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THE WHITE PINE-HEMLOCK FORESTS OF THE ANTHRACITE REGION

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FOREWORD

This paper is a progress report of forest research in the Anthracite Region by personnel of the Station's branch at Kingston, Pa. It is the last in a series of seven reports dealing with the principal forest types of the Anthracite Region. The previous reports are:

1. The Northern Hardwood Forests of the Anthracite Region. Station Paper 1, issued in March 1947.
2. The Red Oak - White Oak Forests of the Anthracite Region. Station Paper 2, issued in May 1947.
3. The Scrub Oak Forests of the Anthracite Region. Station Paper 4, issued in June 1947.
4. The Aspen - Gray Birch Forests of the Anthracite Region. Station Paper 7, issued in August 1947.
5. The White Pine - Oak Forests of the Anthracite Region. Station Paper 8, issued in August 1947.
6. The Chestnut Oak Forests of the Anthracite Region. Station Paper 9, issued September 1947.

This paper presents data on the condition of the forests in the white pine - hemlock type, and recommendations for improving such forests. The recommendations are only tentative; but they should serve as a useful guide until more precise and refined information is available.

The authors thank the many landowners on whose property the sample plots were established; the personnel of the Industrial Forestry Division of the Wyoming Valley Chamber of Commerce, for their advice and assistance; and the many individuals who have shown a desire to help solve the forest problems of the Anthracite Region.

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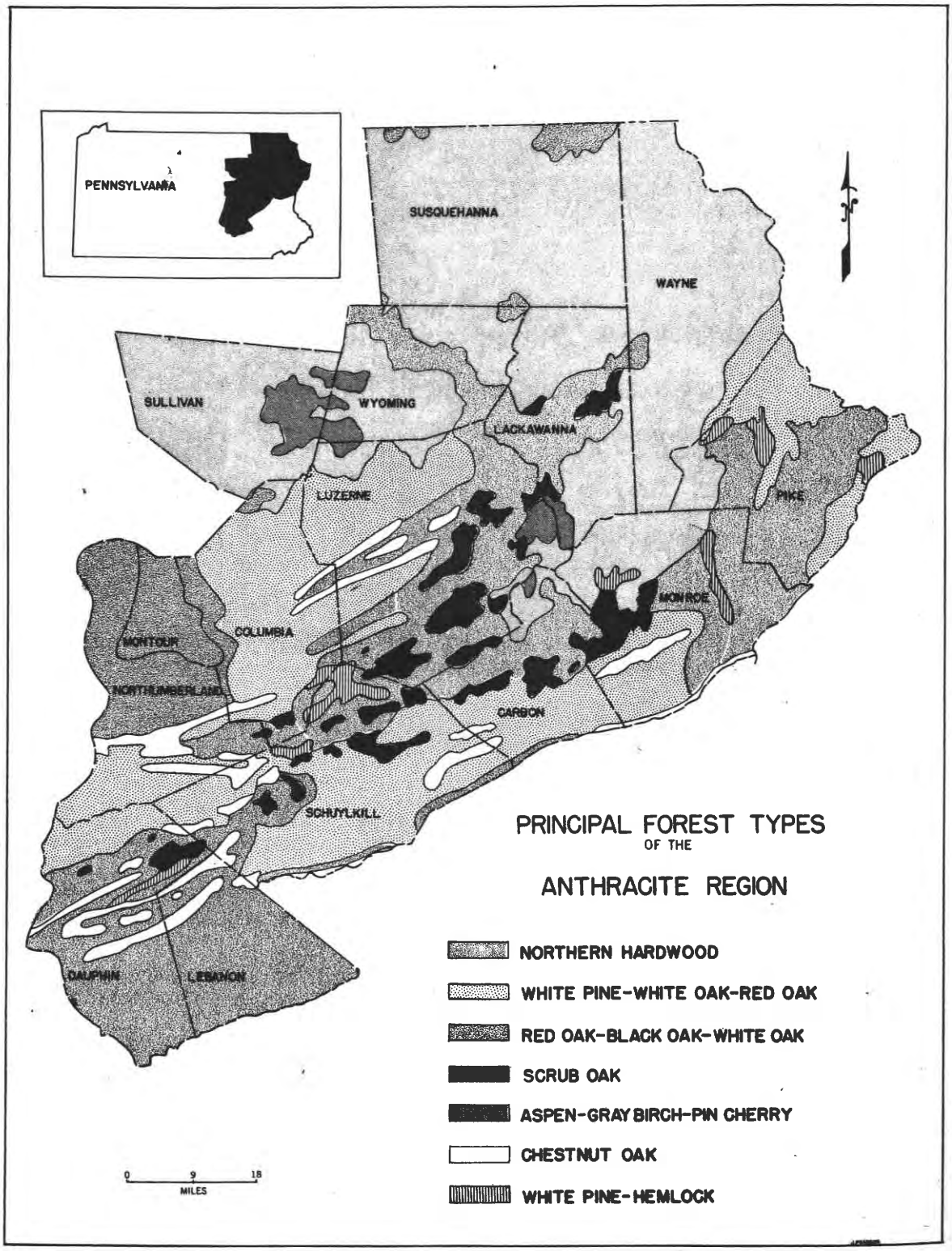
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THE WHITE PINE -- HEMLOCK FORESTS OF THE ANTHRACITE REGION

