate much faster than on private lands. Public lands, with their large proportion of sawtimber stands, are in a good position to provide increasing amounts of quality sawtimber.

Two classes of private owners were analyzed and their growth-removals ratios were similar. Forest industries had a ratio of 1.6 to 1, the lowest of any ownership. They cut more of their timber growth than any ownership, but still had enough of a margin for inventories to build. The other private group had a growth-removals ratio of 1.7 to 1. This group had the lowest growth of any ownership, and supported more harvesting than they are often given credit for.

Timber Outlook

The 13 years since the last survey of Pennsylvania have generally been good ones for the state's forests. The outlook for the state as a whole over the next 30 years is favorable. This estimation is based on projected levels of growing-stock growth, removals, and inventory to 2008:

Resource category	*1978*	*1988*	*1998*	*2008*
	Thousand acres			
Commercial forest land	15,924	15,765	15,608	15,453
	Million cubic feet			
Softwoods				
Growth	61	76	95	119
Removals	30	39	50	63
Inventory	1,767	2,101	2,510	3,015
Hardwoods				
Growth	548	542	537	556
Removals	248	325	423	552
Inventory	19,989	22,636	24,371	25,030
All species				
Growth	609	618	632	675
Removals	278	364	473	615
Inventory	21,756	24,737	26,881	28,045

These projections included a number of assumptions about the change in the commercial forest-land base and future growth and removals rates. Continuing downward pressure on the commercial forest-land base is expected. Agriculture will not be as important a factor in future reductions as moves to reserve or preserve forest lands and the clearing of forest land for nonagricultural purposes like pipeline and transmission line rights-of-way, urban and suburban expansion, and recreational development. Counter-balancing withdrawals will be some increase in forest land due to the abandonment of agricultural (primarily pasture) land. Losses are expected to exceed gains, not by a great deal, but enough that the annual decrease in commercial forest land is projected at 0.1 percent.

Projections for softwoods and hardwoods were developed separately and summed for the total. Projections for each species group were made at the per-acre level and expanded by the commercial forest-land base for the particular year.

Growth projections for hardwoods were based on several assumptions. The first is that the current level of management the resource receives will remain relatively constant. Another important one is that insect (particularly gypsy moth) and disease attacks will continue to plague hardwoods (especially oaks) for at least several decades. This means hardwood growth is projected to stay at 1977 levels for about 20 years. Between the 20th and 30th years, growth will improve as other species fill in gaps created by the insect attacks.

Hardwood removals projections are based on the 1977 trend-level estimate. We project that they will increase at an annual rate of about 2.8 percent. This rate is near the top of a range of possible rate increases suggested by some resource experts. The rate of increase used for projections is higher than the annual rate of increase between the second and third surveys (2.1 percent), because heavier removals pressure is ex-

pected on the hardwood resource to satisfy increased demand for timber products and fuelwood.

Softwood growth projections also were based on the 1977 trend-level growth estimate. We project the growth will increase at an annual rate of 2.4 percent. This was the rate of increase between the second and third surveys. We used this for projections because softwoods are not expected to have the insect and disease problems that hardwoods will. For the removals projections, we used the 1977 trend-level estimate, and we expect softwood removals to increase at an annual rate of 2.6 percent.

These assumptions and projections indicate a slowing of the increase in growing-stock volumes for softwoods and hardwoods. The slowdown will be more pronounced for hardwoods. Over the next 30 years, softwoods are projected to increase their share of the inventory from 8 to 11 percent. Public agencies in Pennsylvania are committed to maintaining or increasing softwoods on their lands, and forest industries are planting softwoods on some of their lands on an experimental basis.

Hardwood inventories will build, though not as fast as softwoods. Still, hardwood volumes will dwarf softwood volumes in 30 years. The proportionately lower hardwood growth offers many more forest management opportunities than problems for industries and forest managers. Overstocking will probably will become increasingly important in the lower growth rate. On the portion of the commercial forest-land base actually surveyed by Resources Evaluation, about one-half of the area was either fully stocked or overstocked with growing-stock trees. Another 39 percent was medium stocked. With removals projected to lag behind growth, more of the medium stocked and fully stocked stands will move to the overstocked condition, causing a loss of growth potential. This creates thinning opportunities.

The species mix of Penn's Woods is likely to change over the projection period. Not only will softwoods assume a larger share of the inventory, but maples, black cherry, beech, and some low-value oaks should increase.

It is not that these trees, with the exception of black cherry, are receiving excellent management, but that they are less pressured by insects and diseases and today's timber markets. Thus, as man and nature affect certain species in the woods, others are left relatively free to grow.

Certain commercially valuable oaks, notably white and northern red oak, will be subject to continued harvesting pressure and remain vulnerable to insect attack. This is not to suggest that timber volumes of these species will definitely decline, but that they are more likely to increase at slower rates, thus becoming a smaller component of the overall inventory. Aspen and gray birch are intolerant species, valuable for wildlife and pulpwood, that have declined in importance and will continue to do so unless increased management and harvesting reverse this trend.

Penn's Woods will not be static over the next 30 years. New harvesting and product technologies, consumer tastes, insect and disease attacks, multiple-use considerations, and perhaps even climatic changes will emerge and change the forest's character. Pennsylvania's forest managers and planners have an exciting and challenging opportunity to direct and shape some of these changes. These are discussed in the section entitled Forest Management Opportunities.

Nontimber Forest Resources and Uses

So far the emphasis of our analysis has been on the timber resource. Since the passage and implementation of the Resources Planning Act of 1974 and the Renewable Resources Research Act of 1978, Resources Evaluation has expanded its inventory and analysis efforts to provide a more comprehensive assessment of all natural resources associated with forest ecosystems. Recognizing that the forest is much more than trees, there are many forest resources other than wood that are worthy of our attention.

The major nontimber resources or uses of Penn's Woods are water, soil, minerals, fish, wildlife, and recreation (including scenic and esthetic values). While these will each be discussed separately as they relate to forest land in the state, it is not possible to isolate them from each other or from the timber resource. It is the combination and interaction of all resources that make up and define a "forest." Each resource or use is an integral part of the whole, and each one adds to the richness and diversity that make the forests of the Commonwealth so special and important.

Keeping this in mind, let's take a closer look at these other resources and uses and see how and why we consider them essential to an analysis of Pennsylvania's forests.

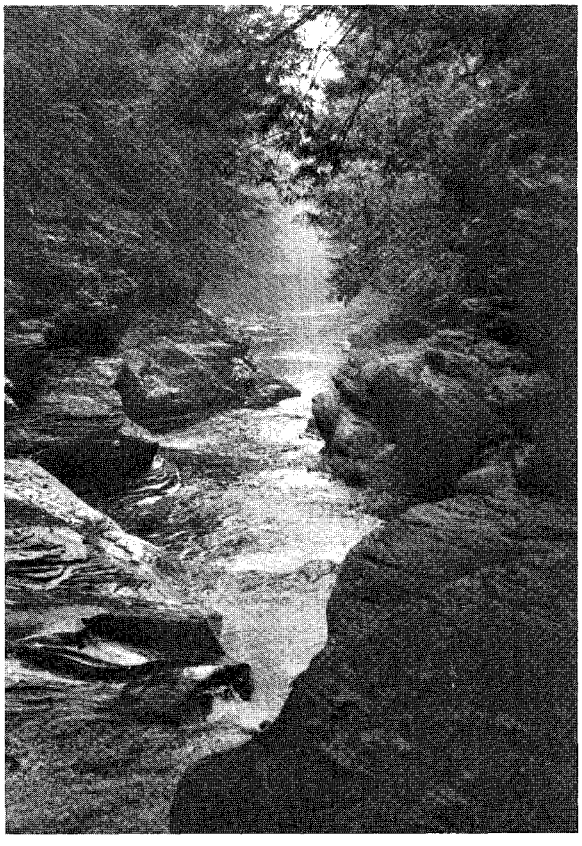
Water

In any state blessed with plentiful forest land, good water is certainly a major and essential product of the forest. This is especially so in Pennsylvania, where 58 percent of the land is forested. Forested areas serve as reception and storage areas for many of the state's rivers and municipal water supplies. A continued supply of good water is critical because Pennsylvania's economic and social development is dependent on it. While somewhat arbitrary separations of the water and other resources of the state are necessary to facilitate discussion, their interactions and interdependencies should be kept in mind.

Pennsylvania is well endowed with abundant surface and ground waters. Surface waters have received the heaviest pressures—both in withdrawls and on site use. Estimates of ground water supplies indicate a large potential to satisfy future needs but this resource is mostly undeveloped. Given the water shortages Pennsylvania has experienced recently, future development of this resource seems certain.

Pennsylvania's forested streams are natural treasures.

Western Pennsylvania Conservancy



Pennsylvania Bureau of Forestry

Western Pennsylvania Conservancy

Surface waters are generally divided into lakes and rivers. Both the lakes and rivers are important, though their roles are somewhat different. Lake Erie, the oldest and warmest of the Great Lakes, supports a port and much recreation, and forms part of the state's border. Lakes and marshland created by the last period of glaciation are found in the northwest and northeast corners of the state. Conneaut Lake is the largest natural lake in the state and like most of Pennsylvania's natural lakes is of glacial origin. Manmade lakes across the state were built by a variety of private, State, and Federal organizations. In varying degrees they provide a wide range of benefits: water quality control, low-flow augmentation, flood control, hydroelectric power, and numerous recreational activities. More than 185,000 acres of pond and lake surface can be fished and more than 174,000 are suitable for boating (Pa. Off. State Plan. and Dev. 1976).

Development of Pennsylvania's natural resources and the growth of her industries and population have been greatly influenced by three major rivers and their tributaries—the Susquehanna, the Ohio, and the Delaware (Fig. 23). From the time of the earliest settlers until the construction of the modern highway system, the navigability of the rivers and land travel made possible by river valleys opened the way to colonization. The Susquehanna system, covering most of the central and southern sections of the state, drains the largest area—20,831 square miles—and is 58 percent forested. The Ohio River system, primarily a result of the confluence of the Allegheny and Monongahela Rivers, drains 15,639 square miles of Western Pennsylvania and is also 58 percent forested. The Delaware River forms the eastern border of the state and drains 6,278 square miles. Forty-two percent of this river basin is covered with commercial forest land. Together, these three river systems have more than 50,000 miles of surface water, of which 16,000 miles and 4,000 miles are available for fishing and boating, respectively. Small portions of two other river systems, the Genesee and Potomac, drain portions of Pennsylvania. Smaller streams are plentiful throughout the state, especially in the west and north where they often cut deeply into the broad Appalachian Plateau.

While a valuable resource, Pennsylvania's waters are also a vulnerable resource. Currently, the state's waters are indeed quite different from those seen by the early Dutch and Swedish colonists. Settlement came slowly to much of Pennsylvania through the mid-1800's. Forest and water problems were likely few and localized. However, from the mid-1800's into the 1920's a series of events occurred which were to affect the lands and waters for many years.

Increasing immigration and discovery of local energy sources helped swell Pennsylvania's population and power the Industrial Revolution. Farming intensified, industries developed to extract and transport the State's abundant resources of coal and wood, and cities and towns

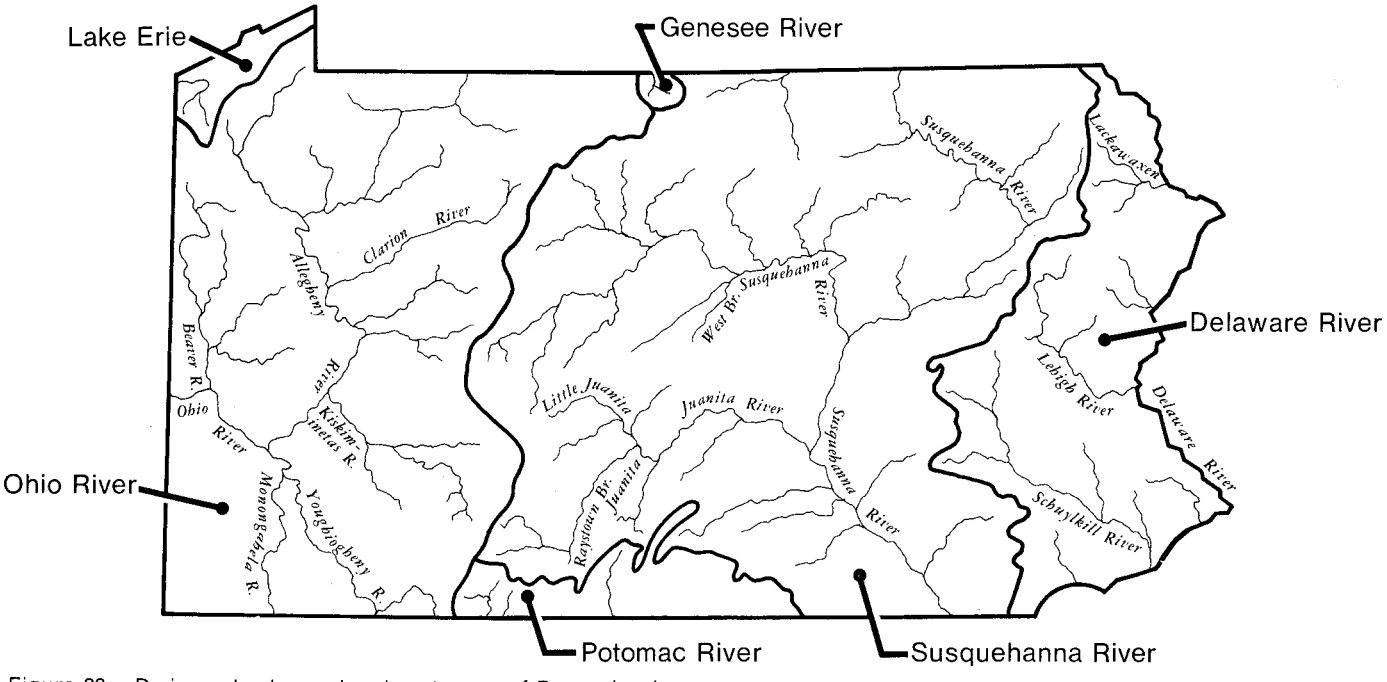


Figure 23.—Drainage basins and major streams of Pennsylvania.

grew. The quality of forests and the waters declined.

Hills and valleys were stripped of their trees, and improper cultivation practices hastened erosion. Large fires were common. Untreated wastes from industries and towns were flushed down the rivers. Results of these abuses were obvious: siltation of river channels, discoloration of previously clear waters, unsuitable drinking water, very high flows during wet seasons, and very low flows during dry seasons. The problems did not go unnoticed, nor would they be solved easily. The immediate profits generated during the boom period belied the economic and social costs that were passed on to subsequent generations. Some of the lands and waters are still polluted as a result of the early shortsightedness.

As lumbering operations moved west and marginal farms were abandoned, nature's tremendous regenerative abilities were evidenced by the "greening up" of many areas. Aided by tree planting and extensive fire protection, the forests grew back vigorously. Stabilization of many watersheds was so improved that by the 1940's forest-related water problems declined in seriousness in relation to those of other sources.

Examining how forests influence and can be managed for water will provide a better understanding of how closely related these two resources are. Forests influence water as it moves from the atmosphere to the stream both above and below ground. Tree and shrub cover first affect precipitation as it falls. Leaves, needles, and branches intercept part of the rain or snow. Some falls or drips through to the forest floor. Another portion of the water is concentrated by stems and branches and flows down the main trunk. The final portion of gross precipitation evaporates from the leaf and stem surfaces directly. The net amount of precipitation reaching the forest floor varies widely, from 0 to 95 percent, depending on the type of precipitation and intensity of the storm (Hewlett and Nutter 1969).

Once the water has reached the forest floor it moves in one of three general ways: evaporation, infiltration, or overland flow. Infiltration, the movement of the water through the soil, is an important process because it serves to reduce overland flow and slow water movement to the stream. Overland flow is not desirable because it is the cause of much erosion and elevated peak flow. The forest floor helps reduce overland flow because it has higher rates of infiltration than does bare soil. The force of falling water is greatly reduced under forest conditions by the layers of vegetation and the organic litter layer. Water hitting the soil with less force causes less of the mineral soil to be dislodged, resulting in clear water for infiltration. Of eight major factors influencing infiltration rates, water quality is often considered the most critical because soil pores are left unblocked, allowing normal drainage. Muddied or clouded water disrupts and blocks soil pores, retarding infiltration and creating potential for overland flow (Hewlett and Nutter 1969).

Certain portions of the water in the soil are subject to use by trees. Most of the water absorbed by the roots moves up through the tree and returns to the atmosphere as water vapor. The transpirational use of water is generally 40 to 60 percent of annual precipitation (personal communication, Howard G. Halverson, USDA Forest Service). However, a relatively large amount of water is still available for water system recharge. Water stored and cleansed by the soil replenishes surface or ground waters with purer water and does so in a slower and more orderly fashion than water yielded by overland flow.

The tempered release of clean water may be the forest's greatest contribution to improving water conditions. Despite the interceptive and absorptive capacities of the forests, floods occur in forested areas. The mean annual precipitation for the state as a whole is approximately 42 inches. Actual precipitation ranges from a low of 36 to a high of 50 inches in some areas, and annual variation may be as much as 10 inches. Snow makes up 7 to 11 inches of the total precipitation, and is heaviest in the northern and mountainous areas. Patterns of distribution are also important. Between 55 and 60 percent of Pennsylvania's precipitation occurs during the spring-summer season mostly in the form of intense rainstorms. Coupled with Pennsylvania's generally steep slopes, characteristically thin mountain soils, and late spring thaws, the seasonality of precipitation has created damaging periodic floods despite the forest cover.

Since the beginning of this century, three management schemes have been used in an attempt to alleviate Pennsylvania's flood problems. Original flood control efforts from 1900 to 1940 centered on reforestation and fire suppression on the many cutover upstream watersheds. Despite the general success of this program, the devastating flood of 1936 vividly demonstrated the need for additional protection.

The next 35 years were characterized by numerous construction projects designed to upgrade water quality and to regulate the quantity of streamflow. Impoundments built during this period varied in size, purpose, and ownership. Many of the large reservoirs were built either by the U.S. Army Corps of Engineers or the State, and often provided significant secondary benefits. Twenty-two of the twenty-five Corps reservoirs completed or due to be completed by 1981 will provide millions of visitors with fishing, boating, water skiing, picnicking, bathing, and other recreational opportunities. Total water surface area of the completed projects is approximately 65,700 acres. Eight of the dams have been put into service since the last survey of Pennsylvania. The State also has several multipurpose reservoirs. Four State Parks use water control impoundments to provide year-round benefits. Pymatuning, the largest of the State-controlled lakes with 14,528 surface acres, is unique; it hosts millions of visitors annually, providing valuable winter recreation and serving partly

as a wildlife refuge for migratory waterfowl.

Throughout the 1970s, mounting concerns over the environmental and economic impacts of large reservoir projects caused a reduction in the number being planned and built. Most recently, the controversial Tocks Island project has been eliminated by the inclusion of the portion of the Delaware River in the National Wild and Scenic Rivers Program. With construction of reservoirs tapering off, emphasis on reducing flood damage is shifting to flood plain mapping and zoning. Effective supervision of building on flood plains is an integral downstream component of a basinwide management plan, complementing the upstream reservoir and reforestation efforts.

Just as too much water creates problems, too little also presents serious difficulties. In a populous state like Pennsylvania, certain minimum flows are necessary to satisfy the demands of cities, farms, and industries. This point was painfully brought home to many eastern Pennsylvania communities during the 1980-81 drought in the Delaware River Basin. Two basic forest management options can be used, alone or in combination, to influence water yields while maintaining water quality.

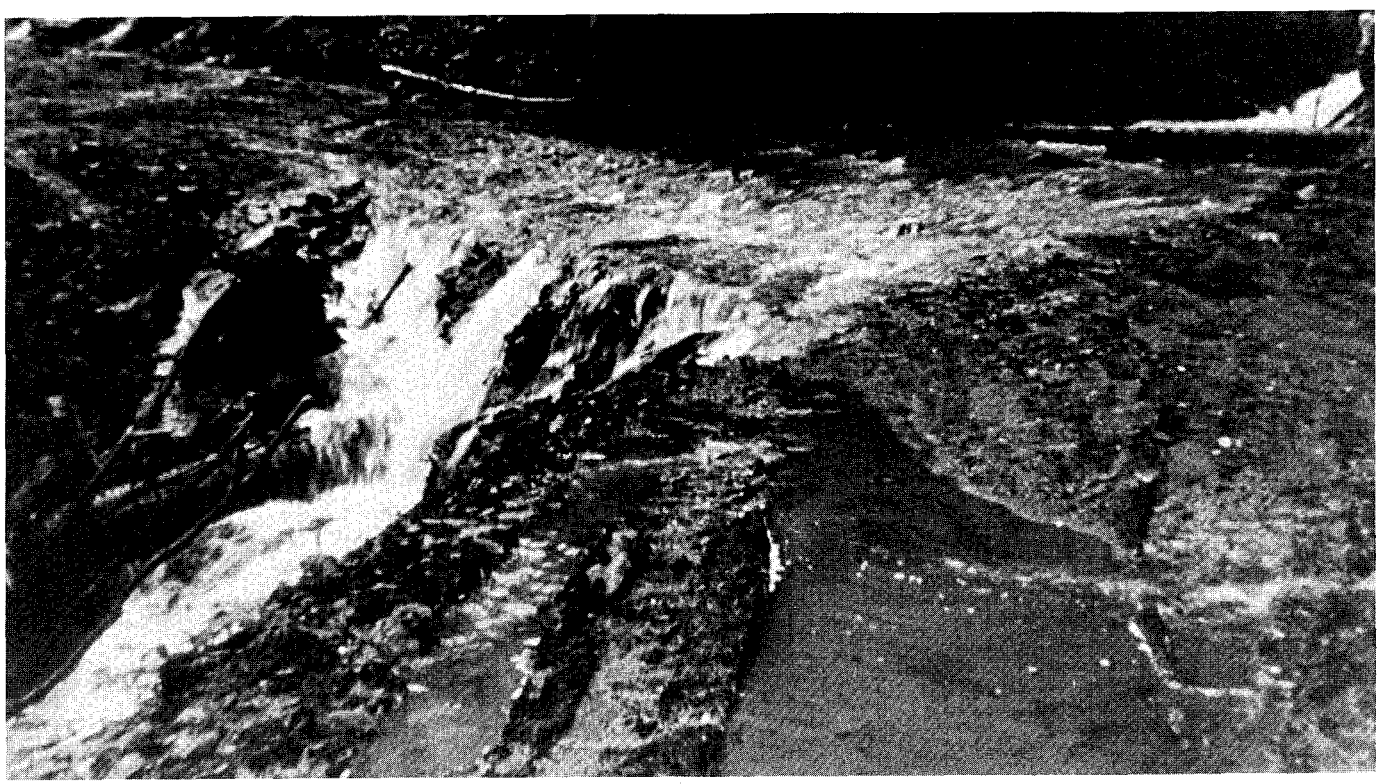
Water yield from a forest is related to the cover type. Conifers maintain most of their foliage throughout the year and so have higher interception and evaporation losses. Converting pine stands to hardwoods, which usually are without leaves for part of the year, is one method for increasing water yield.

The harvesting system chosen for regeneration also affects water yield, especially during periods of low flow. Generally, cutting more trees per unit of area reduces transpiration and makes more water available. Taken to an extreme, the clearcutting of a forested watershed could significantly increase water yields. Harvesting done without streamside logging and with carefully planned, constructed, and maintained logging roads would have little negative impact on water quality.

Cutting streamside vegetation invites physical disruption of the water course as well as the removal of shading trees. Exposing the stream to direct light was found to increase summer maximum water temperatures as much as 8°F in a central Pennsylvania watershed (Lynch et al. 1975).

Improper road building increases stream turbidity drastically until logging is completed. In a West Virginia study of two logged watersheds, the area having a carefully planned, constructed, and maintained road system had only 3 times as much turbidity during logging as it did 2 years after logging stopped. The watershed with an uncontrolled road system had 245 times as much turbidity during logging as it did 2

Poorly maintained logging roads lead to unnecessary soil erosion.



years later (Kochenderfer and Aubertin 1975). The deterioration of water quality is significant not only for humans but also for many forms of aquatic life that have special habitats and narrow limits of tolerance. Dramatic fluctuations in stream temperature, turbidity, speed, and depth adversely affect many stream inhabitants, including important gamefish like trout.

In 1981, the Pennsylvania Forestry Association published a booklet entitled "Timber Harvesting Guidelines." These voluntary guidelines establish recommendations for cutting that would result in minimal disturbance to the land.

The following are guidelines pertaining to water resources:

- Remove only individually selected trees within 50 feet of either side of all perennial streams. Attempt to maintain at least 50 percent of the overhead canopy.
- Locate roads and skid trails as far from watercourses as is practical. The minimum distance between a watercourse and any road and/or skid trail should be 50 feet plus 4 feet for each 1 percent of slope.
- Stream crossings should be avoided if possible.
- Trees cut near streams should not be skidded across the stream.

There are other guidelines that apply to wildlife, logging road construction, and scenic and esthetic values. The booklet is available from the Pennsylvania Forestry Association, 5205 Trindle Road, Mechanicsburg, PA 17055.

Soil

The forest soils of Pennsylvania are a vital but often overlooked forest resource. They directly influence all plant life and hence all wildlife dependent on plants for food and shelter; they exert a strong influence over the quality and quantity of the water resource available to plants and animals; and they dictate which uses of the forest, including recreation, are acceptable. Any discussion of the forest resources, without giving proper attention to this basic, life-giving component of the forest ecosystem would be incomplete.

Soils and trees, naturally, have a very close relationship. Soils provide trees with such essentials as anchorage, water, nutrients, and oxygen for roots. Also, soil provides a medium for mycorrhiza-forming fungi. These fungi increase the absorptive surface area of root systems, which results in improved tree growth and vitality. Trees, on their part, provide organic material from decayed leaves and wood to enrich the upper levels of the soil. Tree roots also often help break up rocks into coarse fragments by growing into cracks and enlarging them as they grow.