Their Present Condition and Possible Treatment

by C. F. Burnham
M. J. Ferree
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INTRODUCTION

The white pine - hemlock forests are found chiefly on well drained slopes and along the sides of ravines. Though the area occupied by this type is less than 8 percent of the forest land in the region, it accounts for a quarter of the saw-timber area and 29 percent of the volume in saw-timber stands.1/

The original stands of white pine and hemlock were probably much more extensive than they are today, especially along the northern branches of the Susquehanna and Delaware Rivers and their tributaries. Dr. Ebenezer Elmer, who accompanied General Sullivan's troops from Easton to Wyoming in June 1779, wrote in his journal: "In some places the timber is very tall and thick, mostly white pine and hemlock with some birch, maple and locust trees. Many of the white pines are 150 foot clear of any limbs" (3).2/ People traveling this same route today often comment on the large areas barren of any timber.

Since the white pine - hemlock forests thrive along the courses of the many streams that traverse the region, particularly in the central portion, they were among the first to feel the bite of the ax. The cutting of white pine for shipmasts started in the last years of the eighteenth century. These were rafted down the Susquehanna to the shipyards on Chesapeake Bay, or down the Delaware to the shipyards near Philadelphia. In 1796 thirty such rafts passed Wilkes-Barre. In 1804 the number increased to 552, containing approximately 22 million board feet. In 1849, the peak year for rafts, 2,243 passed Wilkes-Barre; they contained an estimated 100 million board feet (12).

1/ For definitions see appendix.
2/ Numbers in parentheses refer to Literature Cited, p. 15.

Table 1.--Acreage and volume distribution in the white pine - hemlock type, by stand-size classes[1/]

Item	Saw timber	Pole timber	Unmerchantable[2/] (Seedling and sapling)	All stands
Acres	43,800	57,900	144,800	246,500
Percent	17.8	23.5	58.7	100.0
Sawlog material:				
M bd. ft.....	244,000	39,900	102,100	386,000
Percent.....	63.2	10.3	26.5	100.0
Bd. ft. per acre..	5,571	689	705	1,566
Other material:				
Tons.....1,165,000	844,900	884,500	2,894,400	
Percent.....	40.2	29.2	30.6	100.0
Tons per acre.....	26.6	14.6	6.1	11.7
All material:				
M cu. ft.....	81,040	41,160	50,960	173,160
Percent.....	46.8	23.8	29.4	100.0
Cu. ft. per acre..	1,850.2	710.9	352.1	702.5

1/ Ineson, F. A., Ferree, M. J., and Robinson, D. F. The Anthracite Forest Region--a problem area. Northeast. Forest Expt. Sta. 1946. (In process of publication by U. S. Dept. Agr.) Data are for the entire 15-county area, and should not be confused with the plot data that follow.

2/ "Unmerchantable" as used in this table includes saw-timber and pole-timber tracts less than 10 acres in size. The term "seedling and sapling" does not include these tracts.

Extensive sawmill and tannery operations did not get under way until the first part of the nineteenth century. By 1860 sawmills along the Lehigh River alone cut over 30 million board feet of lumber annually, most of it white pine. Along this same river, huge quantities of hemlock were cut for bark between 1850 and 1900 to supply numerous tanneries. One of the largest tanneries, erected at Goulds-boro in 1856 by Zaddock Pratt and Jay Gould, had a capacity of 100 cords of hemlock bark per hour and an annual output of 75,000 hides (12). The sad part about the cutting of these hemlock stands was the fact that only the bark was used. The rest of the tree was left in the woods.