To understand productivity of forest soils, a brief discussion of soil formation and soil characteristics is helpful. Parent material is of primary importance. The rock from which a soil develops determines very much what type of soil it will be. In western Pennsylvania, sedimentary rocks occur in horizontal beds. Slopes traverse a variety of sediments that give rise to different soils. Shales, including some limestone and calcareous ones, are most often exposed. Throughout the mountains of central Pennsylvania the sedimentary beds are folded. Erosion has left sandstone ridges oriented in a southwest to northeast direction. The side slopes are colluvium (material that has moved downslope through gravity) or shale. The valleys generally have soils derived from weathered limestone. The two northern corners of the state were glaciated. The glaciers transported and redeposited the material, formed gravel deposits, outwash plains and terraces. Some of these soils have stratified layers of sandy gravel which drain easily. Other glaciated soils are high in coarse fragments, and have fragipans (compact and impermeable subsoil layers). In southeastern Pennsylvania, beyond the Great Limestone (Cumberland-Lebanon-Lehigh) Valley, rocks are mainly sedimentary shales and siltstones. Also, there are several igneous rocks producing boulder-strewn soils that restrict agricultural use (Cunningham et al. 1977).

Parent material, as it is influenced by climate, relief, aspect, biological activity, and time, determines what type of soil is created and how productive it will be. For example, topography often directly affects the depth of the soil. Slopes erode near the top, creating shallow soils there, while the eroded material is deposited at the toe of the slope, resulting in deeper soils there. In general, deeper soils are more productive than shallow soils. In Pennsylvania, poorly drained (saturated) soils are common along streams, near the lower portions of slopes, and in low topographic positions. Productive soils require an optimum balance between water and air. Poorly drained soils reduce the amount of oxygen available to roots, often reducing plant growth. Such soils are relatively unstable and will not support developments such as roads and recreation facilities.

General statements of soil productivity often must be qualified. What is to be produced is very important. Agricultural crops have different requirements from timber crops. Agricultural crops usually are more demanding of soil, so a soil that is rated only good for such crops may be excellent for growing trees. Forest soils generally are more rocky and less deep than agricultural soils. After hundreds of years of settlement, farming, and logging, the best agriculture soils have been located and, in the absence of roads, cities, and other developments, are generally in farm use now. Forest use has replaced farm use on many lands that proved marginally productive for agriculture.

In recognition of the value of soils in determining land use, the Pennsylvania legislature passed Act 319, the Farmland and Forest Land Assessment Act of 1974, commonly known as the Clean and Green Law. This law permits forest-land owners to receive a preferential assessment of their land based on the capability

of the soil to produce timber crops. Highly productive land can produce more timber, and is taxed at a higher rate because of its greater potential.

Where are the productive soils of Pennsylvania? To answer this question, we went to a general soil map of the state developed by the USDA Soil Conservation Service and The Pennsylvania State University. Although the state has 340 different soil series, the map was developed from 91 soils that account for 63 percent of the state's area. Each soil was rated for its potential to produce forest crops. By assigning a numerical score to each rating we were able to calculate a woodland suitability class for each of the 58 major groupings of soils (associations) in Pennsylvania, based on the proportion of each soil in each association:

Woodland Suitability Class	*Site index (height at age 50)*	*Yield per acre of even aged, fully stocked, natural stands* [a]			
		Age 60		*Age 90*	
	Feet	*Cubic feet* [b]	*Board feet* [c]	*Cubic feet* [b]	*Board feet* [c]
Excellent	85+	3,700+	18,600+	5,200+	30,950+
Very good	75 to 84	3,700	18,600	5,200	30,950
Good	65 to 74	3,100	13,900	4,400	24,500
Fair	55 to 64	2,600	9,700	3,650	18,300

[a] Adapted from Schnur 1937.
[b] Entire stem inside bark.
[c] International 1/8-inch rule to a 5-inch top; includes all trees with 16-foot log. International 1/4-inch rule is approximately 10 percent less.

Forest soils with excellent potential cover 2.8 million acres (10 percent of the state); very good soils cover 9.8 million acres (34 percent), good soils 13.8 million acres (48 percent), and fair soils 2.4 million acres (8 percent) (Fig. 24). The best soils occur in the glaciated northwest, in the valleys of the Ridge and Valley Province and the broad Cumberland-Lebanon-Lehigh Valley, and Lancaster County. The very good soils are

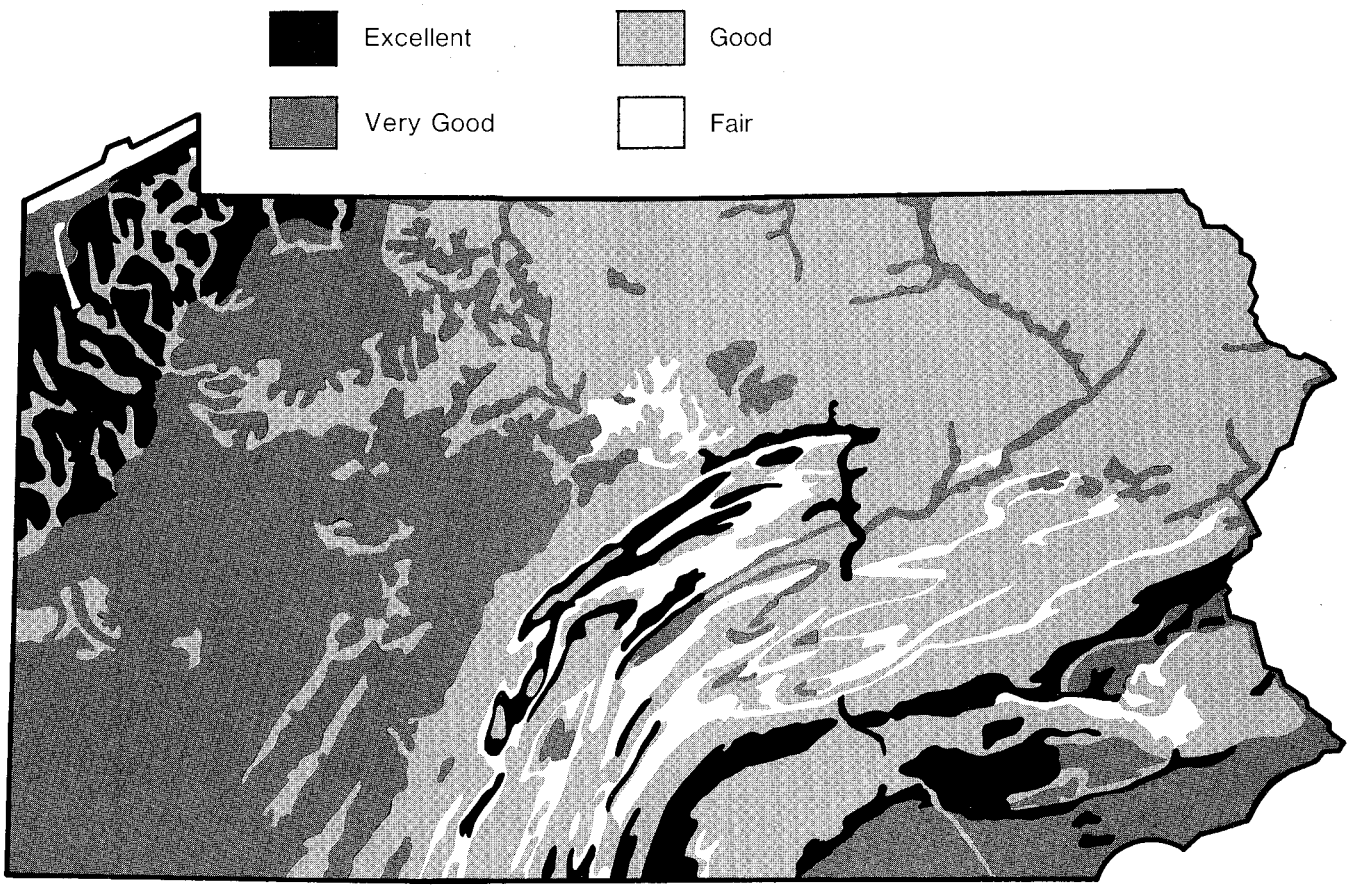


Figure 24.—Distribution of soils in Pennsylvania based on their potential for growing timber.

concentrated in the western half of the state, the northern Susquehanna River drainage, and a strip along the Pennsylvania-Maryland, Delaware, and New Jersey border in the southeast. The good forest soils, which are most prevalent, are concentrated in eastern Pennsylvania. The poorest soils cover the least area and are found in the Lake Erie drainage and the ridges of central Pennsylvania. Of course, there is local variation within these four broad groups. Detailed county data are available from the USDA Soil Conservation Service.

Undisturbed forest cover protects soils very well. Erosion is minimized and compaction is negligible. Disturbance of the forest floor will increase these problems, but to varying degrees. When a forest stand is harvested, for example, the degree of erosion depends more on the logging practices, especially the location, construction, and the use of logging roads, than on the type or extent of the cutting itself (Pennock et al. 1975). Where logging roads are well-planned, constructed, and maintained, erosion will be minimized and usually within a year or two after logging the erosion problem will have disappeared.

To keep soil erosion and stream sedimentation at tolerable levels, the Pennsylvania Department of Environmental Resources (DER) requires an erosion and sedimentation plan where fewer than 25 acres will be disturbed, and an erosion and sedimentation permit where more than 25 acres will be disturbed. For timber sales, DER concludes that 10 percent of the logged area will be disturbed, so a permit is required for a sale area that exceeds 250 acres.

Compaction has two important consequences. When the ability of the soil to absorb water is reduced, the potential for runoff and erosion is heightened. Also, if normal drainage and aeration processes are disrupted, seedling establishment, survival, and growth can be significantly reduced. Besides harvesting, heavy recreational use such as camping and hiking can result in compaction. In areas where compaction is likely to occur, hardened surfaces should be installed to protect the soil. Where soils are compacted, use should be discontinued and the soil loosened if possible.

The forest soils of Pennsylvania are vital and dynamic. Though they can be damaged, they yielded today's second-growth forests despite the tremendous stresses of massive logging operations and subsequent fires at the turn of the century. With greater emphasis on soil conservation this resource can continue to benefit the users of Penn's Woods.

This main haul road was seeded and will return to forest land use naturally with no adverse environmental impact.

Pennsylvania Bureau of Forestry

Minerals

Pennsylvania is blessed with a wealth of mineral resources, especially oil, natural gas, and coal, that originated from ancient forests and that are found today beneath thousands of acres of commercial forest land. If they are left in the ground, they have no impact on the forest resources above them. However, once we begin to extract them, the forests can be affected significantly.

Oil and gas were formed from the decaying remains of dead plants and very small animals. This material collected at the bottom of lakes, swamps, and seas where it mixed with and was covered by sediments or mud. After hundreds of thousands of years, this heavy overburden exerted pressure and heat which, by processes not well understood, changed the organic matter into droplets of oil and vapors of gas. As

pressure increased, the oil and gas were squeezed out of the thin layers of mud and into sedimentary rocks with cracks and pore spaces (Wagner and Lytle 1968). Mostly sandstones, these rocks are common in western Pennsylvania, so the oil and gas fields of the state generally stretch in a broad band east to a line running from Bedford to Tioga Counties.

The first oil well was drilled south of Titusville in Venango County in 1859, making this the first center of oil production in the world. Production spread and by 1891 the oil industry reached a peak annual production of about 31 million barrels. Pennsylvania led all states in oil production until 1895. While production in 1977 was only 2.7 million barrels, Pennsylvania petroleum is still highly prized for its excellent lubricating characteristics.

Gas production had developed concomitantly with oil but has not fluctuated as much. It reached a high of about 150 billion cubic feet in 1954 and in 1977 production totaled 92 billion cubic feet. Pennsylvania uses almost 5 times more gas than it produces. This has led to many empty gas wells being available for storage of natural gas piped in from other areas. The impact on forests of these storage facilities is less than that of active wells.

When oil and gas wells are developed in forested areas, small clearings, usually 1/4 to 1 acre, are made at the well site. Often accompanying these clearings are roads, which provide access to the wells, electric lines, and pipelines, which transport the product to a pumping or compressing station. Depending on the size of the tract and number of wells, the loss of forest land can be significant. Oil wells are drilled at much closer spacing and occupy proportionately more area than gas wells. The latter, when not associated with oil wells, have less impact on the forest resources.

These impacts can be both negative and positive. Oil and gas development generally is bad from a timber viewpoint because of the loss of productive land and the increased management and logging problems it presents. Wildlife in general would benefit due to increased diversity of habitats. Some recreation would benefit from increased access and the opportunity to see the operations. Activities such as wilderness backpacking would suffer. Effects on soil and water resources are negative: during winter and spring, movement of heavy equipment can dam-

Oil wells can have significant impacts on forest resources.

Western Pennsylvania Conservancy

age roads and compact soil; erosion may increase where the vegetation has been removed and the soil is exposed; and saltwater, oil sludge, and oil leaking from corroded pipes can pollute ground and surface water. Environmental disturbance from oil and gas wells tends to be long lasting on the surface resources.

On the Allegheny National Forest, these mineral resources present a special problem. Every acre of the Forest has oil and gas potential. The value of this potential was recognized before Congress established the Forest in 1923, and subsurface rights were made available only for 2 percent of the area. Because of the way these deeds were written on 260,000 acres, an operator needs no permit to build a road, clear the area, and set up a well. Although oil and gas production in this area peaked years ago, the increased demand for fuel and development of new recovery methods have stimulated the search for these resources. Drilling activities are increasing on the Forest. In 1979, 500 new oil and gas wells were drilled in the Forest—roughly double the number of new wells drilled in any year earlier in the decade. This brought the total number of operating wells in the Forest to more than 5,000. The USDA Forest Service is working with developers so that their operations will have minimal adverse effects. Nevertheless, this unrestricted access on so many acres has precluded several forest uses which would normally be allowed, and has made uncertain the potential realization of long-term forest and land use plans.

Oil and gas development is not as disruptive or as widespread as coal mining. Coal is the most abundant and important of the mineral resources of Pennsylvania. The state's coal reserves are estimated to be 31 billion tons, second only to West Virginia in the Northeast, and fifth in the Nation (U.S. Dep. Energy 1980). Pennsylvania's great reserves of high-quality coal, including coking coal, are responsible for the great iron, steel, chemical, glass, and metal-fabricating industries of the state (Edmunds and Koppe 1968). In 1979, production of 89.2 million tons of bituminous coal ranked third in the Nation behind Kentucky and West Virginia. Pennsylvania is the only state where anthracite coal is mined; production in 1979 totaled 4.8 million tons. In fueling homes and industries, this resource has contributed significantly to the economy of the Commonwealth.

Like oil and gas, coal was also formed from the decayed material of prehistoric forests. Dead trees and ferns fell into swamps, forming a tangled mass of decayed matter called peat. After peat was laid down, the areas sank and were covered with water, sand, and mud. The great pressure from this overburden compressed the peat, forcing out oxygen and hydrogen and leaving the carbon that eventually became coal. All of the economically important coal beds were laid down 300 million years ago during the geologic period that bears the name of the state (Pennsylvanian). Coal seams in Pennsylvania range in thickness from a few inches to 12 feet.

The coal fields of the state are concentrated in the west (Fig. 25). Pennsylvania has three types of bituminous coal (high, medium, and low volatile) and two types of anthracite (semianthracite and anthracite). These five coals grade from west to east, and from high carbon content (88 percent) for high-volatile bituminous coal to very high carbon content (94 percent) for anthracite. The reason for this is that the heat and pressure on these coal beds increased from west to east as the earth's crust folded and buckled to create the Appalachian Mountains. Thus, the coal beds in the western bituminous field are relatively horizontal while those in the eastern anthracite fields often are nearly vertical. As will be discussed later, this affects the type of mining and reclamation of mines in the different coal fields.

The first bituminous coal was mined near Pittsburgh in 1761. Anthracite was discovered and mined near Wilkes-Barre later in that decade. Production of coal peaked at 278 million tons in 1917 and then dropped off between the wars only to exceed 208 million tons in 1944. Coal was king in those years, and nearly all of the production came from deep mines. After World War II, cheaper and cleaner natural gas and oil were substituted for coal, and railroads switched from coal to diesel fuel. Production of coal dipped to a low of 79.7 million tons in 1961. The output of Pennsylvania mines has since risen to its current high of 94 million tons in 1979 (Pa. Dep. Environ. Resour. 1979).

Although the anthracite fields of eastern Pennsylvania underlie about one-quarter million acres of commercial forest land, the impact on forest resources from mining this resource has continued to decline. Production reached a peak of 100 million tons after World War I. Since the last forest survey in 1965, production has dropped by 66 percent to a record low of 4.8 million tons in 1979. Schuylkill and Luzerne Counties account for 79 percent of the current output.

The decline is generally attributed to market problems. Anthracite was used for home space heating, and many users simply switched to fuels that were cheaper and easier to use. Anthracite has less sulfur than bituminous coal but still contains too much to be burned in the New York and Philadelphia areas—its primary markets. Particulate air pollution also is a concern in burning anthracite. Air pollution controls now favor bituminous coal. Also, it is more costly to mine anthracite than bituminous coal. Surface mining the steeply inclined seams is expensive, and many deep mines in the area are old and cannot accommodate modern machinery. Miner safety is also a concern that has generated labor problems in these mines.

Most of the anthracite has been mined underground. As the coal was brought out, much refuse material accompanied it. After as much coal was extracted from this material as was economically possible, the culm or slack was dumped into mountainous refuse banks that cover roughly

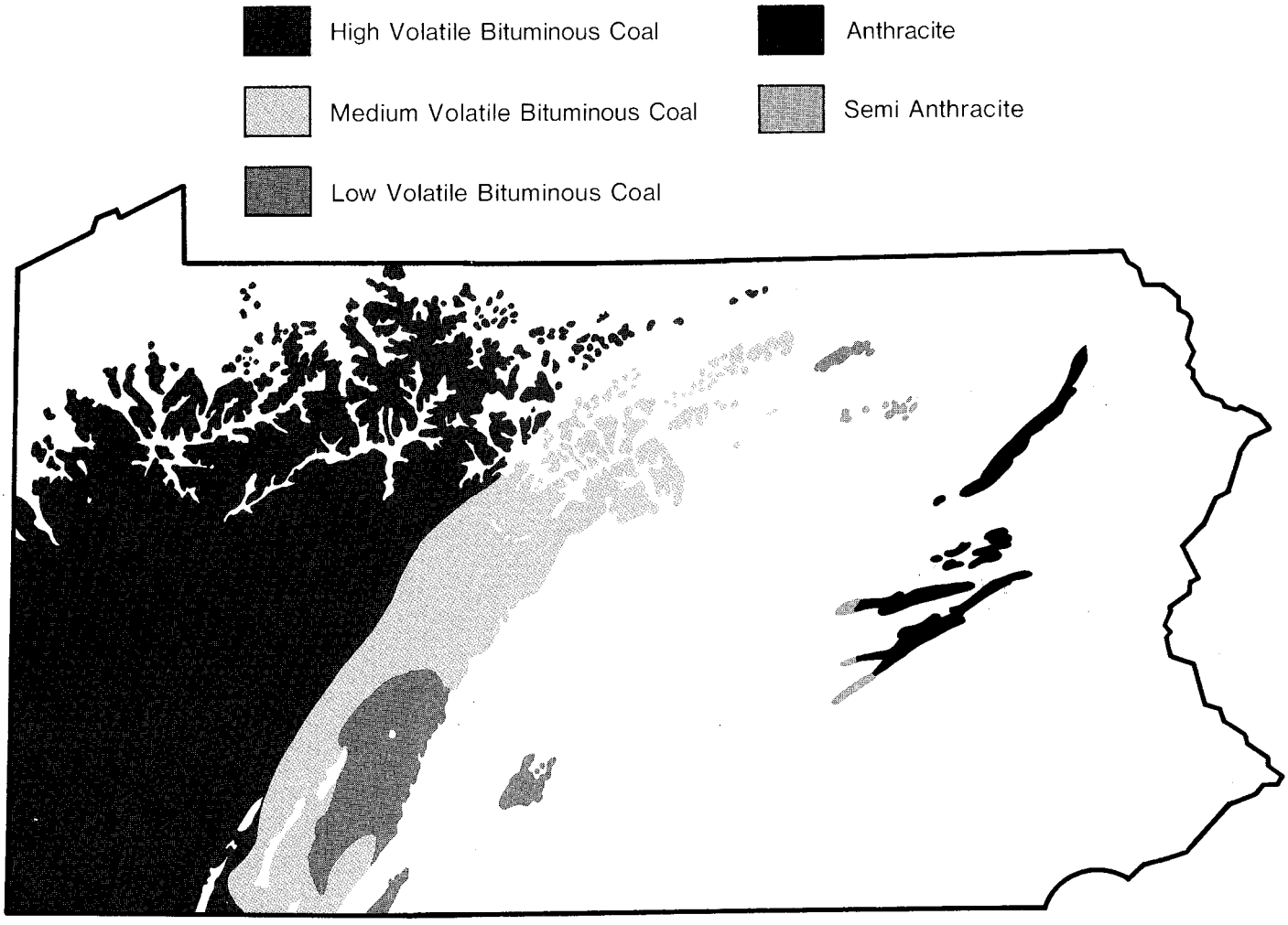


Figure 25.—Distribution of the bituminous and anthracite coal fields in Pennsylvania (Source: Edmunds and Koppe 1968).

12,000 acres, polluting the landscape and rivers. Because of improved technology (more efficient furnaces that can burn powdered coal) and higher prices for anthracite coal, much more coal is being extracted from this "waste" material. Efforts are being made to reduce these banks by using the leftovers as substitutes for cinders on roads, ingredients in cinder-block mix, road surfacing materials, and even as potting soil.

Surface mining of anthracite reached a peak of 13.5 million tons in 1948 and fell to 2.9 million tons in 1979. Stripping the often vertical anthracite seams calls for large, open pit or quarry-type operations, creating problems not encountered in bituminous strip mines. After the coal has been removed from the mine, the hole is backfilled with the overburden that was removed at the outset. It is virtually impossible to restore the pit so that it is filled to the rim. The result is much like a basin with sloped highwalls to the rim. Thus, reclamation to the original contour of the land is difficult, and drainage is often changed considerably. An estimated 28,000 acres have been disturbed by anthracite strip mining.

The story of bituminous coal mining and its effect on the forest resources is much different. From 1965 to 1977, 1.2 billion tons were produced, and 39 percent came from surface (strip) mines. In 1965, stripping production was 23.7 million tons, or 30 percent of the total. In 1979, stripping had almost doubled to 45.1 million tons and accounted for 51 percent of the total. Stripping production was near the record high of 46.6

million tons produced in 1977 (Fig. 26). No doubt, this level will be surpassed in the 1980's as the Nation uses more coal to meet its energy needs and as mining technology advances. Of the 25 counties with active strip mines in 1979, 5 accounted for 29 million tons or 64 percent of the strip-mining production. They are Clearfield, Clarion, Somerset, Cambria, and Jefferson. In 1978, Pennsylvania led the Nation in acres mined with 16,283 (U.S. Dep. Energy 1980).

Although the forest resources are most affected by surface mining, significant production still comes from underground mining, which also affects the forests. Areas of major impact are mine openings, storage points, waste dumps, and haul roads. Besides removing small areas from timber production, deep mining can create larger problems for the forest such as soil erosion, acid stream pollution, subsidence, and burning refuse banks. Pennsylvania's Operation Scarlift has corrected some of these problems on abandoned mines, but much work remains. Despite these problems, surface mining has a greater impact on the state's forest resources and warrants the most attention.

The bituminous fields are covered by 5.7 million acres of commercial forest land, 36 percent of the state's total. While not all of this overlies coal seams that can be extracted by stripping, the potential for surface disturbance is great. Mining technology is continually improving, and even now old strip mines are being dug out again as miners go for deeper seams, which were economically unavailable before the advent of huge earthmoving machines and higher coal prices.

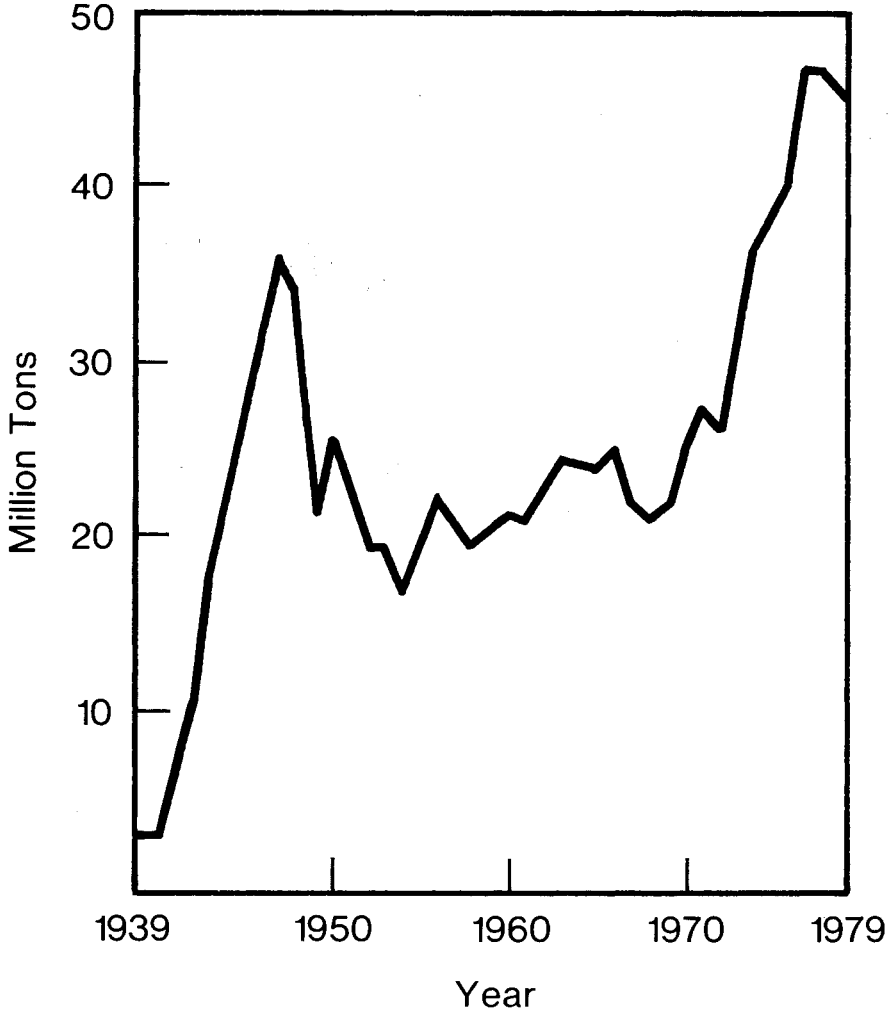


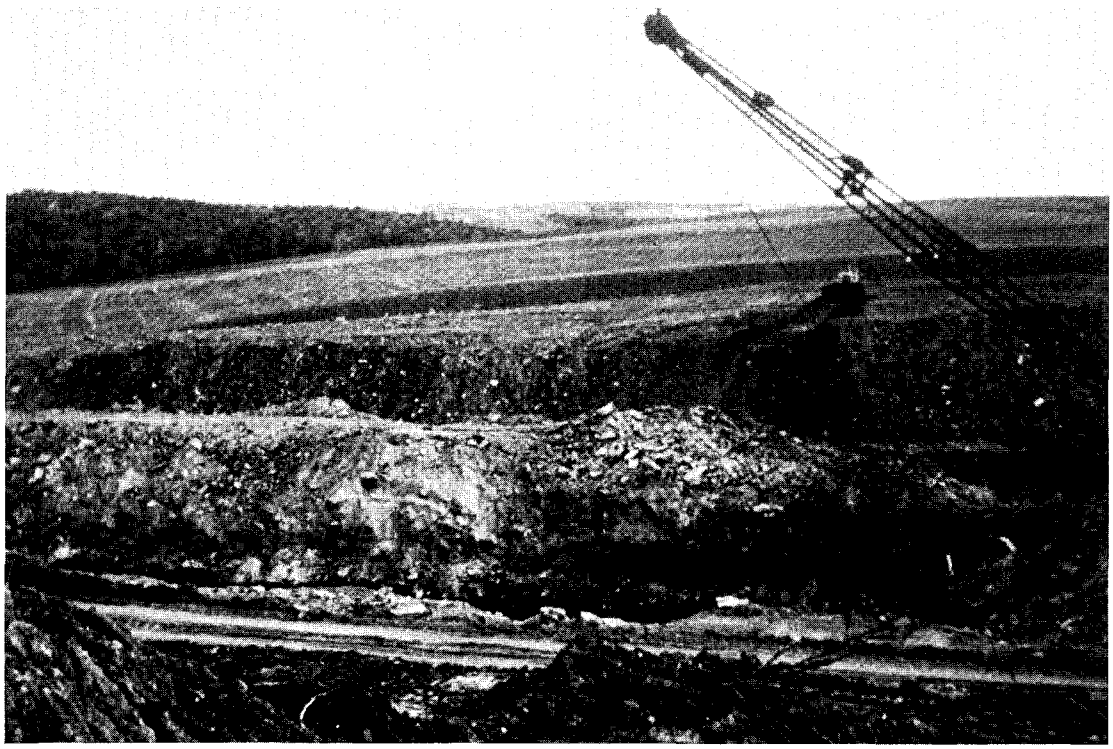
Figure 26.—The production of bituminous coal from strip mines is near the all-time high reached in 1977.

Before 1945, when Pennsylvania became the first state to institute a mine reclamation program, little or no attempt was made to establish vegetation on strip-mined areas. While this left many areas scarred and barren, the effects could have been worse. Overburden from early strip mines was small because large earthmoving equipment was unavailable. Thus, disturbance was not great (compared to today), and topsoil was often available for any reclamation work. Many of these unreclaimed "orphan" mines are being redeveloped, and they will be recalimed and returned to productivity under current regulations. The first reclamation projects occurred in 1919. These were voluntary, and usually entailed planting tree seedlings (conifers) on spoil banks.

From 1945 to 1971, Pennsylvania strip miners operated under the Bituminous Coal Open Pit Mining Conservation Act. During this period an average of less than 10,000 acres were revegetated annually. An estimated 85 percent of reclaimed areas were planted to trees and shrubs, mostly conifers.

In 1971 Pennsylvania enacted the Surface Mining Conservation and Reclamation Act. This act was considered by many as the best in the country. The law has been effective in achieving reclamation of mined areas. One major change, however, was that fewer acres were being planted to trees since grasses were required on all reclaimed sites. The law made tree planting optional except in areas where grasses were not thought to grow well and where slopes were steep enough to need

Strip mining can take land out of forest use when it is reclaimed and revegetated with grass.



stabilizing. Since the law required the top strata of the soil to be saved and replaced after the mine was backfilled, it seemed that grass and legume establishment would be facilitated.

In 1971 and 1972, nearly all strip mines were revegetated with grasses and legumes. But after a few growing seasons, despite fertilization and other treatments, many sites proved too harsh and the grasses died. To keep the areas in vegetation, many mines were planted to trees along with acid- and drought-tolerant grasses. In recent years, 12,000 to 15,000 acres have been reclaimed annually. In 1978, 3 million trees were planted on 3,000 acres, 2,000 of which were originally planted to grasses and legumes that failed. Tree planting on strip mines is making a comeback; the acreage planted to trees doubled every year from 1975 to 1978 (Personal communication, Phil Newell, Pennsylvania Department of Environmental Resources).

Besides having better success with trees, strip-mine operators are finding that tree and grass reclamation costs less than grass and legume reclamation. The most successful species is European white birch, which grows fast and tolerates acidic soils (pH of less than 4). Other popular hardwood reclamation species include black locust, hybrid poplar, and European black alder. In areas where deer populations prevent successful hardwood reclamation (because hardwood seedlings are preferred foods), conifers, especially Japanese larch, are recommended. Scotch, white, Austrian, and red pines are other conifers that have varying success rates for reclamation.

Because Pennsylvania's bituminous coal fields cover a broad range of land uses, terrains and soils, a general statement about land use after strip mining would be unrealistic. For instance, reclaimed areas in the southwest may be used for pasture or for growing hay, while reclaimed areas in the northeastern bituminous coal field (such as Elk County) probably will become forest land. Today, most reclaimed areas will retain the previous general land use. Although it is too early to know the impact of the Federal Surface Mining Control Act of 1977, P.L. 95-87), the new regulations likely will maintain the status quo. Changing the land use of a disturbed area, say from forest land to farmland, requires lengthy explanation and justification. Otherwise, an operator could plant trees and move to another job in a relatively short time. So despite the fact that strip mining is disturbing more forest land each year, it seems that little acreage will be lost from the forest land base due to coal mining.

Administrators of Federal and State laws will work together to ensure that areas disturbed by surface mining are returned to productive use with minimal negative impacts

on the forest resources. Timber, water, soil, wildlife, and recreational use will continue to be affected, often drastically, during the actual mining operation. But when the coal is gone and the land is properly restored, the outlook for these resources should be nearly as good as it was originally.

Fish

We think of fish as a forest resource for many reasons. The main reason is that forests can provide high-quality, silt-free water at levels that are relatively constant. This is essential in providing the basic fish habitat. Fish are sensitive to pollution. In fact, fish are used as indicators of water quality in streams that are being cleaned. Erosion leads to silt in streams, which harms fish by killing insects and other preferred foods, by filling in pools and spawning areas, and by coating their gills, which causes them to suffocate. Well-managed forest land not only provides clean water, but it also provides shade, which keeps water temperatures low enough to sustain viable populations of coldwater fish. Besides helping coldwater game fish, such as trout, forest shade also maintains populations of other smaller nongame fish, some of which may be essential food for larger predatory fish. Forests also support insect populations on which the fish feed. So all fish are dependent on forest land to a certain extent, whether they be game or nongame, coldwater or warmwater.

Stable populations of diverse animal life require habitats that meet their specific needs. With about 170 different species of fish in Pennsylvania, it is not surprising that the state has a variety of aquatic habitats, many of which are in forested settings. The Allegheny National Forest alone supports populations of 71 fish species, six of which acquire special emphasis because their populations are very small. Pennsylvania has more than 45,000 miles of flowing water ranging from headwaters of mountain streams with only brook trout and related species to large rivers supporting 30 or more species (Hoopes 1977). Other surface water includes more than 2,000 impoundments ranging from small farm ponds to reservoirs of thousands of acres; natural lakes, including the glacial lakes of northeast and northwest Pennsylvania; and Lake Erie.

These diverse waters support a wide range of fish life, from tiny minnows that feed on algae and small insects to 55-pound muskellunge that feed on smaller fish. While there are many more species of nongame fish than game fish (including panfish), the latter receive the most attention since catching them is the ultimate goal of more than 1 million fishermen in the state.

Trout fishing dominates the coldwaters of Pennsylvania and is a very popular forest recreational activity. The average trout fisherman spends 10 days afield each year. The three species found in the state are brook trout, which is native; brown trout, which was introduced from Europe; and rainbow trout, which was introduced from California. Trout may be caught in all parts of the state, but are more frequently found in cool, unpolluted freestone and limestone streams and rivers of the mountainous regions. Eighty percent of coldwater fishing occurs on State land, much of which is forested. Salmon also are coldwater fish. Coho and Chinook salmon have been introduced successfully into Lake Erie and its tributary streams. Another salmon, Kokanee, has been introduced to Upper Woods Pond in Wayne County.

Warmwater fishermen spend an average of 12 days a year pursuing a variety of species. Panfish, including bullheads, catfish, crappies, eel, perch, rock bass, and sunfish, are very popular, especially with younger anglers. Bass fishermen are challenged by smallmouth bass, which abound in many streams and rivers such as the Susquehanna, Juniata, and Delaware, and largemouth bass, which are found in hundreds of lakes of all descriptions, including Raystown Lake and Lake Wallenpaupak.

Forested streams often provide excellent trout habitat.

Western Pennsylvania Conservancy

Walleye are next in popularity with the Susquehanna, Delaware and Allegheny Rivers offering the best stream fishing. Pymatuning Reservoir, Lake Wallenpaupack, and numerous smaller lakes also offer good walleye fishing. With the introduction of the Amur pike, Pennsylvania is the only area in the world where one can catch every known member of the pike family (which also includes northern pike, pickerel, and muskellunge). The Delaware also offers exciting fishing when shad make their spring run.

These diverse habitats and healthy populations of so many game fish species have contributed to the increasing popularity of fishing in Pennsylvania. Licenses issued tell the story. In 1965 there were 512,653, and since then the number has risen steadily to 1,004,003 in 1979—a 96-percent increase in 14 years.

The outlook for fishing in the state looks bright due to the work of the Pennsylvania Fish Commission (PFC). A major activity of the PFC is its stocking program. Fishing demand is now so high that if certain streams and lakes were not stocked with fish, the natural populations of game fish would be unable to withstand the pressure, and the quality and quantity of fishing in these waters would drop significantly. The PFC operates 12 fish cultural stations. From July 1, 1979, to June 30, 1980, these hatcheries stocked 54.4 million fish. Fry (very small fish) account for the bulk of these (85 percent), and nearly all are walleye. The others are nearly evenly split between fingerlings (4 to 5 inches long) and adults. Most of the fingerlings are trout and salmon, while nearly all the adults are trout (personal communication, Steve Ulsh, Pennsylania Fish Commission).

Since the average trout released is over 9 inches long, stocking these fish is a major effort. Besides the State hatcheries, two Federal hatcheries (one in the Allegheny National Forest), and 167 cooperative coldwater nurseries run by sportsmen's clubs helped raise trout in 1979. In that year, 800 streams covering 4,920 miles and 90 lakes were stocked. Rainbow and brown trout each accounted for 41 percent of the stocked trout and brook trout accounted for the remaining 18 percent. Many remote and isolated mountain streams receive little fishing pressure and support good populations of native trout. To keep from interfering with these natural strains, these streams are not stocked. Ninety streams in forested settings have been set aside as Wilderness Trout Streams by the PFC (personal communication, Marty Marcinko, Pennsylvania Fish Commission).

The PFC is also involved in other activities. At its Benner Spring Station in Centre County, fish cultural research is conducted in genetics, nutrition, pathology, production statistics, techniques, and mechanization. The PFC also identifies and protects amphibian and reptile species that are threatened or endangered. Recently, the Massasauga rattlesnake was declared an endangered species in Pennsylvania, thus joining two frogs, three salamanders, five turtles, and five fish that have been given special protection. In a cooperative agreement with the Pennsylvania Bureau of Forestry, the PFC has prohibited the removal of reptiles or amphibians from 23 designated Natural Areas in the State Forest System.

Despite the variety of habitats and relatively good populations of many fish species, this resource is not without problems. Water pollution in its myriad forms is the greatest threat to fish. Included are sedimentation, acid mine drainage, petroleum leaks (from pipelines or tankers), industrial wastes, nonpoint-source pollutants from agricultural lands and roads, and possibly acid rain. Also, the loss of shade that results from removing trees from stream banks can present a local problem.

As mentioned previously, undisturbed or well-managed forest land does not contribute to these problems, and in certain instances can alleviate their impact. Forests can be managed for coal, timber, wildlife, and recreation as well as for fish. For instance, strip mines that are properly reclaimed and revegetated with trees will not pollute streams with sediment or acid. Logging operations that leave buffer zones of trees along streams and operations in which roads are properly constructed and maintained will not raise stream temperatures or sediment loads. And although little is known about the effects of acid precipitation on forest ecosystems, forested watersheds might prevent some of this airborne acid from entering streams. Forests can and do provide us with a variety of benefits while simultaneously affecting Pennsylvania's fisheries in many positive and beneficial ways.

In January, 1981 the PFC adopted a policy that shifted the philosophy and mission of the PFC from "recreation first" to "resource first." The aim is "to protect, conserve, and enhance the quality and diversity of the Commonwealth's fishery resource (including reptiles and amphibians) and to provide continued and varied angling opportunity through scientific inventory, classification, and management of that resource." It places a new emphasis on the importance of fish habitat, which is related in many ways to the forest conditions of the State. This policy will be implemented through the 1980's by Project FUTURE.

Wildlife

Wildlife is a renewable resource of great interest to hunters, birdwatchers, photographers, naturalists, and many others. Most wildlife species are closely related to forests at various stages of their lives. About 270 species of birds are found in Pennsylvania during one or more seasons of the year. Of these, 122 depend on forests as their primary habitat, and 54 more use forests at least part of the time. For mammals, 50 of the 60 species in the state use forested habitats extensively, while 7 others are partially dependent on tree-covered areas (Hassinger 1977).

A great variety of wildlife abounds in the Commonwealth be-

cause of the state's favorable climate, topography, land use patterns, and history of sound wildlife management. Forest land amounts to 16.8 million acres and farmland adds another 6.9 million acres of wildlife habitat. That these land uses together account for 82 percent of the land area in the state is significant since nearly all species of wildlife rely on these areas for food and shelter. But another important factor is the physical arrangement and interspersion of farms and forests. The variety of land use patterns leads to diverse habitats which encourage a variety of animal life. For example, the ridge and valley region of central Pennsylvania has broad valleys, which were developed for farming, and ridges, which were left forested. These extensive ridges form long, uninterrupted forested corridors that favor many animals which cannot live in small woodlots isolated by land development. Many other species benefit from the miles of edge where ridges meet farmland as they provide immediate access to both forest and farmland habitats.

Hawk Mountain becomes crowded in September as people seek a good view of the annual raptor migration through the valley.

Western Pennsylvania Conservancy

The arrangement of people is another reason why wildlife is so plentiful. While many animals adapt well to urban and suburban environments, most prefer less intensively developed land uses. Urban development is most heavily concentrated in three major areas (Philadelphia, Pittsburgh, and Wilkes-Barre/Scranton), leaving much undeveloped space for wildlife.

Wildlife can be divided into two broad groups—game and nongame. While most attention is focused on game animals, the nongame group is receiving increasing consideration. In 1981, a bill was introduced into the Pennsylvania General Assembly to allow taxpayers to contribute any or all of their Pennsylvania income tax refund for the purpose of funding increased management of nongame wildlife, and endangered plants, animals, and fish.

In numbers of species, nongame exceeds game by 5 times or more. Songbirds and raptors are perhaps the best known nongame animals. Nongame mammals, such as shrews, moles, mice and rats, are small and often nocturnal, and are rarely seen.

Birdwatching is the most common activity involving nongame animals. Woodpeckers, chickadees, wrens, warblers, sparrows, and herons are but a few of the nongame birds that one may encounter. Though songbirds are most popular, raptors (falcons, hawks, and eagles), owls, and vultures are becoming more popular. The fact that parking space is hard to find on Hawk Mountain (near the border of Schuylkill and Berks Counties) during fall weekends testifies to this.

Threatened and endangered species of wildlife are beginning to receive deserved attention. The Pennsylvania Game Commission (PGC) along with the USDI Fish and Wildlife Service, is determining the status of all species of wild birds and animals in Pennsylvania and developing plans to protect threatened or endangered species. On the Allegheny National Forest the Indiana bat, bog turtle, river otter, bobcat, raven, and great blue heron receive special consideration since their populations are very small on the Forest. In the past, market hunting threatened some species with extinction. Today, closely controlled and regulated hunting is an essential tool in wildlife management. The loss of habitat is by far today's most significant threat to wildlife populations.

The largest animal in the state also happens to be a nongame wildlife species—elk. This impressive animal was once common in Pennsylvania but became extinct in the Commonwealth during the mid-1800's. Between 1913 and 1925, some elk were introduced from Yellowstone National Park into northwestern Pennsylvania. The herd had a rough time of it for 50 years—its population in 1974 was only 38. Since then, thanks to the management of the PGC and the Bureau of Forestry, the size of the herd has increased to over 100 animals. Protected from hunting

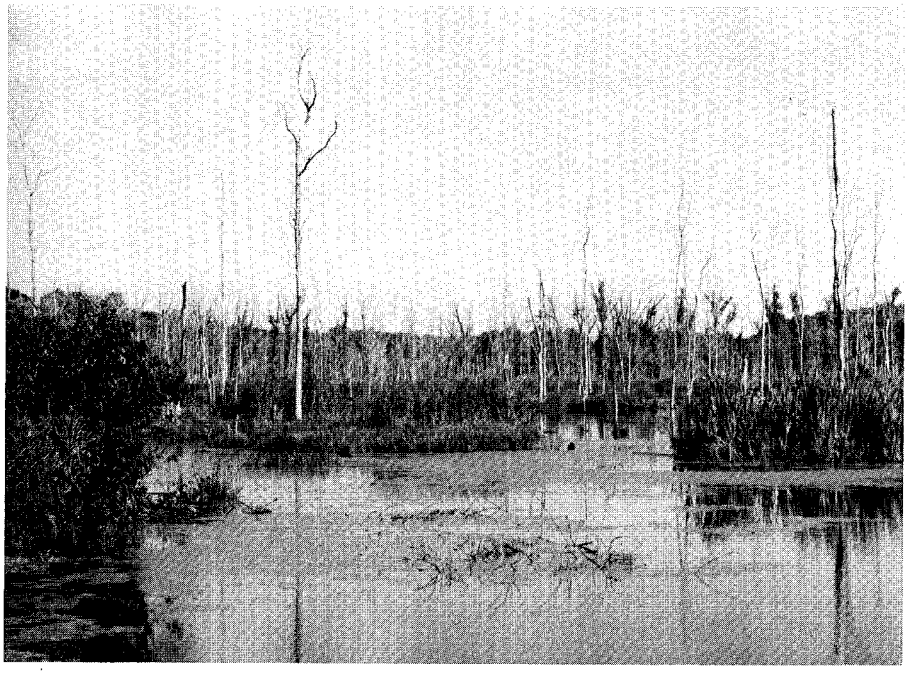
and located in the remote forests of Elk and Cameron Counties, the herd is responding well to the increased supplies of preferred food (aspen shoots and red oak acorns) that are provided on Game Lands and State Forests. Manipulation of their forested habitat is finally starting to pay off, and the future of these majestic animals is promising in the Commonwealth.

Game animals are those harvested by hunting or trapping. Pennsylvania has been and still is the number one hunting state in the United States. For several years the state has been first nationally in number of hunters and hunting licenses sold in nearly every category and in income derived from license sales. For the 1978-79 hunting season, the PGC issued 1,275,104 hunting licenses, an increase of 34 percent since 1965. Sales of additional specialty licenses are increasing rapidly. In 1979, 238,862 archery licenses were sold, a jump of 208 percent since 1965. Muzzle loader licenses were first issued in 1974. In 1979, 25,321 of these were issued and short-term trends indicate a doubling each year for this fast-growing sport.

One reason why hunting is so popular in Pennsylvania is the great access that hunters have to the land. The PGC manages 268 separate Game Land Tracts in 65 counties, and these contain 1.1 million acres of forest land. State Forests add 2 million acres, and the Allegheny National Forest contributes another 0.5 million forested acres. In addition to this 3.6 million acres of public forest land available to the hunter, data from our ownership study indicate that owners of another 7.3 million acres of private forest land permit some public hunting on their land. Thus, a substantial amount of forest land is accessible to the hunter. The PGC also works with many farmers through its cooperative farm-game projects and safety zone program. These add about 4 million acres of farmland that the hunter may use.

Access is only the first step to successful hunting. Once you get on the land, there should be sufficient

This State Game Land in the glaciated portion of the Allegheny Plateau (Erie County) provides wetland wildlife habitats that are relatively uncommon in Pennsylvania.



The white-tailed buck is the object of attention for over 1 million hunters in Pennsylvania each fall.

Pennsylvania Bureau of Forestry

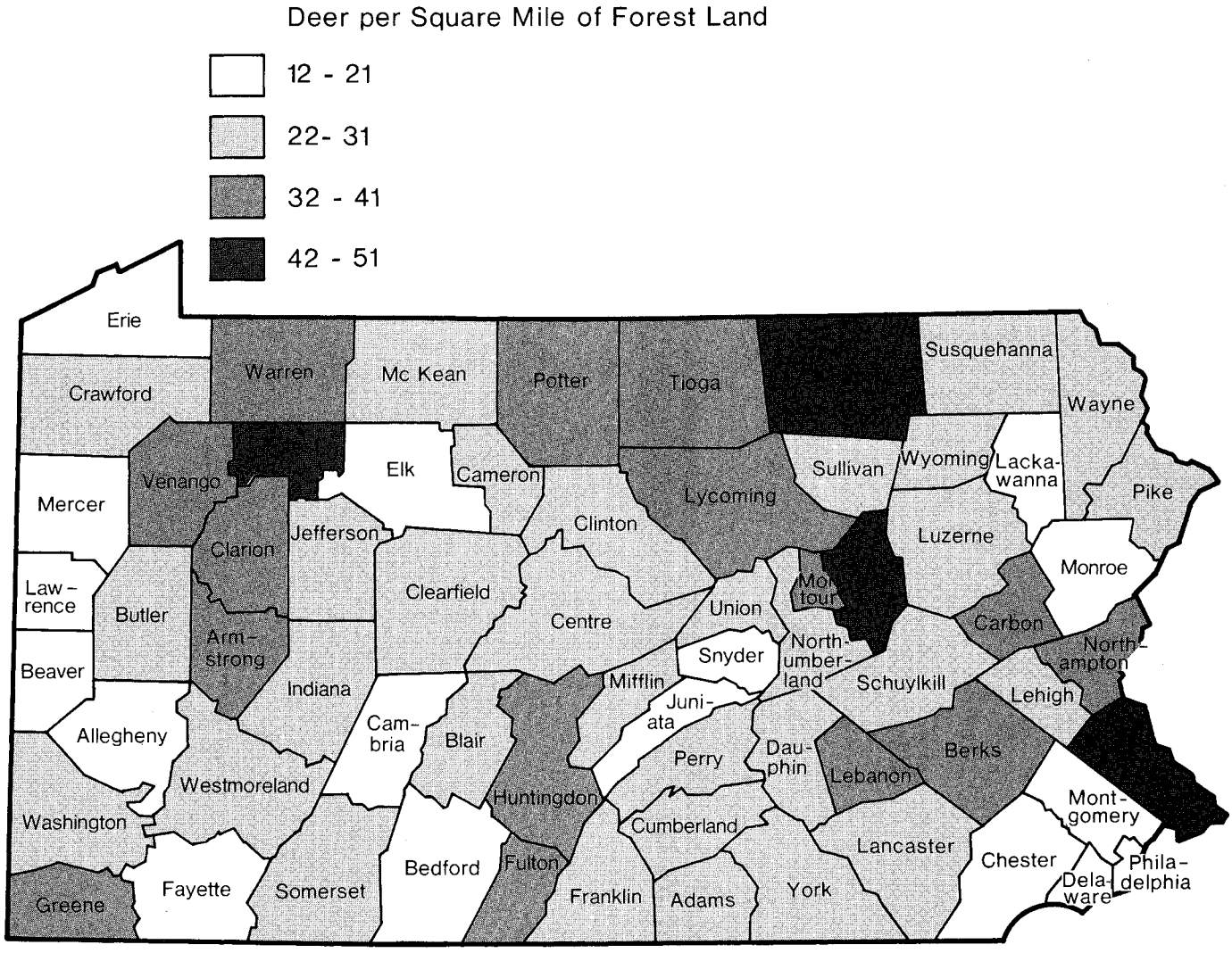
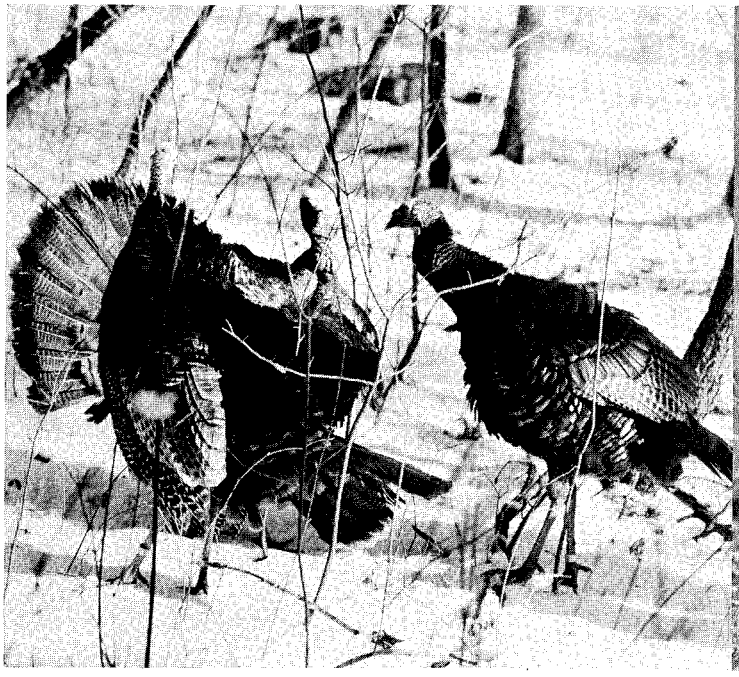


Figure 27.—Densities of white-tailed deer vary considerably between Pennsylvania's counties. (Deer population statistics provided by William K. Shope, Pennsylvania Game Commission).

populations of game animals to provide good hunting. Pennsylvania has good to excellent populations of a variety of game species, most of which are closely tied to the forests of the state. Deer, the most popular game species in Pennsylvania, are found in every county, though densities vary considerably (Fig. 27). Other popular big game animals are wild turkey and black bear. Turkey, which may be hunted in the spring and in the fall, depend on forests in part for food and cover, and are most common in areas with extensive forest land. Black bear, which were not harvested in 1975, 1977, and 1978, are making an excellent comeback. In 1979, 736 were harvested, and in 1980 a near record 921 bears were taken legally. Reproduction and growth rates of bears are very good in Pennsylvania. The PGC has a full-time program of research on and monitoring of this popular animal's activities and population. The highest concentrations of black bear are in the forested regions of north-central and northeastern Pennsylvania.

Other popular game species closely linked to forests are ruffed grouse, gray squirrel, and snowshoe hare. Furbearers associated with woodland include gray and red fox, beaver, and raccoon. Ring-necked pheasant, cottontail rabbit, bobwhite, and mourning dove can be found in brushy seedling and sapling forest stands, but tend more toward agricultural land. Waterfowl, dependent on forests mainly for clean water, are found in marshes and in rivers, ponds, and lakes.

Wild turkeys are elusive big game birds, and the state's forests provide them with essential habitats.



Pennsylvania Game Commission

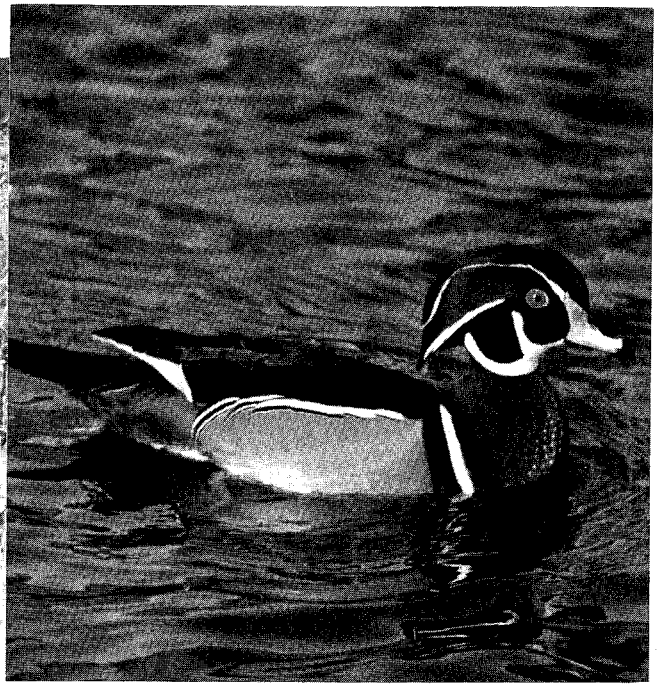
Ruffed grouse populations have declined as the forests, which were cut over early this century, are maturing.

Pennsylvania Game Commission

The black bear is the largest game animal in Pennsylvania, and the recent resumption of an annual hunting season for this forest dweller has proved very popular.

Pennsylvania Bureau of Forestry

The wood duck is one of the few waterfowl species that live in forested habitats.



Western Pennsylvania Conservancy

Deer, being the most economically important wildlife species living in forests, deserve a closer look. There is no doubt that hunting in Pennsylvania is deer-oriented, and receives considerable attention from the PGC. In 1980, 135,477 deer were reported taken by hunters. Another 26,772 were removed from the highways after being killed by cars and trucks. The PGC estimates that as many as 117,000 more deer were killed by hunters or vehicles, but were not reported or actually picked up. Thousands more were killed by free-running dogs, starvation, or other natural causes. These losses amount to about 40 percent of the deer herd annually, and are necessary to maintain a relatively stable population estimated by the PGC to be about 700,000. The PGC uses a multivariable population model to estimate both the deer population for each county and the number of deer that should be harvested to maintain what the PGC feels is the proper number of deer in each county. We have supplied the PGC with our most recent data on the distribution of forest land by stand-size class, an important component of the population model.

The obvious browse line and lack of understory regeneration are clear signs that deer concentrations are excessive in this area.

While keeping the population near the 700,000 level may be desirable from a hunter's viewpoint, there are many foresters who argue that the herd should be reduced to levels compatible with forest renewal. Besides the costly damage done to vehicles, orchards, crops, and shrubs, the damage to forests is severe in many localities. Browse, the tender shoots, twigs and leaves of trees, is a winter staple of a deer's diet. Since deer generally reach no higher than 6 feet above ground for browse, they feed primarily on seedlings and small saplings. When the deer population of an area exceeds the carrying capacity of the natural range and the available forage, the seedlings needed to regenerate the area to forest cover are destroyed. Growing space that would be used by such commercially valuable species as yellow-poplar, cucumbertree, white ash, and red and sugar maple becomes filled with ferns, grasses, sedges, beech, striped maple, and other nonpreferred browse species (Severinghaus 1978). Parklike stands are created, and though easy to walk through, are difficult to regenerate to commercially desirable stands when cut. Thousands of acres of the Allegheny National Forest are in this condition, and while the problem may be most severe there, it exists in other areas of the state as well.

Besides the negative impact of the deer herd on the future timber resources of these areas, other wildlife resources are being damaged. The large deer herd has reduced populations of snowshoe hare and ruffed grouse in northern Pennsylvania and may be adversely affecting turkeys as they compete for food. Even the deer herd itself may be hurt, as the forests of the future will support only low populations if preferred food is unavailable (Severinghaus 1978).

To resolve this problem, many people have suggested reducing deer populations in these hard-pressed forested areas. In 1978, the Northern Hardwood and Plateau Chapters of the Society of American Foresters recommended that the PGC intensify its deer management by (a) using, within county boundaries, deer management units with similar range conditions, and (b) establishing for each management unit deer population goals that represent a proper balance between wildlife, timber, farm, and other natural resource interests (Journal of Forestry 1978). To help determine such population goals, the USDA Forest Service researchers at Warren, Pennsylvania are attempting to identify the greatest density of deer (number of deer per square mile) that will allow natural regeneration to develop satisfactorily. Foresters and others concerned about the forest resources of Pennsylvania hope that in the near future the deer herd will be controlled in these affected areas so that adequate numbers of desirable tree species can be established and grow naturally.

Besides managing game populations by controlling the number of hunters, length of season, and bag

Fencing deer out allows the protected area of this 20-year-old clearcut (in the background) to regenerate naturally.

limits, the PGC supplements wild populations by releasing animals raised on game farms. Currently, ring-necked pheasants and mallard ducks are being produced at six game farms located throughout the state. Turkey releases have been phased out, and pheasant production has been increased. Wildlife propagation is not as successful as fish propagation because released birds are more susceptible to predation and disease.

Managing wildlife habitat is the most basic, enduring, and stable approach to managing wildlife. Because of the many animal species in Pennsylvania, an overriding management objective is to maintain a diversity of habitats that will benefit all wildlife. The arrangement of these habitats also is important. For example, in parts of southeastern Pennsylvania, there is sufficient acreage in woodlots to provide enough food and shelter to support turkey and bear populations. But because these animals require extensive, uninterrupted blocks or corridors of forest, they do not inhabit this part of the state.

Management for diversity entails protection and manipulation. Protection means setting aside and saving certain habitats that are unique, rare, or endangered, and blocks of forest land that can be arranged for wildlife. This is normally done by public agencies, and the PGC and the Bureau of Forestry have protected thousands of acres, mainly forested, of State Game Lands and State Forests from changes in land use. Examples of protected areas are wintering and nesting grounds for game and nongame species and valuable streamside habitat for furbearers.

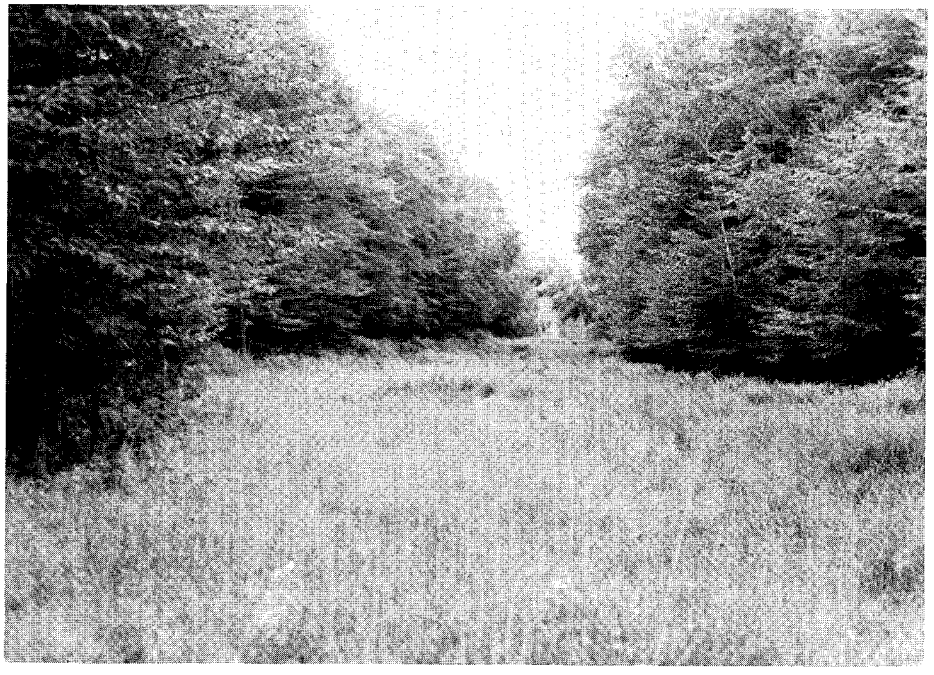
Habitat manipulation is a more common management tool available to the thousands of private forestland owners in Pennsylvania. Service foresters employed by the Bureau of Forestry are available to assist landowners in managing their woodland for wildlife and other forest resources. The PGC, Bureau of Forestry, and USDA Forest Service regularly use habitat manipulation to manage the wildlife on the lands that they administer. Habitat manipulation is the key to a cooperative 5-year fish and wildlife management program initiated in 1980 for the Allegheny National Forest by the USDA Forest Service, USDI Fish and Wildlife Service, Pennsylvania Fish Commission, and Pennsylvania Game Commission, and is also the key to wildlife habitat improvement on the 2 million acres of State Forest land.

The objective of habitat manipulation is to provide a variety of habitats within a forested area with regard to species composition and arrangement, amount of edge between different plant communities, size and distribution of openings and type of vegetation in these openings, and size and age classes of trees.

As examples of this, the Bureau of Forestry established the following forest management guidelines: 2 to 5 percent of the area in permanent herbaceous openings; 5 percent of the area in low or high evergreen cover; 10 percent of the area in deciduous food and cover, primarily shoots and buds of new trees (this guideline is for even-age management areas where clearcutting is used); 25 percent of the tree cover in trees mature enough to produce seed (for wildlife food); and protection of large, old trees for their high seed production and cavity nesting sites (Hassinger 1977). They also call for the protection of spring seeps, which are important for turkey and other wildlife species.

Important techniques used to create, maintain, and sometimes restore a variety of habitats and mixed communities are timber cutting; installation of shallow impoundments; stabilization of streambanks; and the planting of trees, shrubs, and herbaceous plants. Timber cutting, whether timber stand improvement (TSI), border cuts, browse cuts, or commercial regeneration harvests, encourages natural regeneration of sprouts and seedlings. The PGC

This gas pipeline right-of-way is maintained in permanent grass cover and provides habitat diversity and an edge effect desirable for many species of wildlife.



bountiful opportunities for management, the resource is not without its problems. Some critical habitats in private ownership are being lost to other land uses. An example is the loss of some of the lowland bear habitat in the Pocono Mountains of northeastern Pennsylvania to home development. Besides this loss, the fact that large forested areas are being subdivided into a variety of nonforest land uses is detrimental to many wildlife species.

Another problem, unregulated motor vehicle access, can adversely affect waterfowl, turkey, great blue heron, raven, deer, bear, and bobcat. The effects include disturbance during nesting and brood rearing seasons, harrassment of deer and turkeys in key wintering areas, and the possibility of overharvesting of some species in local areas.

What is the future of Pennsylvania's wildlife resource? The strong interest and concern for Pennsylvania's wildlife will continue, as will the recent trend of increasing non-

operates the Howard Nursery (Centre County), which produces and distributes annually 3 million tree (mostly conifer) and shrub seedlings.

Management of forest land for wildlife can be compatible with management for other forest resources, especially timber. The PGC is conducting research on State Game Land No. 176 (Centre County) to determine the effect of a profitable series of systemized block cuttings on wildlife populations, especially cottontail rabbit and ruffed grouse. The idea is to create four distinct age classes of timber within a relatively small area and then repeat this pattern many times in a large area. Possible advantages are profit from timber, increased rabbit and grouse populations, spreading of the deer browsing pressure to lessen the adverse impact on tree regeneration, and increased populations of nongame species.

Despite the generally good populations of wildlife species and the

This 2-year-old aspen regeneration in a small clearcut will make excellent ruffed grouse habitat (Centre County).

consumptive uses of wildlife (uses other than hunting and trapping). As this occurs, the rate of increase in hunting may level off. Possible reasons for this are continued urbanization of the population, difficulty in finding open land, a decrease in the quality of the sport, an increase in the concentration of hunters, and increasing interest in other forms of recreation (personal communication, Jerry Hassinger, wildlife biologist, Pennsylvania Game Commission). Regardless of the trends in nongame/game interests, the wildlife resource will continue to flourish due to the extent and quality of the forests of Pennsylvania.

Recreation

Recreation is a human need, ". . .ideally a change in lifestyle, even if only for a few hours or a weekend. It is a leisure with a purpose" (Jackson 1978). Outdoor recreation allows relief from daily frustrations and revitalizes the spirit. For many Pennsylvanians, outdoor recreation is a most valuable benefit of forest land.

During the 1950's, recreation and leisure became important to the economy of Pennsylvania as people gained more leisure time, money, and greater mobility. Since the second forest survey of Pennsylvania, the Commonwealth has dramatically increased its efforts to develop the state's recreation potential. As evidenced by the statewide comprehensive outdoor recreation report (Pa. Off. State Plan. and Dev. 1976) and its annual updates, the activities of many State agencies in recreation planning are coordinated on a continuing basis.

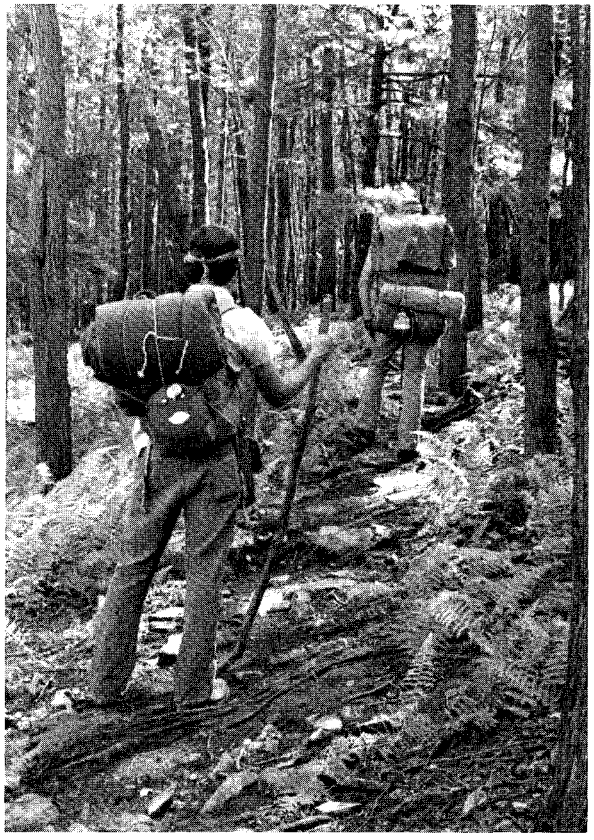
Pennsylvania's climates and landforms provide the resources to support a diverse group of year-round recreational activities. Of the state's 28.8 million acres, approximately 10 million are available for some kind of recreational activity. Private owners control more than half of these lands.

While private lands currently receive the most use, they are nonetheless underutilized. Recreational planning to include private lands has historically been difficult because of the large number of owners and the large acreages they control. An estimated 52 percent of Pennsylvania's private forest-land owners controlling 8.3 million acres allow others on some of their lands for a variety of recreational activities. The most frequently allowed activities are hunting, hiking, and snowmobiling (Birch and Dennis 1980). Efforts to coordinate recreation on private lands are increasing as several State agencies develop cooperative programs.

Pennsylvania's State-owned lands are a most important outdoor recreational resource. After the private lands, State lands are the largest source of recreation land. Of the three State agencies most closely connected with outdoor recreation, the Department of Environmental Resources is the largest land owner. Within DER, the Bureau of Forestry administers more than 2 million acres, and the Bureau of State Parks administers approximately 287,000 acres.

The State Forest System operates 20 forestry districts. Although high-quality timber production is an important goal, the multiple-use principles under which the Forests are managed give equal priority to dispersed recreation. Driving for pleasure and hunting are the two most popular activities on State Forests. Recently, however, hiking and cross-country skiing have shown the most growth. More than 2,500 miles of foot trails are available and the Bureau of Forestry, in cooperation with local hiking clubs, is working to develop more. Trails on the State Forests generally

Hikers make good use of the forested trails in Pennsylvania's publicly owned forests.



Pennsylvania Bureau of Forestry

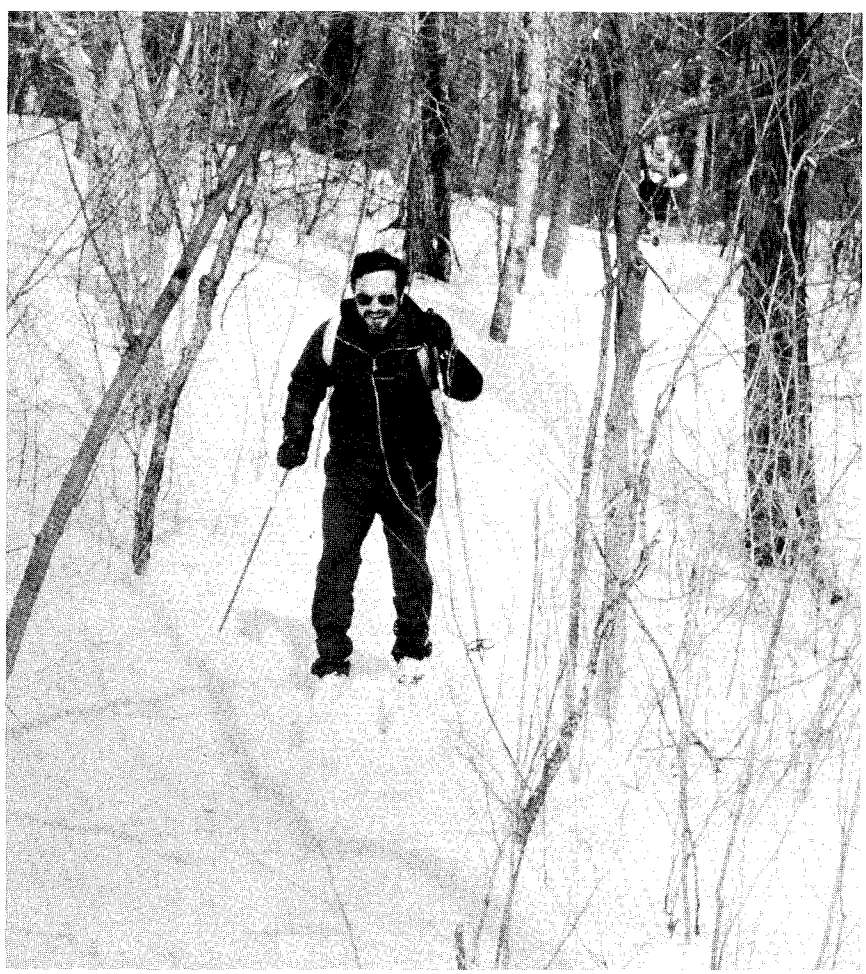
are of two types: long loops (10 to 85 miles long) and short loops, which take 1 to 4 hours to walk. The short loop trails often are interpretive, highlighting unique geologic, scenic, or vegetational features of the forest. Primitive backpack camping is permitted along the long loop trails. Fourteen Wild Areas have been designated where no manmade development is allowed.

The Bureau of State Parks lands are managed to encourage intensive recreation activities. The Bureau has 117 recreational areas; 96 parks, 11 State Forest picnic areas, and 3 environmental education centers. Seven other parks are under development or acquisition. Nearly all of the parks have some forest land which enhances recreational experiences. Water is an important recreational feature of the State Park system. Over half the parks have impoundments of at least 1 acre. These impoundments range from the 1-acre pond at Clear Creek State Park to the 14,528-acre lake at Pymatuning. Numerous other State Parks are near a creek, river, or Lake Erie.

The value of water and trees to the State Parks is reflected in the popularity of activities associated with them. In 1979, picnicking had the greatest number of nontransient visitor days. In descending order, the next most popular activities were swimming, fishing, boating, and overnight camping. In 1979, over 23 million nontransient visitor days were recorded. The total number of visitor days was nearly 38 million, the difference between the two accounted for by transient use—pleasure driving.

Except for the DER, the Pennsylvania Game Commission administers more recreation lands than any other State agency. By mid-1979 they owned 268 tracts totaling 1,207,978 acres. The primary objective on Game Lands is to provide outdoor recreation in the form of sport hunting. Concurrently, they try to provide compatible recreational activities such as birding, hiking, nature photography, fishing, cross-country skiing, and controlled snowmobiling.

Cross-country skiing is becoming very popular in Pennsylvania's forests.

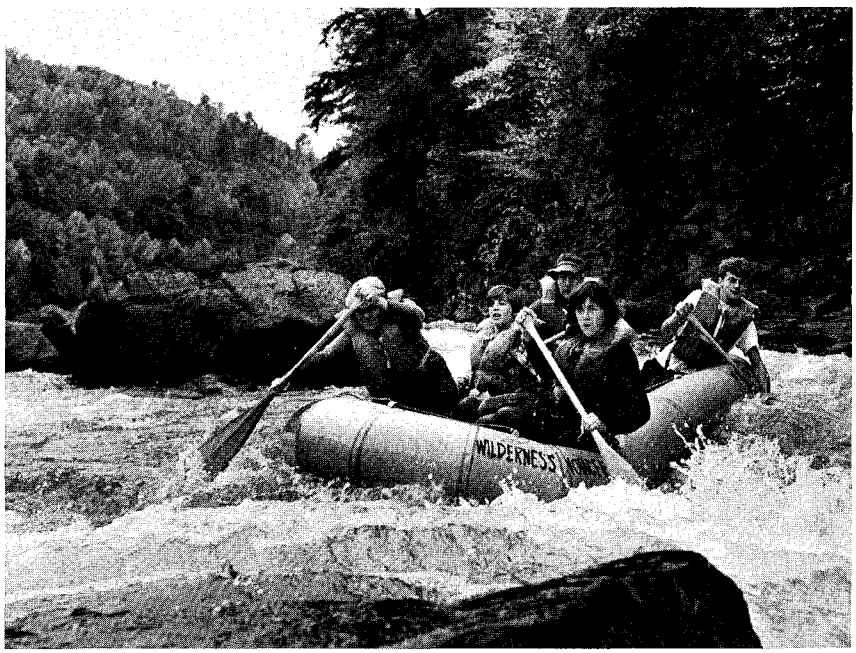


Western Pennsylvania Conservancy

Since the last forest survey of Pennsylvania, much of the State's acquisition and development of outdoor recreation facilities has been stimulated by two State bond issues and, to a lesser extent, Federal funding. The program began in 1964 when Pennsylvanians approved a $70 million bond, known as Project 70, to buy recreational lands in counties lacking park land and open space. Until 1964, most State Parks and Game Lands were in remote portions of the state. Project 70 focused on 43 counties where 90 percent of the population lived, but where less than 27 percent of the State lands were. Of the $70 million, $40 million was authorized for the purchase of State Park land and historical sites; $20 million went to local governments on matching fund basis for parks and open space. The response from the municipalities was positive; to date over 400 projects occupying 163,000 acres have been completed. Another $10 million from Project 70 was shared by the Game and Fish Commission for new lands and access areas to rivers, lakes, and streams (Schellenberg 1978).

Also in 1964, the Federal Land and Water Conservation Fund Act was passed by Congress. Among other actions, this law provided for matching funds to States for the purchase and development of outdoor

Whitewater rafting on the Youghiogheny River can be a thrilling experience (Ohiopyle State Park, Fayette County).



Western Pennsylvania Conservancy

recreation lands. This funding should be increasingly important in future years as current sources of capital are expended.

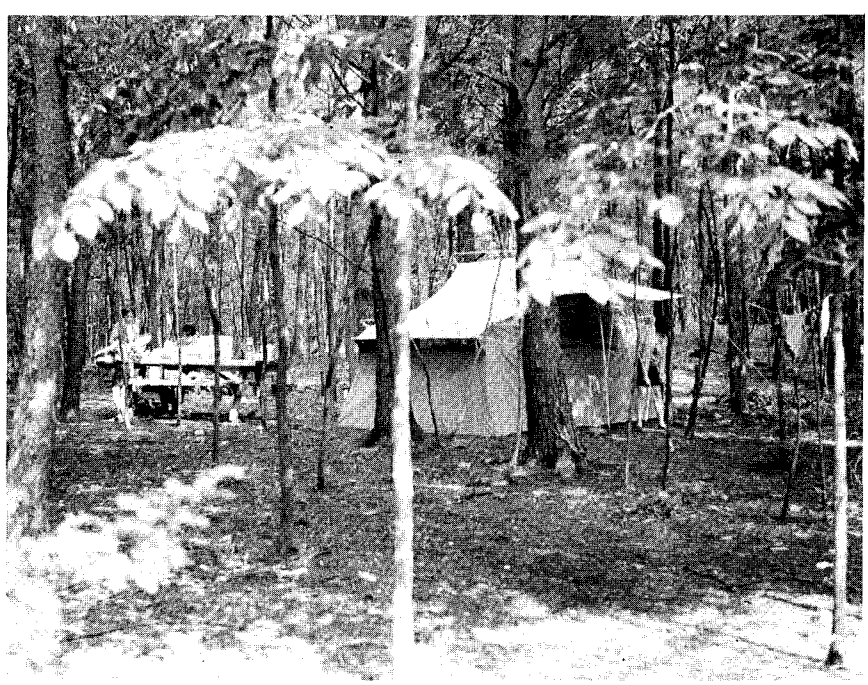
Pennsylvania's second bond referendum was passed in 1967. Known as Project 500, it provided $500 million primarily for the development of lands purchased under Project 70 and for water quality improvement. Of the total, $200 million went for outdoor recreation projects, $200 million for abandoned mine reclamation, and $100 million for sewage plant construction.

Many State Parks have opened since 1965 and many of the Parks under development have been a result of the Project 70 and 500 money. The Pennsylvania Game Commission's goal for its share of the funds has been to maximize the carrying capacity of wildlife on State Game Lands. So in addition to land purchases, money has been used for habitat improvement, waterfowl development, access road improvement, and game hatchery reservations.

The Pennsylvania Fish Commission's policy with Project funding was to improve fishing in all 67 counties. Two new hatcheries were built and 10 existing hatcheries were renovated. These improvements coincided with monies spent on water quality improvement to greatly improve Pennsylvania's fishing.

Capital funding from State bond issues will soon be exhausted. Without these funds, land acquisitions by the State agencies will be more difficult. To meet the anticipated growth in outdoor recreation demand, the DER, Game Commission, and Fish Commission have been working to expand their landowner assistance and cooperative programs. Participating owners receive the benefits of management and protection assistance. Certain programs permit public access to the lands for recreational pursuits. Expansion of the cooperative programs to include more owners of the largest block of potential recreation lands will mean increased recreational opportunities for Pennsylvanians.

Camping has great appeal in Penn's Woods.



Pennsylvania Bureau of Forestry

The Allegheny National Forest accounts for three-fourths of the 650,000 acres of federally managed land and water in Pennsylvania. Located on the scenic Allegheny Plateau in the northwestern corner of the state, the Forest attracts most of its visitors from western Pennsylvania and northeastern Ohio. The Allegheny National Forest is, however, within a day's drive of many major northeastern and Canadian cities, making it accessible to millions of other people.

The most popular activities on the Forest are camping, hunting, mechanized recreational travel, fishing, boating, and picnicking. Most of the developed recreational use and water activities occur on or along the edge of the Allegheny Reservoir, a U.S. Army Corps of Engineers project. In recent years, demand has stabilized for developed recreation and has increased for dispersed activities such as hiking, trailbiking, cross-country skiing, and snowshoeing. The Forest has responded by emphasizing fewer capital-intensive and more resource-based projects in its recreational program. Evidence of this is an increase in trail construction. Roads and trails suitable for snowmobiling and cross-country skiing are being identified and marked.

Two unique features of the Allegheny National Forest are the Hearts Content Tract and Tionesta Scenic and Research Natural Area. The Tionesta is the largest virgin tract of timber between the Smokey Mountains in the South, the Porcupine Mountains in Michigan, and the Adirondacks in New York. The Tionesta has two sections: the 2,018-acre Scenic Area where several trails allow visitors to walk through a virgin hemlock-beech forest; and the 2,113-acre Research Area where scientific study of the ecology of the virgin forest is conducted.

Hearts Content is 122 acres representative of the virgin white pine-hemlock forest that once covered portions of the Allegheny Plateau.

As a result of the USDA Forest Service's second Roadless Area Review and Evaluation (RARE II), two areas in the Allegheny National Forest have been proposed for inclusion in the National Wilderness System. The 9,200-acre Tracy Ridge area and a group of eight islands are awaiting congressional action.

Most other Federal recreation lands contain water impoundments. The USDA Soil Conservation Service has constructed small dams that are turned over to local concerns for management. Army Corps of Engineers dams are usually much larger. Seven of the Corps' projects with recreational facilities are adjacent to a State Park; two projects are adjacent to State Game Lands, and Raystown, the largest reservoir in the state, is mostly within Rothrock State Forest. The National Park Service administers a large outdoor recreation zone—the Delaware Water Gap National Recreation Area. The Tocks Island dam and lake was to be a part of the recreation area, but the river section due to be flooded has been placed into the Wild and Scenic Rivers program.

Pennsylvania is an active participant in the national effort to recognize and protect the special recreational value of portions of our river systems. The Federal effort, authorized by the Wild and Scenic Rivers Act, of 1968, classifies rivers as "wild" (untouched in any way by civilization), "scenic" (basically undeveloped but accessible by roads), or "recreational" (readily accessible, possibly with limited development, and that may have had some impoundment or diversion). Portions of the Allegheny, Delaware, and Youghiogheny Rivers and Pine Creek are under consideration for inclusion in the National System. So far, only a stretch of the upper Delaware River has been given official status.

Pennsylvania expanded the scope of the Federal plan in 1972, by enacting the Pennsylvania Scenic Rivers Act, which included the three Federal classifications and added a fourth—"modified recreational"—where the river can be developed and the flow regulated by low dams. The State system uses public easements granted by landowners along the river to allow access. Citizen committees do most of the work in providing balanced recreational opportunities. Many streams and river sections are being inventoried and evaluated for inclusion in the State System. The Schuylkill River has been designated a Scenic River for almost its entire length. Stoney Creek has been designated a Wild River.

Forest Management Opportunities

Is There a Need to Manage the Forests?

The forests of Pennsylvania today are generally not the result of forest management but of the natural forces that regenerated the land after the extensive cutting and widespread fires that occurred during the early part of this century. The projections that we made for the next 30 years show timber volume continuing to increase under current management levels. The state appears to be adequately endowed with water, fish, wildlife, and recreation resources and opportunities. If most of this cannot be attributed to forest management, why should we discuss forest management opportunities?

Part of the answer is that we can be misled by looking only at today's situation or what we may project for timber volume for the relatively near future. While nearly all forest resources are renewable, we must remember how long it takes to renew these resources. Those who consider timber to be a crop, such as hay or corn, should realize that most hardwood stands take 70 to 120 years to reach maturity. Since timber growing takes so long, careful and thoughtful planning and management can help ensure relatively steady, reliable supplies. The 40-year period prior to 1920 included the harvesting of a tremendous amount of timber—a resource that required hundreds of years to accumulate. Many millions of acres of Pennsylvania's forest land will be maturing over the next 20 to 40 years. While a repeat of extensive, exploitative logging is unlikely, it is probable

that much of the mature timber will be harvested.

Presently in many areas of the state, forests that are harvested by clearcutting or killed by insects are not regenerating satisfactorily. Regeneration failures occur in both the Allegheny hardwood (Marquis 1974) and oak (Marquis et al. 1976 and Merritt 1979) areas of Pennsylvania. These failures might mean that no tree cover is revegetating the area; that only undesirable tree species such as striped maple (*Acer pensylvanicum*), pin cherry (*Prunus pensylvanica*), ailanthus (*Ailanthus altissima*), American beech, and black locust are regenerating the site; or that some desirable species are becoming established at unsatisfactory stocking levels. While research is now being conducted on how to keep deer, acorn weevils, rodents, ferns, and other destructive agents from inhibiting the establishment and development of desirable reproduction, these problems demonstrate a need for sound forest management.

Besides the biological factors of time to maturity and regeneration problems there are socioeconomic factors affecting our 30-year timber projections (see Timber Outlook) that point to the need for forest management. For hardwoods we project a 2.8-percent annual increase over the current level of removals. While this is our best estimate, it would certainly be low if greater demands are placed on the resource. Both national and international forces will shape this demand. Pennsylvania's hardwood timber is now reaching a size and quality that is well suited for manufacture into fine furniture. Europeans are very interested in this resource, and, if current trends hold true, may be importing even more oak than they are now (Kingsley and Powell 1979). In fact, a Belgian firm is constructing a secondary manufacturing plant in Lock Haven that will require significant quantities of oak lumber.

Demand for Pennsylvania's hardwoods for fuel by both the commercial and residential sectors no doubt will increase. The state's forests would certainly contribute to the proposed national forest biomass energy program (USDA For. Serv. 1980a). Also, the USDA Forest Service has predicted that at current prices, national demand for softwood will outstrip supply (USDA For. Serv. 1980c). To offset this deficit, greater emphasis may be placed on utilizing hardwoods. These factors, independently or in combination, may result in substantially higher timber removals than we project.

Also, we should keep in mind that the rosy picture painted in our projections is for growing-stock volume for all commercial species growing on all commercial forest land. Much of this timber volume simply will not be available to timber industry given the objectives of today's private landowner, harvesting technology, and market conditions. Many private landowners never intend to cut and sell their timber. Further, much of the timber owned by people willing to cut is located in inaccessible areas, on steep slopes, or along roads or streams where logging would detract from the scenery or damage the water resource. Not all of the projected timber volume will be of the desirable species or size that timber industries need. So any projected surplus of growth over removals may not be the case for timber industries that are seeking economical supplies of specific raw materials. Thus, forest industries are strong advocates of increased levels of forest management on all commercial forest-land ownerships.

Another part of the answer as to why we discuss forest management opportunities is that many forest-land owners, regardless of national needs, what is "right" for the forest, or any other external considerations, may wish to enhance the benefits that their forest land can produce for them. Most private landowners see their situation in terms of immediate need; they do not perceive long-term management of forest land for timber to be in their self-interest. Many landowners are interested in the income derived from timber sales or in money saved by providing their own firewood, but they need more than these economic stimulants to motivate them to manage their forests. They need to feel that management would enhance the other benefits derived from owning forest land—benefits such as a diverse songbird population, a scenic view, an unpolluted and productive trout stream, a well-used deer trail, or a solitary retreat where they can find some peace and quiet.

Forest management can be used to enhance these and many other tangible and intangible benefits that landowners perceive to be in their personal interest. For those landowners who have written or unwritten objectives and goals that they wish to realize from their forest land—be they esthetic enjoyment, plentiful wildlife, clean and reliable water supplies, wilderness experiences, or quality sawtimber trees—some discussion of forest management opportunities is desirable.

Because owner objectives are so diverse and the combinations of potential forest benefits so numerous, we will discuss only a few of the more common and applicable management opportunities. However, most of the various resources and benefits are related. Management for a certain benefit or series of benefits usually results in the production of other benefits as well.

Basic Features of Forest Sites

Before looking at opportunities directed at creating or enhancing specific benefits, there are two criteria worth mentioning that have some impact on all of the various opportunities: potential site productivity and size of tract.

Potential site productivity is an estimate of how much timber volume an acre of forest land could produce at the culmination of mean annual increment if it were fully stocked with growing-stock trees. While the four classes that we normally use specify a range of annual growth in cubic feet, we recommend that the four classes be used only as relative indicators of site quality.

Knowing which sites are more productive than others has many uses. From the point of view of forest industry, for example, the better sites will grow more timber in less time with less cost. Highly productive sites would thus receive top priority for management. For owners interested in managing land for diverse wildlife habitats, knowing which areas will react the fastest to cutting or other vegetation manipulation may influence his or her choice of areas to work in as well as the timing. Private landowners of 10 acres or more of contiguous forest land can receive preferential assessment of their land for tax purposes based on their land's productivity (see discussion of Act 317, the Clean and Green Law, under Soils).

Among major ownership groups, forest industry lands have the highest site quality, followed in descending order by other private, National Forest, and other public. One might expect this since forest industries would make a conscious effort to acquire lands with the greatest potential for growing timber. The low ranking of the public agencies, generally the Bureau of Forestry, the Game Commission, and the USDA Forest Service, also is not surprising. Much of the forest land that they administer was purchased in tax sales after it was cut and burned over and found to be of little use. Much of this land occupies hillsides and ridges and generally is less productive than lower slope or bottomland sites.

The five forest-type groups that account for nearly 100 percent of the commercial forest land in the state vary in average site qualities. In order of decreasing potential they are: white and red pine, northern hardwoods, elm/ash/red maple, aspen/birch, and oak/hickory. The major reason for this relates to water as a limiting factor. Many of the white and red pine, northern hardwoods, and elm/ash/red maple types occur either in areas that receive greater than average annual precipitation or on sites where adequate water is available throughout the growing season (e.g., lower slopes, bottomland, and streamsides). The oak/hickory types usually are found on drier sites (e.g., mid to upper slopes and ridges) and therefore, are not as productive.

Site quality also varies from one geographic unit to another. The Western Unit has the best potential followed by the Southwestern, Southeastern, Northeastern, Allegheny, North-Central, South-Central, and Pocono Units. This ranking generally follows the distribution of soils based on their potential for growing timber (see p. 51). This is most interesting because the Western Unit currently has the lowest volume and growth per acre of all of the units. Opportunities for forest management seem to have the greatest potential in that part of the state.

Size of tract is an estimate of the extent of a forested tract of the same general management condition—forest type (softwood versus hardwood) and stand size. Its economic value often depends on the type of forest that one is managing. Some say that any tract less than 50 acres is too small to yield a profitable return, but the owner of a 15-acre tract of high-value timber may not agree.

Certainly, size of tract has many management implications. Some species of wildlife such as black bear require extensive and unbroken areas of forest land. People interested in a wilderness experience will avoid areas that have been split into many small tracts. Watershed management for stable yields of clean water is made easier if most of the watershed is forested. Management for a variety of forest benefits is influenced by size of tract.

Overall, 60 percent of the commercial forest land (excluding State and National Forests) is in tracts of 1 to 50 acres, 20 percent in tracts of 51 to 100 acres, 14 percent in tracts of 101 to 500 acres, and 6 percent in tracts of 500 acres or more. These proportions hold true for sawtimber and poletimber stands, but 84 percent of sapling-seedling stands and nonstocked areas are in tracts of 50 acres or less. This would be expected since most of these stands result from heavy cutting or farm abandonment, and neither tends to occur in large blocks.

Variation between units is great (Fig. 28). At one extreme is the Allegheny Unit with 38 percent of its forest land in tracts over 100 acres. At the other extreme is the Southeastern Unit with only 4 percent of its forest land in tracts over 100 acres. This indicates that access to woodlots probably is good in the southeast, which favors certain kinds of timber harvesting and recreational opportunities, but precludes management for black bear habitat or wilderness experience. Size of tract is helpful in identifying practical forest management opportunities.

Opportunities for Enhancing Various Benefits

Although managing forest land for multiple benefits is most common, (and, usually hard to avoid), to simplify our discussion we will deal individually with some of the principal benefits and identify possible opportunities which forest-land owners can use to increase these benefits.

Wood fiber, whether for sawlogs, pulpwood, firewoods, chips, or some other product, is one of Pennsylvania's foremost forest resources. Although net growth is more than twice removals and inventories are increasing each year, there are opportunities to increase timber yields and improve timber quality for those landowners who may wish to do so.

One approach is to increase net growth by reducing cull increment and mortality (the two factors that reduce gross growth to net growth). For the period from 1964 to 1977, the annual loss due to cull increment was 40 million cubic feet and the annual loss due mortality was 105 million cubic feet. Much of this loss is difficult to control, and anything less than intensive forest management will not affect it appreciably. Management can be useful in reducing losses from the three major causes of mortality and cull increment: wildfire, disease, and insect attack.

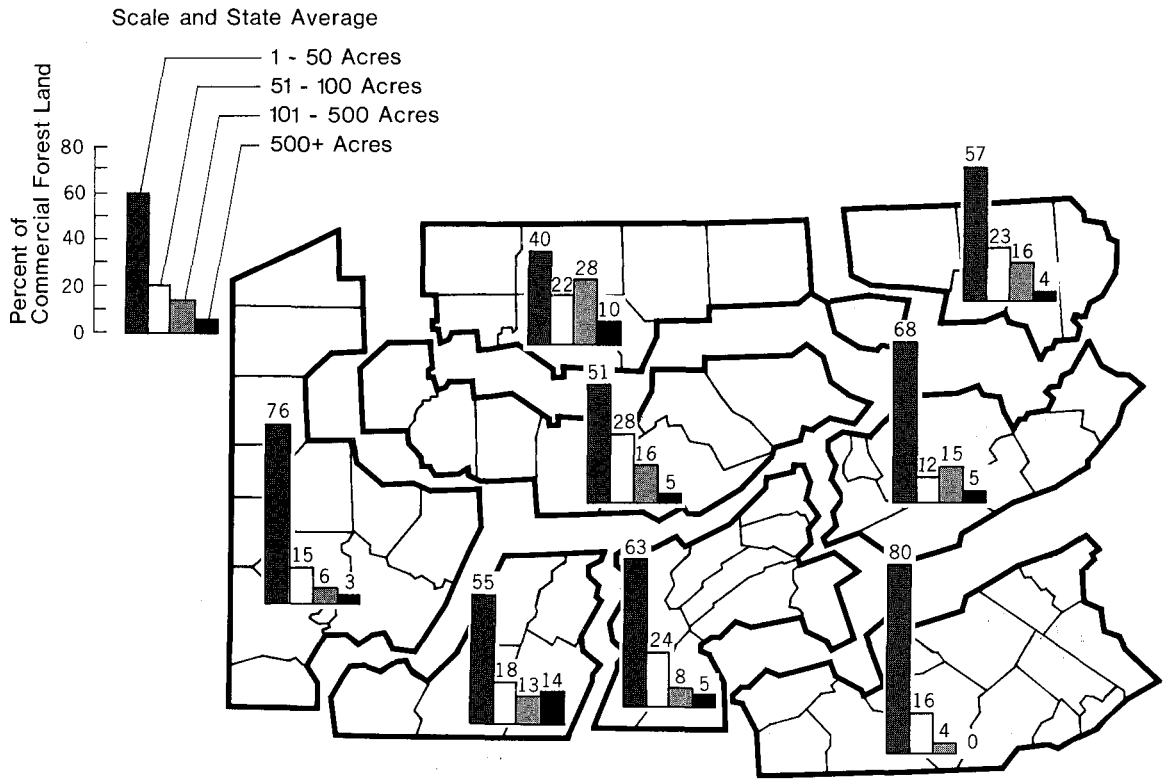


Figure 28.—Size-of-tract distribution in Pennsylvania, by geographic unit (State and National Forest data are not included).

Fire protection has been very successful in the last 60 years (Haines et al. 1978). The total number of forest fires and acres burned decreased, and the number of fires larger than 10 acres fell significantly. Most fires occur in the eastern and south-central counties, but the distribution is not even. The major threat of fire begins in mid-March, peaks in April, and ends in mid-June. There is a second, less severe, fire season that begins in early October and ends in late November. Campfires no longer are the major cause of wildfires in Pennsylvania—incendiarism is. In 1980, 684 fires were set deliberately, and they burned 3,604 acres. This accounted for 35 percent of the 1,860 fires that year, fires which burned a total of 8,562 acres (Pa. For. 1981).

Since most wildfires are caused by man, there are some steps that landowners can take to prevent such fires on their land. One approach is through education—of themselves and the people who may use their forest land. With incendiarism as prevalent as it is, good public relations with neighbors and users is important. Also, the Pennsylvania Forestry Association has established a fund that will pay up to $100 for information leading to the arrest and conviction of anyone who maliciously sets a forest fire in Pennsylvania. A $500 reward is offered by the Bureau of Forestry.

Vigilance is crucial. Owners should learn to recognize and eliminate hazardous conditions, both natural and manmade. Owners can clean out heavy accumulations of dead and fallen trees and remove debris along roads or in use areas. Any burning of debris such as leaves or brush should be done carefully, and only after consulting local forestry officials on fire danger conditions. Debris burning is a major cause of wildfire in Pennsylvania. Roads and trails can be constructed to open inaccessible areas and to serve as barriers to the spread of a fire. Safety strips around public use areas, railroad rights-of-way, public access roads are other means of preventing fire.

Not all fire is harmful to forests. Skilled application of a controlled fire can reduce hazardous accumulations of fuel, help control insects and disease, prepare planting sites, eliminate undesirable plant species, and improve wildlife habitat. Such prescribed burning should be planned and conducted only by people trained in the use of this management tool.

Disease of forest trees contributes much to cull increment and mortality. There are many diseases that infect hardwood species, but the major problems result from heart rots, root rots, and stem cankers. Most diseases enter a tree through an infection court such as a scar, a

branch stub, or a stump. Fire is closely related to disease in that it damages many hardwoods by burning away enough of the bark to create entrances for disease. Decay is common in trees that originated from sprouting high on a stump.

Several management activities can reduce the impact of disease. Maintaining a healthy, vigorous, and fast-growing stand will be beneficial. The faster a tree grows, the sooner open wounds will heal and the shorter time such wounds will be susceptible to attack. Improvement cuts to eliminate diseased trees and thinnings to stimulate growth will help. Eliminating decayed trees and shifting the growth potential to sound trees will result in a higher usable yield of wood volume at the time of final harvest. In selecting a potential crop tree from a group of sprouts, choose the stem that has a low origin (at or below ground level) and is asserting dominance. When cutting trees, keep stumps as low as possible to minimize high-stump sprouting.

Insect pests also create problems in certain areas. In the 1960's, mortality increased in many oak stands in central Pennsylvania after attacks by an oak leaftier, and oak leafrollers, followed by the two-lined chestnut borer. But current concern centers on the gypsy moth.

During the 1970's, gypsy moth populations increased, collapsed, and increased again. Infestation is spreading west through the state, but areas being hit hardest are in central and eastern Pennsylvania. The gypsy moth has been present in 5 million acres of forest land affecting 38 counties. As of 1980 the infested area covered about 36 percent of the total susceptible forest area of mixed oak stands (Nichols 1980). Over a 5-year period (1972 to 1976), the average mortality in gypsy moth infested stands in Pike and Monroe Counties was 13 percent (Gansner and Herrick 1979). Jim Nichols, Division Chief of the Pennsylvania Bureau of Forestry Division of Forest Pest Management, estimates that heavily infested areas have experienced 20 percent mortality over the last 10 years (personal communication). For the state as a whole, our survey data show that annual mortality of oak is only 0.7 percent or about 7 percent over 10 years. This indicates that mortality resulting from gypsy moth damage is not severe statewide. It is, however, a serious problem in local situations, undoubtedly reducing the growth of oak trees that are not killed.

Attempts to control gypsy moth generally have been ineffective. Methods have included spraying and trapping the moth, and releasing predators and parasites that feed on the moth. The main reason why these methods are not working well is that they do not alter the current stand conditions that favor the gypsy moth. Logging followed by fires and the chestnut blight at the turn of the century have created millions of acres of relatively even-aged stands composed primarily of oak.

Gypsy moth is expected to continue to spread across Pennsylvania. The oak forests will continue to lose both growth and standing volume to this insect over the next several decades.

Regulating forest composition through management promises to be a most effective method of protecting forests from gypsy moth (Knight and Heikkenen 1980), as different tree species vary in susceptibility to defoliation. The following is a list of tree species by gypsy moth food preference class (adapted from Houston and Valentine 1977):

Gypsy moth defoliation has turned this late spring scene into one resembling midwinter.

Most preferred

Class 1

Chestnut oak
White oak

Class 2

Black oak
Northern red oak
Scarlet oak

Class 3

Alder
American basswood
Apple
Bigtooth aspen
Gray birch
Paper birch
Post oak
Quaking aspen

Intermediate

Class 4

American beech
American chestnut
American elm
American hornbean
Black cherry
Blackgum
Black walnut
Butternut
Common persimmon
Cucumbertree
Eastern hemlock
Eastern hop-hornbean
Flowering dogwood
Hackberry
Hickory
Pitch pine
Red maple
Red pine
Sassafras
Slippery elm
Sugar maple
Table-Mountain pine
Virginia pine
Witch-hazel

Least preferred

Class 5

Black locust
Eastern red-cedar
Red spruce
Scotch pine
White ash
Yellow-poplar

Such opportunities obviously are not appropriate for extensive tracts of oak, especially since many sites are particularly well suited to growing oak. In such instances, maintaining good stocking and normal distribution of age classes, removing suppressed and overmature oaks, developing a ground cover of seedlings, and protecting against fire and grazing should lessen adverse impacts from the gypsy moth.

Sometimes there is little the landowner can do to reduce mortality on his or her forest land. If the area should sustain heavy mortality and there are markets available, salvaging the dead material before it becomes unusable will allow at least something to be recouped from the loss. There may be difficulties where access to dead material is inadequate or where the dead material is scattered throughout the stand. However, where possible, salvage is an important timber management practice that merits consideration.

Much research has been conducted on the silviculture (the development and care of forests) of oak/hickory, Allegheny hardwood (cherry/maple), and northern hardwood forests (Roach and Gingrich 1968; Sander 1978; Marquis et al. 1975; Roach 1977; Marquis 1979; Bennett and Armstrong 1981; Leak et al. 1969). A basic principal mentioned frequently in this research is that by properly adjusting the stocking of stands, wood production can be maximized on usable trees. The idea is to first eliminate the cull trees from the stand and then to adjust the stocking of the remaining trees so that the stand is growing at its optimal rate, concentrating the full growth potential on the smallest number of trees. This stocking level actually occurs over a relatively broad range of conditions, but for production of high-quality sawtimber trees it is usually in the range that Resources Evaluation calls medium stocking (60 to 99 percent).

In general, the forests of Pennsylvania are at least adequately stocked (Fig. 29). Only about 4 per-

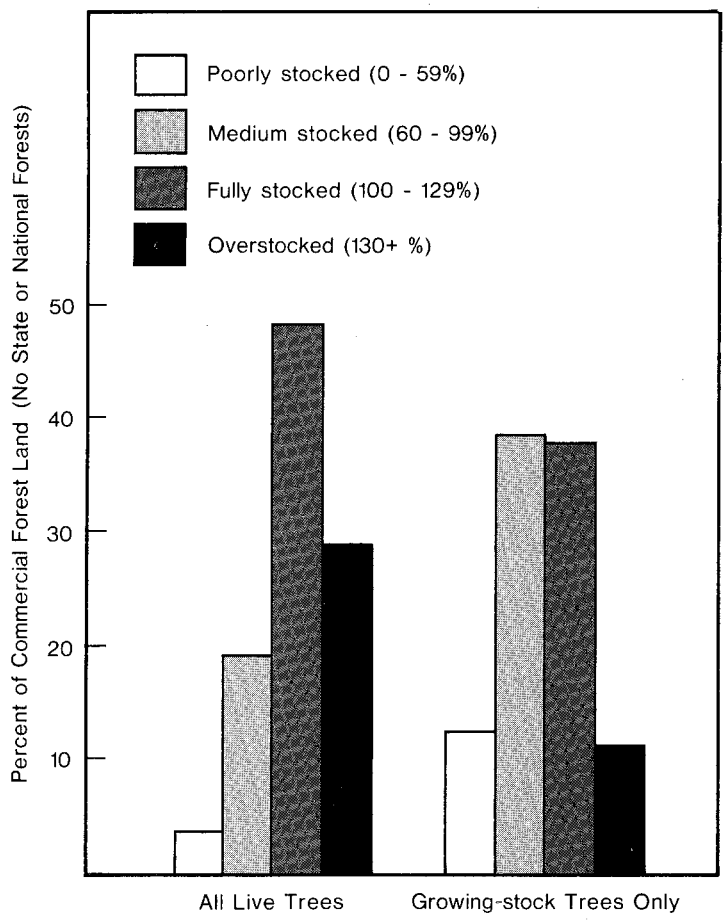


Figure 29.—Comparison of stocking of all live trees versus growing-stock trees only.

cent is poorly stocked, but 77 percent is more than medium stocked. If the cull trees were removed from the stands so that only growing-stock trees were left, medium stocking would immediately improve from 19 to 39 percent of the area (Fig. 29). The proportion of poorly stocked stands would increase to 12 percent, and the proportion of fully and overstocked stands would drop to 49 percent. This identifies cull removal as a forest management practice that can improve the stocking needed for maximum wood production. Total removal of cull trees can adversely affect the wildlife resource, as is discussed later.

After removing the culls, there still remains about 7 million acres of commercial forest land (excluding State and National Forest land) that could be thinned from full or overstocking to medium stocking. This would release the remaining trees to grow faster and yield the landowner some financial return if the thinnings can be marketed as sawlogs, pulpwood, firewood, or some other timber product.

Timber growth on many of the unmanaged forests in the state could be enhanced by some type of planned cutting. For use as lumber, almost one in six live trees over 5 inches in diameter is classed as rough cull or rotten cull. There is more than 1.8 billion net cubic feet of volume in these cull trees alone. This volume is equal to nearly 23 million cords of potential firewood. Even after excluding from this estimate the significant portion of trees that should be left uncut because of their value for wildlife, there remains sizeable fuelwood potential. Besides cull trees there is the potential to recover for fuel the unused material left in the woods after the merchantable trees have been cut and the usuable volume removed, the wood that may be buried or burned onsite as the byproduct of land clearing, and the wood from dead trees that are not needed by wildlife.

Assuming that oil, gas, and coal prices will continue to rise, the use of wood as a renewable alternative fuel will intensify. Pennsylvania's forests are in a favorable position to meet part of this increasing demand. The potential supply of fuelwood seems plentiful, and the production of other forest resources, especially other types of timber products, can be increased substantially if the fuelwood is harvested according to sound forestry practices. So there are opportunities to improve the quality and productivity of Penn's Woods while helping people meet some of their fundamental energy needs.

Defective trees, such as this beech, take up growing space that healthy trees could be using, yet they provide valuable shelter for cavity-using wildlife species.

Pennsylvania Bureau of Forestry

To gain a general picture of the timber management practices needed in Penn's Woods, our field crews placed each forested ground plot they measured into one of seven recommended treatment classes (see Appendix for treatment class definitions). Statewide, the most common condition was that the stand was growing satisfactorily and required no treatment; these stands covered 5.5 million acres or 40 percent of the commercial forest land excluding State and National Forests. The other six classes and their percentages in decreasing importance are: timber stand improvement, 16 percent; stand mature and ready to be harvested and regenerated, 13 percent; improvement cut, 11 percent; stand conversion, 9 percent; thinning, 6 percent; and remove current stand and regenerate, 5 percent.

There are interesting variations from this statewide average when the same information is shown by geographic unit (Fig. 30). For instance, in the Northeastern Unit, only 17 percent of the stands need no treatment, but 31 percent need thinning. The South-Central Unit seems relatively well off with 60 percent of its stands needing no treatment. But this unit has the greatest proportion needing improvement cuts—17 percent. In the Southwestern Unit, nearly one-

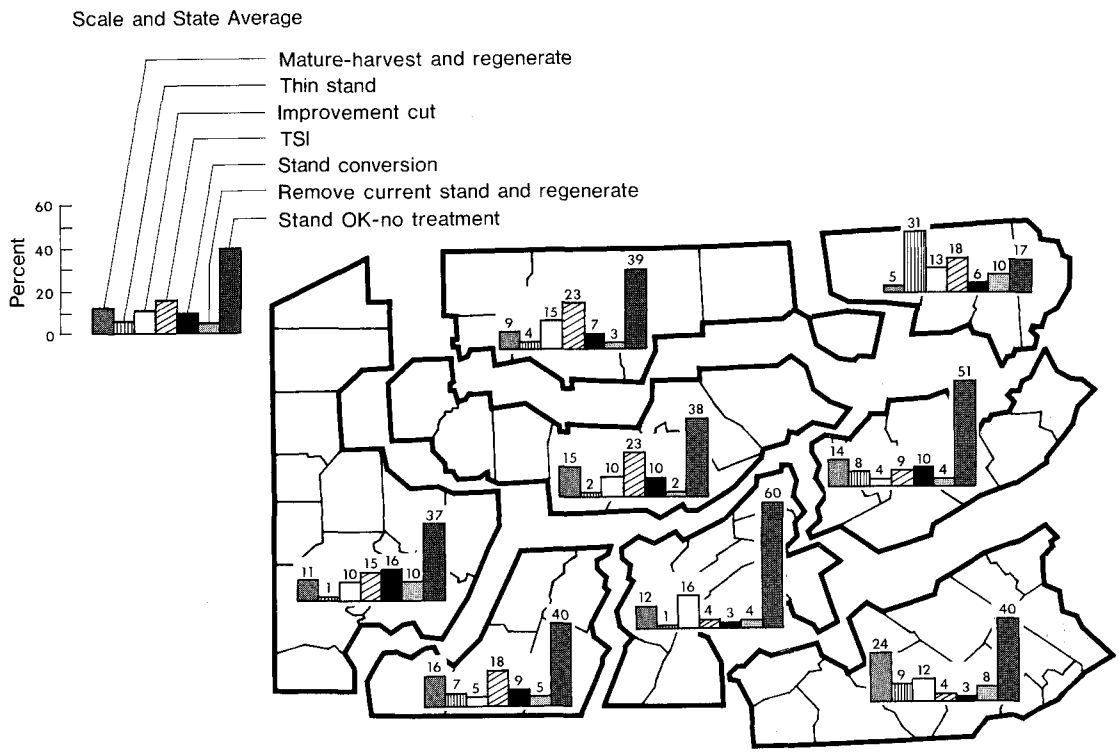


Figure 30.—Percentage of commercial forest land (excluding State and National Forests) in each geographic unit, by recommended treatment class.

fourth of the forests are ready for harvesting; this statistic is supported by the high percentage of sawtimber stands and high volumes per acre that are found in the region. The Allegheny and North-Central Units show the greatest need for TSI.

When the data are organized by forest-type group, "stand in good condition" is the most prevalent class for all type groups. The white and red pine group shows the greatest need for thinning. Many plantations are at the stage where production will stagnate unless the better trees are given more room to grow. Sixteen percent of the oak/hickory stands are mature and ready for regeneration, but only 10 percent of the northern hardwood stands are in this condition. Twenty-one percent of the northern hardwood stands need some TSI. In the aspen/birch group, nearly one-third of the stands could be improved by converting the stand to a more productive forest type. This is indicative of the transitory nature of the aspen/birch types in Pennsylvania.

This discussion of recommended treatment opportunities is no substitute for an on-the-ground inspection by a professional forester. The Bureau of Forestry, USDA Forest Service, USDA Soil Conservation Service, forest industries, and private consultants are some of the most important agencies or people a landowner can turn to for assistance on all aspects of forest management. Our field crews provided this information to portray broad management opportunities for timber production only at this extensive level.

Another important way in which a landowner can increase the amount of wood from his or her land is to strive for greater utilization when trees are cut. This means using the logging residues, such as branches and other wood above the merchantable bole, as much as possible. Material that is unacceptable for pulpwood may be useful for firewood. And if not useful for firewood, perhaps it can be chipped for pulp, fuel, mulch, bedding, or any of the many uses that cellulose has. Often it is not economical to use residues because of high costs of extracting and transporting the material. But over the past few years there has been a growing appreciation by loggers and wood processors of this previously ignored resource, and utilization rates have been improving (Wharton and Bones 1980).

Management practices to enhance wildlife benefits from forest land may be closely related to those used to increase wood production. Growing wood fiber requires periodic cultural treatments. During this cycle of cutting and regeneration, wildlife habitat is affected (see the earlier discussion of habitat manipulation under Wildlife). Timber management

can be compatible with wildlife habitat management (Roach 1974). The landowner could receive income by managing for timber and at the same time enhance the necessary food and shelter requirements for a variety of wildlife species. This dual approach may be particularly appealing to the many hunting and fishing clubs that own approximately 556,000 acres of forest land in Pennsylvania (Dennis and Birch 1980).

This is not to say that all timber cutting is necessarily good for wildlife. The landowner or forest manager concerned with both timber and wildlife needs to be aware of the impacts of timber management on wildlife, and may need to make certain modifications in the usual timber management practices. For example, timber management practices usually are carried out on blocks of forest land or stands, some of which may be too large to maximize habitat diversity. While one 15-acre clearcut may mean low administration costs and good regeneration of desirable shade-intolerant tree species, five 3-acre openings in the forest will do much more to create diversified conditions and more edge for a wide assortment of animal species.

Another possible conflict between timber and wildlife management, and one that has received greater attention with the recent increase in cutting trees for firewood, is the removal of cull or dead trees. From a strict wood production viewpoint, all cull trees should be removed as they are unproductive and take up valuable space that could be used by healthy and rapidly growing trees. Firewood cutters, seeking to assist timber growers, normally use cull and dead trees if they are not too rotten. From the wildlife viewpoint, such trees often provide cavities that are used for nesting, escape, winter cover, and food seeking and storage. Rather than removing these trees, certain actions can be taken to improve and expand this particularly valuable wildlife habitat (Evans and Conner 1979). The trade-offs and values involved in managing woodland for wildlife and firewood were discussed by Carey and Gill (1980).

Rotten cull trees often are good den trees for cavity nesting wildlife. An average acre of Pennsylvania forest land contains about six rotten trees over 5 inches in diameter; the range is four in the Southeastern Unit to nine in the Allegheny Unit. Red maple makes up the greatest proportion of the state's rotten trees with 19 percent, followed by oaks with 16 percent, beech with 10, black locust with 8, sugar maple with 7, and black cherry and sweet birch with 6 each.

There are fewer cull trees now than in 1965, but there are still more

At a time when other food may be scarce, browse from the tops of trees harvested in late fall or winter is especially beneficial to deer.

Pennsylvania Bureau of Forestry

A cavity or hollow at the base of a tree can provide adequate shelter for nesting birds.

Pennsylvania Bureau of Forestry

than enough to support populations of the 33 kinds of birds and 17 mammal species that make some use of tree cavities and space under loose bark or crevices between surface roots (Hassinger 1980).

There also are opportunities for management that favors mature, mast-producing trees. Here is how the major mast-producing species in Pennsylvania rank in percentage of numbers of sawtimber trees:

Species	*Percent of all species*
oak	39
black cherry	9
beech	4
hickory	3
Total	55

While it is comforting to realize that such a high percentage of the state's sawtimber trees are valuable food products for wildlife, there are many stands in which stocking can be increased by sound forest management. Management also can favor other species of trees, shrubs, and vines that many animals depend on for food and cover.

Esthetic enjoyment of forest land is the most important single benefit that private landowners derived in the last 5 years and the one that they expect will be the most important over the next 5 years (Birch and Dennis 1980). Natural stand development, particularly as the trees become relatively large in diameter and height, can produce stands that are scenic and attractive. But there are a variety of management practices that can be applied to forest land to enhance the esthetic enjoyment derived from viewing wooded environments. In fact, managed stands generally have been found to be more attractive than unmanaged stands (Brush 1979).

The aspect of forest esthetics that managers can control most easily is the structure of forest stands. Three-dimensional spaces can be shaped by varying stand density and canopy height. A variety of forest spaces are possible, ranging from open clearings to dense thickets. To produce forests containing an attractive mixture of stands with a variety of sizes, ages, height, and species compositions required some form of even-age management. Timber production and wildlife habitat management are compatible with this approach.

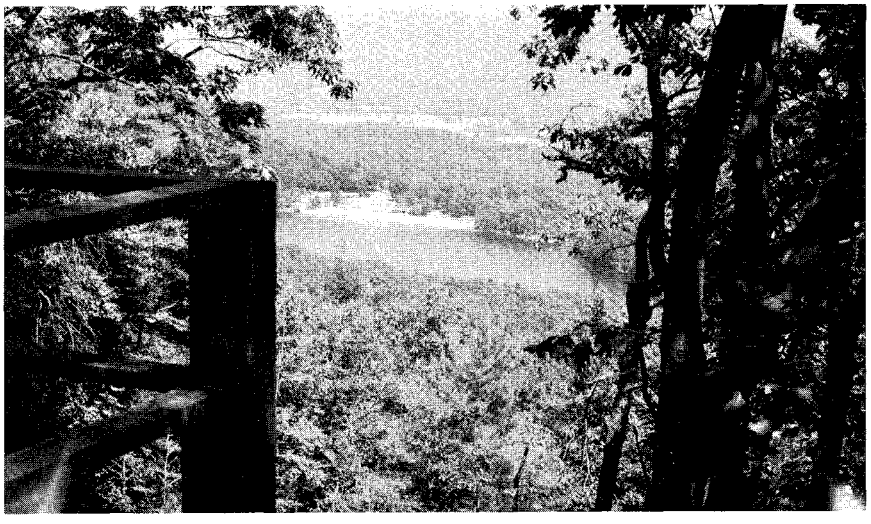
Openings are very important in this type of forest landscape. The number, size, shape, orientation, spacing, and timing of openings leaves the landowner or manager with great flexibility in enhancing the esthetic characteristics of the landscape (USDA For. Serv. 1980b). Generally, the shape of an opening is

more pleasing if it is free form and not geometrical. The edges should be feathered (partial cutting of trees near edge to create a transition in heights between areas) so that the openings will blend well with the surrounding area. It is helpful to retain some residual trees in an opening, either in groups or uniformly across the areas. In some instances it may be important to reduce the visibility of openings (especially during the first year or two until they revegetate satisfactorily) through the use of screening or by taking advantage of the natural topography. In other instances, openings can be used to create or enhance scenic vistas of meadows, lakes, streams, rock formations, or distant views. Roadside or trailside openings can be appropriate for this use.

Another type of landscape which can be created by the selection system of management is an unbroken forest with a high percentage of large trees (18 to 30 inches in dbh) in mixture with smaller trees. Large stems are attractive to many people, but unless they are already present in the stand it will take many decades for them to develop. If timber production also is a goal, the normal age used to select trees for cutting will need to be increased so as to grow trees to larger size before individual stems can be harvested. A minimum of 20 years extension normally is required to achieve a significant increase in the size of hardwoods. This type of landscape should be limited to relatively short segments along vehicular routes to eliminate the almost certain monotony that would otherwise result.

Cutting and logging are effective tools in esthetic forest management, but they also can result in temporarily unsightly conditions. Logging and skid roads should be carefully planned, constructed, maintained, and eventually revegetated unless permanent access is desired. Logging equipment should be compatible with the site conditions. For example, rubber-tired skidders should not be used on compactible soils or during seasons when deep rutting can occur. Also, one can use several treatments to reduce the negative visual impact of logging residues. These include complete removal, chipping, lopping with or without scattering, and piling or yarding with or without burning. Burning should be done only under the strictest controls and must be in conformance with local laws and ordinances.

A scenic overlook can be created by planned cutting of an area or a specific group of trees (Cowans Gap State Park, Fulton County).



Pennsylvania Bureau of Forestry

Property owners can commit all or part of their forest land to scenic easements. An easement is a legal agreement between the owner and a conservation organization. The owner agrees to establish certain restrictions over the property. Examples would be restrictions against the removal of all trees; the use of eased lands as a landfill, a quarry, or a mineral excavation site; and future building construction. The restrictions in each easement agreement reflect the desires of the property owner. The conservation organization agrees to regularly inspect the eased areas for any violation and to ensure that conditions of the agreement are met. Besides the benefits of conservation, easements offer the opportunity to gain benefits through charitable income tax donations and the reduction of inheritance taxes without the sale or loss of land.

Recreation and wilderness management of forest land usually are closely associated with esthetic management since walking or driving through an area is one of the most popular outdoor recreational activities. Hunting, fishing, birdwatching, and outdoor photography are tied to wildlife habitat management.

Opportunities for enhancing recreational or wilderness values are closely related to size, location, and condition of the forested area as well as its proximity to roads and the sights and sounds of man's activities. From the earlier discussion on size of tract, we saw that there are relatively few large, unbroken, tracts of forest land (Fig. 28). Although most lands best suited for wilderness experiences are in State Forests or the Allegheny National Forest and are managed as such by the Bureau of Forestry and the USDA Forest Service, there are some large and remote privately owned forested tracts that could be managed for wilderness values. Such a management strategy is more a matter of managing use (people) than managing the physical resource (Hendee et al. 1978). Smaller and more accessible tracts could be managed for dispersed recreation activities such as hiking, camping, cross-country ski-

ing, and snowmobiling. And many landowners find real recreational value in simply managing their woodland for other forest benefits, such as timber or firewood production. The 835 Tree Farmers who manage 576,262 acres of forest land in Pennsylvania can testify to this (personnel communication, Linda Rosenberg, American Forest Institute).

This discussion of forest management opportunities has looked at some of the many ways to enhance wood fiber production, wildlife habitat, esthetics, and recreational experiences, and has mentioned a few of the multiple-benefit combinations that can result. But it has not provided an example of how a landowner can manage his woodland for many different benefits at the same time. One example that serves this purpose well is the woodland management plan that is being implemented on the East Woods tract of the Tyler Arboretum in central Delaware County (Arnold 1979; Montgomery 1980).

This 93-acre tract is a showcase for demonstrating how landowners, through the proper application of silviculture, can integrate timber production with wildlife, esthetic, and recreational values. A management plan was prepared by Bureau of Forestry service forester in conjunction with arboretum officials. The area was inventoried and divided into seven distinct stands—each to be managed for specific objectives. After trees to be removed to meet these objectives were marked, a logger was brought in to harvest sawlogs and firewood. The logging was done following proper environmental guidelines. The sawlogs were sold, the firewood was distributed at a reduced price to members of the arboretum, and the logged areas are now nearly unrecognizable as such. Wood products were removed at a profit, esthetic values were enhanced, wildlife habitats were created or improved, the water quality of the watershed was maintained at a high level, and hiking and interpretive trails were constructed to enable people to see how forest management can provide all of these benefits.

In conclusion, we have identified many of the numerous opportunities that exist for landowners to manage their properties to meet their personal objectives. If our society continues to make increased demands on Pennsylvania's forests, there are many opportunities to manage these renewable forest resources to meet these needs. The Commonwealth's forests are resilient and dynamic. With proper management, they should continue to provide plentiful and desirable uses and benefits that our society has become accustomed to.

Literature Cited

Arnold, Fred C. Silviculture at the arboretum. John J. Tyler Arbor. Bull. 2(4):33-34; 1979.

Barnard, Joseph E. Sampling with partial replacement contrasted with complete remeasurement inventory designs: an empirical examination. In: Proceedings of the symposium on monitoring forest environment through successive sampling. Syracuse, NY:SUNY College of Environmental Sciences and Forestry; 1974.

Barnard, Joseph E. Example of a specific regional inventory: the United States northeastern double sampling with partial replacement design. In: Proceedings of the joint meeting of the groups on forest resource inventory and forest management planning and managerial economics of the International Union of Forestry Research Organizations. Bucharest: 1978, June 18-24.

Bennett, Arthur L.; Armstrong, Malcolm M. Insurance silviculture in the black-cherry type. J. For. 79(3):146-149, 154; 1981.

Bickford, C. A.; Mayer, C. E.; Ware, K. D. An efficient sampling design for forest inventory—the northeastern forest resurvey. J. For. 61:826-833; 1963.

Birch, Thomas W.; Dennis, Donald F. The forest-land owners of Pennsylvania. 1980; USDA For. Serv. Resour. Bull. NE-66. 90 p.

Bones, James T. The forest resources of West Virginia. 1978; USDA For. Serv. Resour. Bull. NE-56. 105 p.

Bones, James T.; Dickson, David R. Veneer, 1976—a periodic assessment of regional timber output. 1978; USDA For. Serv. Resour. Bull. NE-55. 13 p.

Bones, James T.; Sherwood, John K., Jr. Pennsylvania timber industries—a periodic assessment of timber output. 1979; USDA For. Serv. Resour. Bull. NE-59. 26 p.

Boyce, Stephen G.; McClure, Joe P.; Sternitzke, Herbert S. Biological potential for the loblolly pine ecosystem east of the Mississippi River. 1975; USDA For. Serv. Res. Pap. SE-142. 27 p.

Braun, E. Lucy. Deciduous forests of eastern North America. New York: Hafner Press; 1950.

Brush, Robert O. The attractiveness of woodlands: perceptions of forest-land owners in Massachusetts. For. Sci. 25(3):495-506; 1979.

Carey, Andrew B.; Gill, John D. Firewood and wildlife. 1980; USDA For. Serv. Res. Note NE-299. 5 p.

Considine, Thomas J., Jr.; Powell, Douglas S. Forest statistics for Pennsylvania—1978. 1980; USDA For Serv. Resour. Bull. NE-65. 88 p.

Cunningham, R. L.; Ciolkosz, E. J.; Petersen, G. W.; Matelski, R. P.; Pennock, R., Jr.; Shipp, R. F.; Kuhl, A. D.; Ratcliff, I. W., Jr.; Lipscomb, G. H.; Peechatka, W. N.; Schadel, A. Soils of Pennsylvania. 1977; Pa. State Univ. Coll. Agric., Agric. Exp. Stn. Prog. Rep. 365. 24 p.

Dennis, Donald F.; Birch, Thomas W. Hunting and fishing clubs as woodland managers. Pa. Game News 21(7):42-43; 1980.

Edmunds, William E.; Koppe, Edwin F. Coal in Pennsylvania. 1968; Pa. Dep. Environ. Resour. Bur. Topogr. and Geol. Surv., Educ. Ser. 7. 29 p.

Evans, Keith E.; Conner, Richard N. Snag management. In: Proceedings of the workshop management of northcentral and northeastern forest for nongame birds. 1979; USDA For. Serv. Gen. Tech. Rep. NC-51. p. 214-225.

Fenneman, Nevin M. Physiography of eastern United States. New York: McGraw-Hill Book Co., Inc.; 1938.

Ferguson, Roland H. The timber resources of Pennsylvania. Upper Darby, PA: USDA For. Serv. Northeast. For. Exp. Stn.; 1958. 46 p.

Ferguson Roland H. The timber resources of Pennsylvania. 1968; USDA For. Serv. Resour. Bull. NE-8. 147 p.

Frayer, Warren E.; Furnival, George M. Area change estimates from sampling with partial replacement. For. Sci. 13:72-76; 1967.

Gansner, David A.; Herrick, Owen W. Forest stand losses to gypsy moth in the Poconos. 1979; USDA For. Serv. Res. Note NE-273. 5 p.

Haines, Donald A.; Main, William A.; McNamara, Eugene F. Forest fires in Pennsylvania. 1978; USDA For. Serv. Res. Pap. NC-158. 20 p.

Hassinger, Jerry. Wildlife management in Pennsylvania's State Forests. In: Proceedings of the symposium on nongame species. 1977 October 1; Kleinfeltersville, PA. Pennsylvania Game Comm. and National Audubon Society; 1977: p. 51-77.

Hassinger, Jerry. Dead wood is alive—part II. Pa. Sportsman 21(9):26; 1980.

Hendee, John C.; Stankey, George H.; Lucas, Robert C. Wilderness management. 1978; USDA For. Serv. Misc. Pub. 1365. 381 p.

Hewlett, John D.; Nutter, Wade L. An outline of forest hydrology. Athens, GA: Univ. Ga. Press; 1969.

Hoopes, Rickalon. Management of Pennsylvania's fisheries resources. In: Proceedings of the symposium on nongame species. 1977 October 1; Kleinfeltersville, PA. Pennsylvania Game Commission and National Audobon Society; 1977; p. 29-49.

Hough, A. F.; Forbes, R. D. The ecology and silvics of forests in the high plateau of Pennsylvania. Ecol. Monogr. 13:299-320; 1943.

Houston, D. R.; Valentine, H. T. Comparing and predicting forest stand susceptibility to gypsy moth. Can. J. For. Res. 7:447-461; 1977.

Illick, Joseph S. Pennsylvania trees. 1923a; Pa. Dep. For. Bull. 11 4th ed. 237 p.

Illick, Joseph S. The forest situation in Pennsylvania. 1923b; Pa. Dep. For. Bull. 30. 4 p.

Jackson, James P. Recreation and forests. Am. For. 84(9):36-39, 53-54; 1978.

Journal of Forestry. SAF backs intensified deer management in Pennsylvania. J. For. 76(4):254; 1978.

Kingsley, Neal P.; Powell, Douglas S. The forest resources of Kentucky. 1978; USDA For. Serv. Resour. Bull. NE-54. 97 p.

Kingsley, Neal P.; Powell, Douglas S. Oak: Where is it? Where's it been? Where's it going? In: Proceedings of the 7th annual hardwood symposium of the Hardwood Research Council; 1979 May; Cashiers, NC: Hardwood Research Council; 1979; p. 12-28.

Knight, Fred B.; Heikkenen, Herman J. Principles of forest entomology. 5th ed. New York: McGraw-Hill Book Co.; 1980.

Kochenderfer, James N.; Aubertin, Gerald M. Effects of management practices on water quality and quantity: Fernow Experimental Forest, West Virginia. In: municipal watershed management symposium proceedings. 1975; USDA For. Serv. Gen. Tech. Rep. NE-13. p. 14-24.

Leak, William B.; Solomon, Dale S.; Filip, Stanley M. A silvicultural guide for northern hardwoods. 1969; USDA For. Serv. Res. Pap. NE-143. 34 p.

Liscinsky, Steve. Poletimber for wood and wildlife: ten years of study. Pa. Game News 49(2): 41-43; 1978.

Lynch, James A.; Sopper, W. E.; Corbett, E. S.; Aurand, D. W. Effects of management practices on water quality and quantity: the Penn State experimental watersheds. In: Municipal watershed management symposium proceedings. 1975; USDA For. Serv. Gen. Tech. Rep. NE-13. p. 32-46.

Marquis, David A. The impact of deer browsing on Allegheny hardwood regeneration. 1974; USDA For. Serv. Res. Pap. NE-308. 8 p.

Marquis, David A. The Allegheny hardwood forests of Pennsylvania. 1975; USDA For. Serv. Gen. Tech. Rep. NE-15. 32 p.

Marquis, David A. Shelterwood cutting in Allegheny hardwoods. J. For. 77(3):140-144; 1979.

Marquis, David A.; Eckert, Philip L.; Roach, Benjamin A. Acorn weevils, rodents, and deer all

contribute to oak-regeneration difficulties in Pennsylvania. 1976; USDA For. Serv. Res. Pap. NE-356. 5 p.

Marquis, David A.; Grisez, Ted J.; Bjorkbom, John C.; Roach, Benjamin A. Interim guide to regeneration of Allegheny hardwoods. 1975; USDA For. Serv. Gen. Tech. Rep. NE-19. 14 p.

Merritt, Clair. An overview of oak regeneration problems. In: Proceedings on regenerating oaks in upland hardwood forests. 1979 February 22-23 West Lafayette, IN. John S. Wright Forestry Conference, Purdue University; 1979; p. 1-10.

Montgomery, Robert J. Woodlands management to date. 1980; John J. Tyler Arbor. Bull. 3(1):5-8.

Nelson, James C.; Roach, Benjamin A.; Frank, O. Lynch; Ward, Wilbur. Timber management. Chapter 4. In: Clearcutting in Pennsylvania. University Park, PA: Pennsylvania University, College of Agriculture, School of Forest Resources; 1975; p. 33-49.

Nichols, James O. The gypsy moth. Harrisburg, PA: Pennsylvania Department of Environmental Resources, Bureau of Forestry; 1980; 34 p.

Pennock, Roger, Jr.; Wood, Gene W.; Shogren, Paul W., Jr.; Reinhart,

Kenneth; Miles, Vernal C.; Younkin, Paul. The forest soil. Chapter 3. In: Clearcutting in Pennsylvania. University Park, PA: Pennsylvania State University, College of Agriculture, School of Forest Resources; 1975; p. 21-32.

Pennsylvania Department of Environmental Resources. Annual report on mining activities. Harrisburg, PA: Pennsylvania Department of Environmental Resources; 1979; 363 p.

Pennsylvania Forests. Pennsylvania update. Pa. For. 71(2):4; 1981.

Pennsylvania Land Policy Project. A land use strategy for Pennsylvania: a fair chance for the "faire land" of William Penn. Harrisburg, PA: Pennsylvania Office of State Planning and Development; 1975; p. 112-113.

Pennsylvania Office of State Planning and Development. Pennsylvania's recreation plan. Harrisburg, PA: Pennsylvania Office of State Planning and Development; 1976; p. IV-12.

Powell, Douglas S., Erdmann, Gayne E. Red maple. In: Forest cover types of the United States and Canada. Eyre, F. H., ed. Washington, D.C.; Society of American Foresters; 1980; p. 34-35.

Roach, Benjamin A. Scheduling timber cutting for sustained yield of wood products and wildlife. 1974; USDA For. Serv. Gen. Tech. Rep. NE-14. 13 p.

Roach, Benjamin A. A stocking guide for Allegheny hardwoods and its use in controlling intermediate cuttings. 1977; USDA For. Serv. Res. Pap. NE-373. 30 p.

Roach, Benjamin A.; Gingrich, Samuel F. Even-aged silviculture for upland central hardwoods. 1968; U.S. Dep. Agric., Agric. Handbk. 355. 39 p.

Sander, Ivan L. Silvicultural systems for the oak-hickory forest type. In: North America's forests: gateway to opportunity. St. Louis, MO: 1978 Joint Convention of the Society of American Foresters and the Canadian Institute of Forestry; 1978; p. 344-348.

Schellenberg, John. Project 500's 10th birthday. Pa. For. 68(1): 5-7,15-16; 1978.

Schlesinger, Richard C. Hard maples increasing in an upland stand. In: Proceedings of the 1st Central Hardwood Forest Conference; Carbondale; IL: Southern Illinois University; 1976; p. 177-185.

Schnur, G. Luther. Yield, stand, and volume tables for even-aged upland oak forests. 1937; U.S. Dep. Agric. Tech. Bull. 560. 88 p.

Severinghaus, C. W. Problems in Penn's woods. Pa. For. 68(2): 17,21; 1978.

USDA Forest Service. A national energy program for forestry. 1980a; USDA For. Serv. Misc. Pub. 1394. 16 p.

USDA Forest Service. National forest landscape management, volume 2, chapter 5: timber. 1980b; U.S. Dep. Agric., Agric. Handbk. 559. 223 p.

USDA Forest Service. Review draft of an analysis of the timber situation in the United States 1952-2030. Washington, D.C.; U.S. Department of Agriculture, Forest Service; 1980c; 541 p.

U.S. Department of Commerce, Bureau of the Census. 1967 census of manufacturers—Pennsylvania. Washington, D.C.; U.S. Department of Commerce, Bureau of the Census; 1970.

U.S. Department of Commerce, Bureau of the Census. 1970 census of population, general social and economic characteristics, Pennsylvania. 1972; U.S. Dep. Commer. Bur. Census Final Rep. PC(1)-C40 Pa. 730 p.

U.S. Department of Commerce, Bureau of the Census. 1972 census of manufacturers—Pennsylvania. Washington, D.C.; U.S. Department of Commerce, Bureau of the Census; 1975.

U.S. Department of Commerce, Bureau of the Census. 1977 census of manufacturers—Pennsylvania. 1979; U.S. Dep. Commer. Bur. Census, Prelim. Rep. MC77-A-39(P). 13 p.

U.S. Department of Commerce, Bureau of the Census. 1977 per capita money income estimates

for states, counties, incorporated places, and selected minor civil divisions in the northeast region of the United States. 1980; U.S. Dep. Commer. Bur. Census, Curr. Popul. Rep. Ser. P-25. 882. 49 p.

U.S. Department of Energy. Bituminous coal and lignite production and mine operations—1978. 1980; U.S. Dep. Energy DOE/EIA-0118(78). 81 p.

Wagner, W. R.; Lytle, W. S. Geology of Pennsylvania's oil and gas. 1968; Pa. Dep. Environ. Resour. Bur. Topogr. and Geol. Surv. Educ. Ser. 8. 28 p.

Wharton, Eric H.; Bones, James T. Trends in timber use and product recovery in Pennsylvania, 1966-77. 1980; USDA For. Serv. Res. Note NE-297. 4 p.

Appendix

Definition of terms

Accretion. The estimated net growth of growing-stock trees that were measured during the previous inventory, divided by the length of the period between surveys. It includes the growth on trees that were cut during the period, plus those trees that died and were used.

Annual mortality trend level. The estimated mortality of growing stock or sawtimber for a specific year (1977 for Pennsylvania) based on average rates of diameter growth and mortality for the period. This estimate is consistent with the average annual change during the period between surveys and with the current inventory.

Annual net growth trend level. The estimated growth of growing stock or sawtimber for a specific year (1977 for Pennsylvania) based on average rates of diameter growth and mortality for the period. This estimate is consistent with the average annual change during the period between surveys and with the current inventory.

Annual removals trend level. The estimated removals of growing stock or sawtimber for a specific year (1977 for Pennsylvania) obtained from a trend line for the period. This line is established by fitting a curve to actual removals data for several years during the period. The actual removals for the year given can vary from the trend estimate because of fluctuations in market conditions and other factors.

Average annual net growth. The change, resulting from natural causes, in growing-stock or sawtimber volume of sound wood in growing-stock or sawtimber trees during the period between surveys, divided by the length of the period. Components of average annual net growth include the increment in net volume of trees that are present at the beginning of the period and that survive to the end (accretion), plus average annual ingrowth, minus average annual mortality, and minus the net volume of trees that became rough or rotten during the period (cull increment).

Average annual removals. The net growing-stock or sawtimber volume of trees harvested or killed in logging, cultural operations—such as timber stand improvement—or land clearing, and also the net growing-stock or sawtimber volume of trees neither harvested nor killed but growing on land which was reclassified from commercial forest land to noncommercial forest land during the period between surveys. This volume is divided by the length of the period.

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

Coarse residues. Manufacturing residues suitable for chipping, such as slabs, edgings, and veneer cores.

Commercial forest land. 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.

Commercial species. Tree species presently 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.

Cull increment. The net volume of growing-stock trees on the previous inventory that became rough or rotten trees in the current inventory, divided by the length of the period between surveys.

Diameter at breast height (dbh). The diameter outside bark of a standing tree measured at 4½ feet above the ground.

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.

Fine residues. Manufacturing residues not suitable for chipping, such as sawdust and shavings.

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

Forest land. Land at least 10 percent stocked with trees of any size or that formerly had such tree cover and is not currently developed for nonforest use. The minimum area for classification of forest land is 1 acre.

Forest type. A classification of forest land based on the species forming a plurality of live-tree stocking. The many forest types in Pennsylvania were combined into the following major forest-type groups:

a. *White pine and hemlock*—forests in which white pine, red pine, or hemlock, singly or in combination, comprise a plurality of the stocking; in Pennsylvania, common associates

include red maple, red oaks, white oaks, beech, black cherry, and aspen.

b. *Spruce/fir*—forests in which spruce, fir, or tamarack, singly or in a combination, comprise a plurality of the stocking; this type is rare and localized in Pennsylvania.

c. *Scotch and Virginia pine*—forests in which Scotch, Virginia, or pitch pines or eastern redcedar, singly or in combination, comprise a plurality of the stocking; in Pennsylvania, common associates include white pine, oak, yellow-poplar, and white ash.

d. *Oak/pine*—forests in which hardwoods (usually white, scarlet, chestnut, northern red, or black oaks) comprise a plurality of the stocking but where Scotch, Virginia, or pitch pines or eastern redcedar comprise 25 to 50 percent of the stocking; in Pennsylvania, common associates besides those listed above include red maple, black cherry, and hickory.

e. *Oak/hickory*—forests in which upland oaks, hickory, yellow-poplar, black walnut, or redmaple (when associated with central hardwoods), singly or in combination, comprise a plurality of the stocking and in which Scotch, Virginia, or pitch pines or eastern redcedar comprise less than 25 percent of the stocking; in Pennsylvania, common associates include white ash, sweet birch, black cherry, black locust, and sugar maple.

f. *Oak/gum*—bottomland forests in which wet-site oaks or gums, singly or in combination, comprise a plurality of the stocking; in Pennsylvania, our survey encountered only one field plot in this group, and it was dominated by swamp white oak and had associates of quaking aspen, black cherry, red maple, and white ash.

g. *Elm/ash/red maple*—forests in which elm, river birch, sycamore, willow, or red maple (when growing on wet sites), singly or in combination, comprise a plurality of the stocking; in Pennsylvania, common associates include red oaks, white oaks, hickory, black cherry, white ash, and sugar maple.

h. *Northern hardwoods*—forests in which sugar maple, beech, yellow birch, black cherry, or red maple (when associated with northern hardwoods), singly or in combination, comprise a plurality of the stocking; in Pennsylvania, common associates include white ash, hemlock, sweet birch, northern red oak, basswood, aspen, white oak, white pine, and hickory.

i. *Aspen/birch*—forests in which aspen, paper birch, or gray birch, singly or in combination, comprise a plurality of the stocking; in Pennsylvania, common associates include red maple, black cherry, sugar maple, and oak.

Growing-stock trees. Live trees of commercial species classified as sawtimber, poletimber, saplings, and 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 and larger in dbh, 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.

Industrial wood. All roundwood products except fuelwood.

Ingrowth. The estimated net volume of growing stock trees that became 5.0 inches or larger in dbh during the period between inventories, divided by the length of the period between surveys.

International ¼-inch rule. A log rule, or formula, for estimating the board-foot volume of logs. The mathematical formula is:

$$(0.22D^2 - 0.71D)(0.904762)$$

for 4-foot sections, where D = diameter inside bark at the small end of the 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 ⅛ statute mile wide; and lakes, reservoirs, and ponds less than 40 acres in area. (b) Resources Evaluation: same as (a) except that the minimum width of streams, etc., is 120 feet, and the minimum size of lakes, etc., is 1 acre.

Logging residues. The unused portions of growing-stock trees harvested or killed in the process of logging.

Manufacturing plant residues. Wood materials that are generated when converting round timber (roundwood) into wood products. This includes slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and pulp screening. If these residues are used, they are referred to as plant byproducts.

Miscellaneous private lands. Privately owned lands other than forest industry and farmer-owned lands.

Mortality. The estimated net volume of growing-stock trees on the previous inventory that died from natural causes before the current inventory, divided by the length of the period between surveys.

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.

Noncommercial forest land. Productive-reserved, urban, and unproductive forest land.

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, and highways.

Nonstocked areas. Commercial forest land that is stocked with less than 10 percent of minimum full stocking with growing-stock trees.

Plant byproducts. Wood products, such as pulp chips, recycled from manufacturing plant residues.

Poletimber stands. Stands stocked with at least 10 percent of minimum full stocking with growing-stock trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of poletimber exceeds that of sawtimber.

Poletimber trees. Live trees of commercial species meeting regional specifications of soundness and form and at least 5.0 inches in dbh, but smaller than sawtimber trees.

Productive-reserved forest land. Forest land sufficiently productive to qualify as commercial forest land, but withdrawn from timber utilization through statute, administrative designation, or exclusive use for Christmas tree production.

Primary wood manufacturing plant. A plant that converts round timber into wood products such as woodpulp, lumber, veneer, cooperage, and dimension products.

Pulpwood. Roundwood converted into 4- or 5-foot lengths or chips, and chipped plant byproducts that are prepared for manufacture into woodpulp.

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

Rough trees. (a) The same as rotten trees, except that rough trees do not meet regional specifications for freedom from defect primarily because of roughness or poor form, and (b) all live trees of noncommercial species.

Roundwood products. Logs, bolts, or other round timber generated by harvesting trees for industrial or consumer uses.

Saplings. Live trees 1.0 through 4.9 inches in dbh.

Sapling-seedling stands. Stands stocked with at least 10 percent of minimum full stocking with growing-stock trees with half or more of such stocking in saplings or seedlings or both.

Sawlog. A log meeting regional standards of diameter, length, and defect, including a minimum 8-foot length and a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods. (See specifications under Log Grade Classification.)

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 (dob) for softwoods and a 9.0 inches dob for hardwoods.

Sawtimber stands. Stands stocked with at least 10 percent of minimum full stocking with growing-stock 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 trees. Live trees of commercial species at least 9.0 inches in dbh for softwoods or 11.0 inches for hardwoods that contain at least one 12-foot sawlog or two noncontiguous 8-foot sawlogs, and that meet regional specifications for freedom from defect.

Sawtimber volume. Net volume in board feet, International ¼-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.

Seedlings. Live trees less than 1.0 inch in dbh that are expected to survive.

Site class. A classification of forest land by inherent capacity to grow crops of industrial wood. Classifications are based on the mean annual growth of growing-stock trees attainable in fully stocked natural stands at culmination of mean annual increment.

Softwoods. Coniferous trees, usually evergreen and having needles or scalelike leaves.

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 growing-stock 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 of the more uniform character of pulpwood.

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/or number of trees in a stand compared to the basal area and/or number of trees required to fully use the growth potential of the

land (or the stocking standard). In the Eastern United States this standard is 75 square feet of basal area per acre for trees 5.0 inches, and larger, in dbh or its equivalent in numbers of trees per acre for seedlings and saplings.

Two categories of stocking are used:

All live trees—these are used to classify forest land and forest types.

Growing-stock trees—these are used to classify stand-size classes.

Timber products. Manufacturing plant byproducts and roundwood (round timber) products harvested from growing-stock trees on commercial forest land; 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 volumes of trees removed from the inventory for roundwood products, plus logging residues, volume destroyed during land clearing, and volume of standing trees growing on land that was reclassified from commercial forest land to noncommercial forest land.

Treatment class. A class assigned by the field crews to each forested plot, describing the management treatment necessary to maintain or improve the condition of the stand. The classes are:

a. *Harvest mature stand and regenerate*—The trees appear mature for sawlog production, and the stand is ready for harvesting and regeneration. This treatment includes selection cuts, clearcuts, shelterwood cuts, and seed tree cuts.

b. *Thin stand*—A cutting made in an immature stand to stimulate the growth of the trees that remain and to increase the total production of the stand. Trees removed represent a surplus. Thinnings are made after the sapling stage, and remove trees which are not in the dominant position in contrast to other intermediate cuts. Generally the stand is even-aged and polesize.

c. *Improvement cutting*—An intermediate, selection cut made primarily to remove trees of undesirable form or species (including damaged, injured, and dead trees) from the stand. Removal of unmerchantable trees will be listed under timber stand improvement.

d. *Timber Stand Improvement (TSI)*—Weeding, clearing, liberation cuts, and other silvicultural practices generally associated with removal of nonmerchantable materials.

e. *Convert stand to another type by thinning and/or planting*—Recommended for stands that are being taken over by undesirable tree species. It may also apply to stands that are understocked by desirable species.

f. *Remove current stand and regenerate*—Stands needing this treatment are not mature but still should be removed and regenerated to improve their productivity. Examples are stands where the optimum growth is past and late-aged stands where the trees have been suppressed. Clearcutting is the most common type of harvesting method used for this situation.

g. *Stand in good condition and on schedule*—Besides stands that are in good condition and would not be improved by any of the above treatments, this treatment class also applies to stands on marginal land that are not in the best condition for wood production.

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

Unproductive 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.

Unused manufacturing residues. Plant residues that are dumped or destroyed and not recovered for plant byproducts.

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. Noncommercial forest land within urban areas that is surrounded by urban development (not parks), whether commercial, industrial, or residential.

Planning and Designing the Survey

Pennsylvania's third forest survey was planned and designed to satisfy national, regional, and state information needs in an efficient manner. This was accomplished in several ways.

Considerable cooperation was sought and achieved among the public agencies managing forest land in the state. Pennsylvania's Bureau of Forestry completed its inventory of State Forests in 1977. The Allegheny National Forest was inventoried in 1974. Resources Evaluation helped design these surveys and was able to ensure that most of the data provided by these surveys were compatible with data provided by our own survey. Working with the Bureau of Forestry and the Allegheny National Forest enabled Resource Evaluation to reduce the land inventoried by more than 2 million acres.

Another method employed to improve the efficiency of the third survey was to use the 1955 and 1965 inventories while capitalizing on the new survey. Stratified double sampling with partial replacement (SPR) was the sampling design used to accomplish this task (Bickford et al. 1963; Barnard 1978). By remeasuring a subsample of the previous surveys, we were able to update the 1955 survey and the 1965 survey area and volume estimates to 1978. Taking these updated inventory estimates and combining them with estimates based only on data from new plots, we developed statistically improved

estimates for forest area and timber volume. The next section on processing provides more detail. For the same cost, SPR yields more statistically accurate estimates than other methods (Barnard 1974).

In developing the estimates for the current survey, a sample was established on aerial photography dating from 1967 to 1971, the most recent photography available. Each aerial photo plot (first phase) was classified into one of several photo-interpretation (PI) strata. The strata were based on land use and, if forested, timber volume. For each stratum a ground plot subsample (second phase) was chosen randomly from the photo plot sample. In Pennsylvania, the photo sample consisted of 79,373 plots. A subsample of 1,743 was selected to be observed on the ground.

Approximately 70 percent of the photo plots established on the ground were photo-interpreted as forested and thus in one of four timber volume classes. Each timber volume stratum was sampled with equal intensity, using a selection rule known as proportional allocation. This represented a change from the second survey when optimal allocation was employed. Under optimal allocation higher timber-volume strata were sampled more heavily.

On the ground, land use was verified, and on the forested plots tree data were recorded. The plots consisted of a cluster of 10 prism points systematically arranged to cover approximately 1 acre. At each point, trees 5 inches in diameter and larger were selected for tally by using a prism with a basal-area factor of 37.5 square feet per acre.

The other sets of independent estimates based on updating the 1955 and 1965 surveys required the remeasurement of 504 ⅕-acre fixed-radius plots originally established during the first survey and 497 10-point plots originally established during the second survey. The fixed-radius plots were measured for the third time and were used in the growth and removals calculations.

Processing the Data

The processing of Pennsylvania's third forest survey represented a major advance in forest area and timber volume calculations because, in many cases, total estimates were developed directly for individual counties in the state. In the past, totals were developed for geographic units and prorated back to the county level. Prorations were based on the stratification, by county, of the photo-interpretation points. Now with the estimates usually developed on a county by county basis, the reliability of these estimates has been improved. This new technique also helps users who wish to analyze trends.

Not all counties had individually estimated totals. Those counties that were too small (less than 60 forested Resources Evaluation ground plots) or that showed too much variation were grouped with one or more nearby counties which could or could not stand alone themselves. The resulting groups of counties were called "supercounties". Data for the supercounties are presented in the county tables at the end of "Forest Statistics for Pennsylvania—1978" (Considine and Powell 1980).

The Northeastern Forest Experiment Station uses the data processing system FINSYS, or Forest Inventory System, developed by Wilson and Peters [2] to process and compile tree and plot information into statistical tables. FINSYS uses the totals developed from two companion programs, AREA and SPeeR, as input along with field data. FINSYS consists primarily of a series of computer programs that edit field-tally data for errors, compile edited data into tables, and print county, geographic unit, and state summary resource estimates in tabular form.

FINSYS has several unique features, one of which is its flexibility. The system is not restricted to the northeastern forest survey but can be used for any large-scale forest inventory. The user specifies what tables are to be produced. While a standard set of tables are produced for our resource report, others can be produced for special information requests.

Another feature of FINSYS is its ability to produce a variance and sampling error for each estimate. These figures provide the user with a measure of the estimate's reliability.

Because Pennsylvania's data came from three sources, the actual processing procedure was very complicated. Not all data were compatible with FINSYS and in some instances had to be processed manually.

Commercial forest area statistics were developed in several stages. First, information from the Resources Evaluation survey was used by the computer program AREA, based on Frayer and Furnival (1967), to produce a total estimate of commercial forest land for each county or supercounty. A current estimate for each county or supercounty was produced for each plot type: ⅕-acre remeasured, 10-point remeasured, and 10-point new ground. These three totals were inversely weighted by their variances and combined to form a single, independent total estimate. This combined estimate is statistically more accurate than a single estimate. FINSYS used these county totals and plot data to develop a set of tables of commercial forest land area by county or supercounty. FINSYS then summed these county tables to produce geographic unit and state level tables.

In those counties where State Forest and Allegheny National Forest lands occur, the area data from these ownerships were manually added to the appropriate tables. The Pennsylvania Bureau of Forestry and the National Forest provided us with the necessary updated area data. These data were free from sampling errors since all commercial forest land in these ownerships has been mapped and measured without sampling. Because of this, that data could not be

[2] Wilson, R. W.; Peters, R. C. The northeastern forest inventory data processing system. USDA For. Serv. Res. Pap. NE-61 and NE-70 to NE-80.

added to the Resource Evaluation plot data until all automatic data processing had been completed.

Calculation of timber volume estimates followed a different path than did area estimates. A computer program SPeeR, calculated county or supercounty totals based on our plot data. State Forest county totals were developed manually to make them compatible with our totals. They were added to our totals. These combined totals, plus our plot data and State Forest plot data, were used in FINSYS to produce volume tables by county, geographic unit, and state.

National Forest volume data, unlike area data, had to be updated before being added. The Forest was last inventoried in 1974. Growth data from that inventory and removals data from 1974 through 1977 were used to update the necessary volume tables from 1974 to 1978. These were then manually added to the FINSYS tabular output to produce the final volume tables.

Commercial Tree Species of Pennsylvania

Scientific Name [a]	*Common Name*	*Occurrence* [b]
	SOFTWOODS	
Juniperus virginiana	eastern redcedar	vr
Larix laricina	tamarack (eastern larch) [c]	r
Picea abies	Norway spruce [d]	r
P. glauca	white spruce [d]	vr
P. mariana	black spruce	vr
P. rubens	red spruce	vr
Pinus banksiana	jack pine [d]	r
P. echinata	shortleaf pine	vr
P. pungens	Table-Mountain pine	vr
P. resinosa	red pine	c
P. rigida	pitch pine	c
P. strobus	eastern white pine	c
P. sylvestris	Scotch pine [d]	c
P. virginiana	Virginia pine	c
Tsuga canadensis	eastern hemlock	vc
	HARDWOODS	
Acer rubrum	red maple (soft) [c]	vc
A. saccharinum	silver maple	r
A. saccharum	sugar maple (hard) [c]	vc
Betula alleghaniensis	yellow birch	c
B. lenta	sweet birch (black) [c]	c
B. nigra	river birch	vr
B. papyrifera	paper birch (white) [c]	r
Carya spp.	hickory	c
Castanea dentata	American chestnut	vr
Celtis occidentalis	hackberry	vr
Cornus florida	flowering dogwood	r
Diospyros virginiana	common persimmon	vr
Fagus grandifolia	American beech	c
Fraxinus americana	white ash	c
F. nigra	black ash	vr
F. pennsylvanica	green ash	r
Gleditsia triacanthos	honeylocust	vr
Gymnocladus dioicus	Kentucky coffeetree	vr
Ilex opaca	American holly	vr
Juglans cinerea	butternut	r
J. nigra	black walnut	r
Liquidambar styraciflua	sweetgum (red gum) [c]	vr
Liriodendron tulipifera	yellow-poplar (tulip tree) [c]	c
Magnolia acuminata	cucumbertree	r
Nyssa sylvatica	blackgum (black tupelo) [c]	c

Commercial Tree Species (cont.)

Scientific Name	*Common Name*	*Occurrence*
	HARDWOODS	
Platanus occidentalis	American sycamore	r
Populus deltoides	eastern cottonwood	vr
P. grandidentata	bigtooth aspen	c
P. tremuloides	quaking aspen	c
Prunus serotina	black cherry	vc
Quercus alba	white oak	vc
Q. bicolor	swamp white oak	r
Q. coccinea	scarlet oak	c
Q. falcata var. *falcata*	southern red oak	vr
Q. imbricaria	shingle oak	vr
Q. macrocarpa	bur oak	vr
Q. muehlenbergii	chinkapin oak	vr
Q. palustris	pin oak	r
Q. phellos	willow oak	vr
Q. prinus	chestnut oak	vc
Q. rubra	northern red oak	vc
Q. stellata var. *stellata*	post oak	vr
Q. velutina	black oak	c
Robinia pseudoacacia	black locust	c
Salix nigra	black willow	vr
Tilia americana	American basswood	c
Ulmus americana	American elm	c
U. rubra	slippery elm	c
U. thomasii	rock elm	r

[a] Little, Elbert L., Jr. 1979. Checklist of United States trees (native and naturalized). U.S. Dep. Agric., Agric. Handbk. 541. 375 p.
[b] Based on the frequency of tally of commercial species 5 inches or larger in dbh on forest survey field plots: vr: very rare (<0.05 percent); r: rare (0.05 to 0.49 percent); c: common (0.5 to 4.9 percent); and vc: very common (>5.0 percent).
[c] Names in parentheses are other frequently used names.
[d] Species introduced into Pennsylvania.

Page intentionally left blank

Table 1.—Pennsylvania's forest land 1978 (in thousands of acres)

County and unit	Commercial forest land						Productive reserved					Urban	Unproductive			Total forest land
	Allegheny National Forest	State Forest	State Game Lands	Other public [a]	Private	Total	Allegheny National Forest	State Forest	Other public	Christmas tree	Total		State Forest	Other	Total	
Allegheny	--	--	1.1	--	128.3	129.4	--	--	22.9	--	22.9	11.5	--	11.4	11.4	175.2
Armstrong	--	--	4.7	1.2	213.9	219.8	--	--	0.5	--	0.5	--	--	--	--	220.3
Beaver	--	--	3.4	0.6	135.0	139.0	--	--	6.8	--	6.8	2.1	--	--	--	147.9
Butler	--	--	7.8	0.1	235.6	243.5	--	--	12.8	--	12.8	0.3	--	--	--	256.6
Crawford	--	--	16.6	1.4	304.3	322.3	--	--	9.3	--	9.3	--	--	10.5	10.5	342.1
Erie	--	--	8.4	0.6	203.1	212.1	--	--	2.2	--	2.2	1.0	--	--	--	215.3
Greene	--	--	8.7	--	205.5	214.2	--	--	1.3	--	1.3	--	--	--	--	215.5
Indiana	--	--	12.2	0.5	287.3	300.0	--	0.4	4.2	--	4.6	--	--	--	--	304.6
Lawrence	--	--	1.7	--	76.0	77.7	--	--	2.5	--	2.5	0.7	--	0.4	0.4	81.3
Mercer	--	--	5.2	0.3	162.6	168.1	--	--	6.0	--	6.0	1.2	--	--	--	175.3
Washington	--	--	5.3	0.7	203.5	209.5	--	--	1.9	--	1.9	2.2	--	--	--	213.6
Westmoreland	--	5.5	11.3	11.5	270.4	298.7	--	3.9	2.6	--	6.5	1.5	--	--	--	306.7
Western Unit	--	5.5	86.4	16.9	2,425.5	2,534.3	--	4.3	73.0	--	77.3	20.5	--	22.3	22.3	2,654.4
Bedford	--	26.3	46.0	0.7	348.7	421.7	--	2.0	10.1	--	12.1	--	2.9	--	2.9	436.7
Blair	--	--	30.6	21.3	157.7	209.6	--	--	3.4	--	3.4	0.3	--	7.9	7.9	221.2
Cambria	--	0.9	27.0	18.8	208.7	255.4	--	0.2	7.7	--	7.9	1.0	0.1	11.3	11.4	275.7
Fayette	--	13.9	19.3	1.3	269.7	304.2	--	0.3	18.4	--	18.7	0.7	0.6	10.9	11.5	335.1
Somerset	--	25.7	29.5	6.5	344.5	406.2	--	2.4	21.1	--	23.5	--	0.3	--	0.3	430.0
Southwestern Unit	--	66.8	152.4	48.6	1,329.3	1,597.1	--	4.9	60.7	--	65.6	2.0	3.9	30.1	34.0	1,698.7
Cameron	--	125.6	12.7	--	102.3	240.6	--	7.7	0.9	--	8.6	--	1.6	--	1.6	250.8
Elk	106.4	69.3	63.9	4.4	218.3	462.3	--	3.4	0.8	--	4.2	0.3	6.1	--	6.1	472.9
Forest	112.8	2.2	7.1	0.3	125.0	247.4	--	--	3.0	--	3.0	--	--	--	--	250.4
McKean	128.8	2.5	21.3	8.6	390.3	551.5	3.0	--	4.3	--	7.3	0.3	0.2	0.3	0.5	559.6
Potter	--	260.8	16.7	1.2	316.8	595.5	--	2.3	0.3	--	2.6	--	2.7	--	2.7	600.8
Sullivan	--	38.0	49.0	2.3	162.1	251.4	--	1.7	0.1	--	1.8	--	0.7	0.3	1.0	254.2
Tioga	--	137.9	19.3	1.9	314.5	473.6	--	8.7	1.9	--	10.6	--	4.4	--	4.4	488.6
Warren	137.0	--	33.5	0.6	288.8	459.9	1.0	--	0.7	--	1.7	--	--	--	--	461.6
Allegheny Unit	485.0	636.3	223.5	19.3	1,918.1	3,282.2	4.0	23.8	12.0	--	39.8	0.6	15.7	0.6	16.3	3,338.9
Centre	--	113.4	58.3	6.8	325.0	503.5	--	8.4	1.0	--	9.4	--	20.5	12.7	33.2	546.1
Clarion	--	--	13.7	--	203.6	217.3	--	--	4.7	--	4.7	0.3	--	--	--	222.3
Clearfield	--	85.4	23.8	4.4	455.5	569.1	--	2.2	0.2	--	2.4	--	7.4	--	7.4	578.9
Clinton	--	183.5	11.3	4.2	230.0	429.0	--	14.3	1.1	--	15.4	--	67.5	0.7	68.2	512.6
Jefferson	--	9.0	32.5	1.9	230.4	273.8	--	--	1.5	--	1.5	--	--	--	--	275.3
Lycoming	--	154.1	38.5	11.2	350.2	554.0	--	6.1	2.0	--	8.1	1.3	34.7	--	34.7	598.1
Venango	--	--	18.7	1.2	293.2	313.1	--	--	9.8	--	9.8	--	--	--	--	322.9

North-Central Unit	--	545.4	196.8	29.7	2,087.9	2,859.8	--	31.0	20.3	--	51.3	1.6	130.1	13.4	143.5	3,056.2
Dauphin	--	7.5	40.5	10.6	91.2	149.8	--	--	7.4	--	7.4	2.7	0.1	--	0.1	160.0
Franklin	--	32.7	14.9	14.8	137.2	199.6	--	3.5	0.2	--	3.7	--	4.2	--	4.2	207.5
Fulton	--	27.8	16.7	--	134.1	178.6	--	1.5	--	--	1.5	--	1.7	--	1.7	181.8
Huntingdon	--	46.7	30.3	7.5	300.5	385.0	--	5.9	18.0	--	23.9	--	15.6	--	15.6	424.5
Juniata	--	9.4	8.1	3.4	132.5	153.4	--	0.1	1.1	--	1.2	--	6.8	--	6.8	161.4
Mifflin	--	44.6	2.7	0.9	114.9	163.1	--	0.3	0.2	--	0.5	--	17.1	--	17.1	180.7
Perry	--	32.1	14.4	--	164.2	210.7	--	3.7	0.7	--	4.4	--	8.6	--	8.6	223.7
Snyder	--	23.3	1.3	0.7	67.1	92.4	--	1.2	--	--	1.2	--	4.2	--	4.2	97.8
Union	--	51.4	0.8	1.7	55.5	109.4	--	5.9	0.1	13.6	19.6	--	8.1	--	8.1	137.1
South-Central Unit	--	275.5	129.7	39.6	1,197.2	1,642.0	--	22.1	27.7	13.6	63.4	2.7	66.4	--	66.4	1,774.5
Bradford	--	3.3	43.4	0.3	333.8	380.8	--	--	0.7	--	0.7	0.6	--	--	--	382.1
Lackawanna	--	4.4	4.3	9.0	170.2	187.9	--	0.1	3.6	--	3.7	3.5	2.0	0.3	2.3	197.4
Susquehanna	--	--	12.6	--	307.4	320.0	--	--	0.3	--	0.3	--	--	0.9	0.9	321.2
Wayne	--	--	11.5	2.9	292.8	307.2	--	--	2.3	--	2.3	--	--	1.0	1.0	310.5
Wyoming	--	--	27.6	--	133.8	161.4	--	--	--	--	--	--	--	1.0	1.0	162.4
Northeastern Unit	--	7.7	99.4	12.2	1,238.0	1,357.3	--	0.1	6.9	--	7.0	4.1	2.0	3.2	5.2	1,373.6
Carbon	--	0.9	25.5	17.3	117.2	160.9	--	--	27.2	--	27.2	--	--	0.7	0.7	188.8
Columbia	--	--	16.4	--	123.0	139.4	--	--	0.9	--	0.9	1.6	--	--	--	141.9
Luzerne	--	--	33.1	4.1	326.3	363.5	--	--	27.4	--	27.4	0.3	--	--	--	391.2
Monroe	--	6.5	35.3	0.8	241.2	283.8	--	2.1	14.5	--	16.6	--	0.2	1.3	1.5	301.9
Montour	--	--	0.2	0.2	23.2	23.6	--	--	--	--	--	0.3	--	--	--	23.9
Northumberland	--	--	9.6	--	103.4	113.0	--	--	0.1	--	0.1	--	--	--	--	113.1
Pike	--	49.6	21.3	--	202.1	273.0	--	9.9	12.9	--	22.8	--	2.5	1.5	4.0	299.8
Schuylkill	--	7.8	22.0	8.5	261.2	299.5	--	--	25.4	21.4	46.8	0.7	0.5	0.7	1.2	348.2
Pocono Unit	--	64.8	163.4	30.9	1,397.6	1,656.7	--	12.0	108.4	21.4	141.8	2.9	3.2	4.2	7.4	1,808.8
Adams	--	19.0	0.1	1.0	83.7	103.8	--	1.0	1.6	--	2.6	--	0.5	--	0.5	106.9
Berks	--	0.9	13.3	7.9	129.5	151.6	--	--	15.5	--	15.5	1.9	0.1	--	0.1	169.1
Bucks	--	--	4.1	--	75.6	79.7	--	--	14.0	--	14.0	8.6	--	0.7	0.7	103.0
Chester	--	--	0.9	2.7	84.0	87.6	--	--	13.7	--	13.7	--	--	--	--	101.3
Cumberland	--	33.7	1.6	0.1	74.2	109.6	--	1.9	1.4	--	3.3	1.0	1.8	--	1.8	115.7
Delaware	--	--	--	--	--	--	--	--	1.9	--	1.9	16.0	--	--	--	17.9
Lancaster	--	--	7.5	0.7	87.9	96.1	--	--	2.4	--	2.4	--	--	--	--	98.5
Lebanon	--	--	20.9	2.7	26.6	50.2	--	--	9.8	--	9.8	--	--	--	--	60.0
Lehigh	--	--	3.4	0.1	49.3	52.8	--	--	0.1	--	0.1	1.4	--	--	--	54.3
Montgomery	--	--	--	0.6	64.9	65.5	--	--	0.5	--	0.5	6.0	--	--	--	72.0
Northampton	--	--	4.0	6.8	45.2	56.0	--	--	2.3	--	2.3	0.3	--	--	--	58.6
Philadelphia	--	--	--	--	--	--	--	--	3.0	--	3.0	2.1	--	--	--	5.1
York	--	--	2.4	0.7	138.3	141.4	--	--	16.7	--	16.7	0.3	--	--	--	158.4
Southeastern Unit	--	53.6	58.2	23.3	859.2	994.3	--	2.9	82.9	--	85.8	37.6	2.4	0.7	3.1	1,120.8
All counties	485.0	1,655.6	1,109.8	220.5	12,452.8	15,923.7	4.0	101.1	391.9	35.0	532.0	72.0	223.7	74.5	298.2	16,825.9

[a] These figures are broken down into ownerships in worksheet titled Pennsylvania—Third Inventory—Public Ownership, July 20, 1978.

Table 2.—Distribution of net growing-stock volume on commercial forest land, by species and forest-type group, Pennsylvania, 1978
(In millions of cubic feet)

Species	Forest-type group									All forest-type groups
	White pine and hemlock	Spruce/ fir	Scotch and Virginia pine	Oak/ pine	Oak/ hickory	Oak/ gum	Elm/ash red maple	Northern hardwoods	Apen/ birch	
White/red pine	322.6	2.2	33.0	7.4	148.4	--	12.4	107.7	7.3	641.0
Virginia pine	--	--	41.4	13.1	14.5	--	1.2	1.4	--	71.6
Other yellow pines	5.7	5.1	34.9	25.2	61.0	--	--	17.1	1.3	150.3
Hemlock	244.4	--	--	--	118.2	--	10.3	497.6	1.2	871.7
Other softwoods	0.6	18.8	2.1	--	1.6	--	1.5	4.5	3.3	32.4
Total softwoods	573.3	26.1	111.4	45.7	343.7	--	25.4	628.3	13.1	1,767.0
Select white oaks[a]	35.7	--	4.2	11.3	1,167.9	6.3	13.4	137.8	5.7	1,382.3
Northern red oak	36.8	--	1.7	12.8	2,192.1	--	24.0	321.7	8.6	2,597.7
Other oaks[b]	8.7	2.1	0.4	13.4	1,165.0	--	14.1	98.3	1.1	1,303.1
Chestnut oak	17.1	--	2.9	7.8	1,964.0	--	4.0	61.2	1.4	2,058.4
Hickory	7.0	--	0.8	1.1	422.8	--	19.5	101.7	3.4	556.3
Yellow birch	12.2	--	--	--	19.2	--	4.7	144.6	0.3	181.0
Sweet birch	17.8	5.5	--	1.8	243.1	--	8.1	445.2	6.6	728.1
Sugar maple	18.4	--	W	--	147.4	--	13.7	1,800.6	10.8	1,990.9
Red maples[c]	96.1	0.9	0.9	13.4	1,150.6	0.6	205.8	1,874.2	27.0	3,369.5
Beech	25.7	--	--	--	76.9	--	6.0	792.1	0.1	900.8
Blackgum	2.0	1.0	W	0.5	83.0	--	6.8	22.8	0.8	116.9
White ash	8.2	1.7	2.4	--	243.0	--	17.1	603.4	3.7	879.5
Aspen	22.9	0.7	1.3	1.4	83.4	3.0	5.5	232.6	129.7	480.5
Basswood	6.7	--	--	--	42.7	--	--	289.8	3.0	342.2
Yellow-poplar	2.3	--	3.2	--	444.8	--	9.9	98.7	--	558.9
Black walnut	0.9	--	--	--	48.4	--	6.1	12.1	--	67.5
Black cherry	23.4	1.6	W	4.9	225.7	1.6	18.1	1,601.2	15.8	1,892.3
Black locust	--	2.1	1.8	--	144.1	--	1.0	30.2	W	179.2
Other hardwoods	11.7	0.7	2.6	3.9	164.8	--	98.4	109.1	12.8	404.0
Total hardwoods	353.6	16.3	22.2	72.3	10,028.9	11.5	476.2	8,777.3	230.8	19,989.1
All species	926.9	42.4	133.6	118.0	10,372.6	11.5	501.6	9,405.6	243.9	21,756.1

[a] Includes white, swamp white, and bur oaks.
[b] Includes scarlet, southern red, shingle, pin, willow, post and black oaks.
[c] Includes 25.8 million cubic feet of silver maple.
W—Less than 50,000 cubic feet.

Table 3.—Aboveground green weight of live trees, by species and source, Pennsylvania[a] (In thousands of tons)

Species	Growing stock			Rough and rotten			Seedlings and saplings[c]
	Merchantable stem[b]	Topwood and branchwood	Total	Merchantable stem[b]	Topwood and branchwood	Total	
White/red pine	22,573.5	5,182.3	27,755.8	1,307.0	382.1	1,689.1	3,504.1
Virginia pine	2,978.2	514.1	3,492.3	209.4	38.7	248.1	861.1
Other yellow pines	6,683.0	2,236.0	8,919.0	157.7	80.2	237.9	2,741.0
Hemlock	30,923.4	11,378.0	42,301.4	4,180.1	1,842.3	6,022.4	4,871.7
Other softwoods	1,376.5	646.9	2,023.4	126.1	73.2	199.3	1,693.0
All softwoods	64,534.6	19,957.3	84,491.9	5,980.3	2,416.5	8,396.8	13,670.9
Select white oaks	59,851.5	19,704.0	79,555.5	2,052.0	2,139.6	4,191.6	4,648.6
Northern red oak	121,891.6	47,307.6	169,199.2	4,163.1	2,581.7	6,744.8	6,963.3
Other oaks	56,938.3	18,800.3	75,738.6	1,693.3	742.8	2,436.1	4,595.7
Chestnut oak	100,584.1	30,517.0	131,101.1	8,353.7	3,492.5	11,846.2	8,761.7
Hickory	29,213.7	6,556.5	35,770.2	1,203.2	387.3	1,590.5	3,658.9
Yellow birch	6,291.9	2,324.3	8,616.2	1,252.3	643.9	1,896.2	1,690.3
Sweet birch	32,296.1	9,105.6	41,401.7	3,956.1	1,487.8	5,443.9	8,100.9
Hard maple	76,950.6	24,814.3	101,764.9	6,240.6	2,606.3	8,846.9	12,114.5
Red maples	116,651.0	33,589.2	150,240.2	10,084.0	3,843.4	13,927.4	37,952.8
Beech	36,999.5	13,199.1	50,198.6	6,674.3	3,422.7	10,097.0	7,077.7
Blackgum	4,899.7	950.0	5,849.7	623.4	203.1	826.5	3,522.4
White ash	33,910.6	6,999.6	40,910.2	2,146.7	651.9	2,798.6	8,175.2
Aspen	14,764.3	3,872.7	18,637.0	636.6	290.0	926.6	6,958.7
Basswood	9,877.0	1,476.6	11,353.6	891.9	153.8	1,045.7	680.0
Yellow-poplar	22,904.6	3,360.4	26,265.0	352.9	81.3	434.2	1,440.7
Black walnut	3,554.0	732.3	4,286.3	484.1	153.2	637.3	1,001.0
Black cherry	62,568.6	13,006.3	75,574.9	7,249.2	1,933.3	9,182.5	15,766.9
Black locust	7,780.5	1,529.0	9,309.5	2,329.6	940.2	3,269.8	2,247.4
Other hardwoods	17,871.1	3,422.4	21,293.5	15,364.2	4,630.3	19,994.5	43,869.7
All hardwoods	815,798.7	241,267.2	1,057,065.9	75,751.2	30,385.1	106,136.3	179,226.4
All species	880,333.3	261,224.5	1,141,557.8	81,731.5	32,801.6	114,533.1	192,897.3

[a] Excludes Allegheny National Forest.
[b] Trees 5 inches and larger in dbh, between a 1-foot stump and a 4-inch top.
[c] Also excludes State Forest estimates.

Table 4.—Pennsylvania's forest industries 1967-77[a]

1972 SIC code	Industry group and industry	Number of establishments			Number of establishments with 20 or more employees			Number of employees (in thousands)			Payroll 1967 dollars[b] (in millions)			Value added by manufacture 1967 dollars[c] (in millions)		
		1967	*1972*	*1977*	*1967*	*1972*	*1977*	*1967*	*1972*	*1977*	*1967*	*1972*	*1977*	*1967*	*1972*	*1977*
24	Lumber and wood products	NA	1,285	1,326	NA	246	245	NA	22.2	20.5	NA	126.7	104.6	NA	269.9	244.0
2411	Logging camps, log contractors	253	197	262	5	6	9	0.8	0.7	1.1	3.0	2.9	5.4	7.1	6.6	14.7
242	Sawmills and planing mills	680	555	480	55	62	61	5.2	4.4	4.7	21.5	23.1	21.0	39.3	45.0	51.6
243	Millwork, plywood, struc. membs.	NA	231	249	NA	80	74	NA	6.7	6.3	NA	38.5	34.0	NA	69.7	69.6
244	Wood containers	NA	66	115	NA	24	32	NA	1.4	1.9	NA	7.1	8.3	NA	12.3	15.9
245	Wood building and mobile homes	NA	52	63	NA	46	45	NA	6.5	4.1	NA	42.4	23.5	NA	110.5	53.8
249	Misc. wood products	NA	184	157	NA	28	22	NA	2.4	2.4	NA	12.7	12.4	NA	25.8	38.0
25	Furniture and fixtures[d]	NA	230	227	NA	99	73	NA	NA	NA	NA	NA	NA	NA	NA	NA
2511	Wood household furniture	NA	108	114	NA	44	34	NA	4.6	3.6	NA	23.3	15.9	NA	41.3	32.3
2517	Wood TV and radio cabinets	NA	4	2	NA	3	1	NA	NA	D	NA	D	D	NA	D	D
2521	Wood office and furniture	13	16	13	6	6	5	0.8	0.7	0.6	4.4	3.8	3.1	8.9	6.6	6.8
2531	Public bldg., related furniture	31	26	19	17	15	7	1.5	NA	0.6	7.8	D	3.3	12.4	D	6.6
2541	Wood Partitions	75	76	79	24	31	26	2.1	NA	1.7	13.0	D	9.9	18.0	D	18.2
26	Paper and allied products	439	429	400	299	282	268	43.6	42.4	40.2	287.4	307.9	289.6	607.9	659.9	802.8
2621	Papermills, except building paper	25	26	23	24	22	21	9.8	9.6	8.6	78.6	82.8	80.3	142.9	153.0	163.1
2631	Paperboard mills	19	20	17	18	17	16	2.5	NA	1.8	19.6	D	14.9	43.2	D	35.3
264	Misc. converted paper products	162	157	160	94	85	89	12.9	12.9	15.0	77.2	89.8	97.7	206.8	244.5	400.3
265	Paperboard containers and boxes	225	219	193	157	151	137	17.9	17.0	14.4	108.3	111.4	93.5	205.2	214.6	192.3
2661	Building paper and board mills	8	7	5	6	7	5	0.5	NA	0.5	3.7	D	3.3	9.7	D	9.4

[a] Source: U.S. Dep. Commer. Bur. Census 1970, 1975, 1979.
[b] Deflated using consumer price index (1967 = 100), Bureau of Labor Statistics.
[c] Deflated using producer price index (1967 = 100), Bureau of Labor Statistics.
[d] Only those industries who clearly use quantities of wood.
NA Data either not available or comparable due to changes in industry classification by the Bureau of Census.
D Data withheld to avoid disclosure for individual manufacturing plants.

Metric Equivalents

1 acre = 4,046.86 square meters or 0.404686 hectares

1,000 acres = 404.686 hectares

1,000,000 acres = 404,686 hectares

1,000 board feet = 3.48 cubic meters [a]

1 cubic foot = 0.028317 cubic meters

1,000 cubic feet = 28.317 cubic meters

1,000,000 cubic feet = 28,317 cubic meters

1 cord (wood, bark, and airspace) = 3.6246 cubic meters

1 cord (solid wood, pulpwood) = 2.4069 cubic meters

1 cord (solid wood, other than pulpwood) = 2.2654 cubic meters

1,000 cords (pulpwood) = 2,406.9 cubic meters

1,000 cords (other products) = 2,265.4 cubic meters

1 ton (short) = 907.1848 kilograms or 0.9071848 metric tons

1,000 tons (short) = 907.1848 metric tons

1 inch = 2.54 centimeters or 0.0254 meters

1 foot = 30.48 centimeters or 0.3048 meters

Breast height = 1.4 meters above ground level

1 mile = 1.609 kilometers

1 square foot = 929.03 square centimeters or 0.0929 square meters

1 square foot per acre basal area = 0.229568 square meters per hectare

---

[a] While 1,000 board feet is theoretically equivalent to 2.36 cubic meters, this is true only when a board foot is actually a piece of wood with a volume of 1/12 of 1 cubic foot. The International 1/4-inch log rule is used by the USDA Forest Service in the East to estimate the product potential in board feet. When a conversion is used, the reliability of the estimate will vary with the size of the log measure. The conversion given here, 3.48 cubic meters, is based on the cubic volume of a log 16 feet long and 15 inches in diameter inside bark (dib) at the small end. This conversion could be used for average comparisons when accuracy of 10 percent is acceptable. Since the board-foot unit is not a true measure of wood volume and since products other than dimension lumber are becoming important, this unit may eventually be phased out and replaced with the cubic-meter unit.

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-505-012:1

Powell, Douglas S.; Considine, Thomas J., Jr. An analysis of Pennsylvania's forest resources. Broomall, PA: Northeast. For. Exp. Stn.; 1982; USDA For. Serv. Resour. Bull. NE-69. 97p.

A comprehensive analysis of the current status and trends of the forest resources of Pennsylvania. Topics include forest area, timber volume, biomass, timber products, timber's role in the state's economy, growth, and removals. Forest area, volume, growth and removals are projected through 2008. A detailed treatment is given to water, soil, minerals, fish, wildlife, and recreation as they relate to forest resources. Also identified are forest management opportunities for increasing the production of major forest resources and enhancing the benefits derived from Pennsylvania's forests.

ODC(748):905.2—014.

Keywords: Forest survey, trends, projections, area, volume, growth, removals, nontimber forest resources, forest management opportunities.

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.