Virgin hemlock stumpage in Pennsylvania was worth $1.00 per

thousand board feet in 1900 (13). Fifteen years earlier the same timber was worth only 50 cents per thousand, and the hardwoods--beech, birch, and maple--were thrown in free of cost. The large tanneries used the bark from these hemlock trees and had trouble selling the peeled logs. Today hemlock is worth $12-15 on the stump and the supply cannot possibly meet the demand.

A few stands of virgin white pine and hemlock remain, but they are either publicly owned or are in the hands of private individuals or associations who plan to keep them in a virgin state as museum pieces. Ricketts Glen State Forest Park and the Bear Creek Association's holdings adjacent to Bear Creek Village are excellent examples of what these original white pine - hemlock stands looked like.

This brief glance into the past serves as a contrast to the present condition of this forest type. While the type does contain some of the best remaining saw timber in the Anthracite Region, it has shrunk in area and in timber volume to a mere fraction of what it was.

In volume-per-acre yields the white pine - hemlock forests are the most productive forests in the Anthracite Region. However, because of its present small acreage this type ranks fourth in total lumber production. Heavy cutting and fires have been constantly converting this coniferous mixture to hardwoods. This conversion has gradually reduced the extent of the type until now it is confined to coves or along streams where the fire hazard is low. Hemlock's affinity for moisture and low temperatures and its inability to withstand droughts are the principal factors that limit its extent to moist bottom-lands (6).3/

The white pine - hemlock mixture has high economic value. White pine commands a top price on the lumber market. The use of hemlock lumber is increasing rapidly and its stumpage price is rising constantly; the sale of bark for its tannin content brings added revenue. Moreover, the associated hardwoods such as black cherry, red oak, basswood, and yellow poplar are high-quality species that fetch good prices. Aesthetically this forest type is surpassed by no other in the region. Its location along mountain streams and lakes, plus the shade afforded by its dense foliage, makes it ideal for recreational purposes.

3/ Hough, A. F. The dying of hemlock and other species on the Allegheny National Forest. Allegheny Forest Expt. Sta. Tech. Note 9. 1939. (2 pp., mimeographed.)

Table 2.--Summary of conditions on average white pine - hemlock stand

(Site I)

Average condition		Saw timber	Pole timber	Seedling and sapling
Volume per acre	Cubic feet..	4,261	1,676	143
	Tons..	112	44	4
	Board feet..	18,443	1,504	--
Average age	Years..	90	40	20
Trees per acre				
Pole size (3.6" d.b.h.) and larger	Number..	295	784	250
Seedling-sapling (0.6-3.5" d.b.h.)	Number..	88	699	1/ 6,970
Reproduction (under 4.5' high)	Degree..	Very poor	Poor	Very good
Quality				
Cu.-ft. volume in poorly formed trees	Percent..	8	23	15
Origin				
Cu.-ft. volume in sprout-origin trees	Percent..	5	5	4
Vigor	Percent			
	in vigor class 1..	7	10	25
	vigor class 2..	32	8	50
	vigor class 3..	46	48	25
	vigor class 4..	15	34	0
Cull	Percent			
	of total cu.-ft. volume..	4	2	--
	of total bd.-ft. volume..	4	--	--
Annual mortality	Cubic feet per acre..	1	2	--
	Percent of total growth..	1	2	--
Annual growth per acre	Cubic feet..	100	80	20
	Tons..	2.6	2.1	0.5
	Board feet..	555	100	--
Ingrowth	Percent			
	of annual cu.-ft. increase..	2	11	100
	of annual bd.-ft. increase..	15	67	--

1/ Includes trees down to 0.1 inch d.b.h.

PRESENT CONDITION

Temporary sample plots were studied to determine the present condition of the white pine - hemlock forests. These plots were distributed equally among saw-timber, pole-timber, and seedling-and-sapling stands. Since the white pine - hemlock type is found mostly on site I, the plots were limited to site I. Age, growth rate, mortality, cull factors, and stand composition were measured.

These measurements show that the average saw-timber stand has a volume of 18,443 board feet per acre. This is three times the over-all average for the timber of the region. Yet, these forests produce only about one-half of what they could produce. The virgin tract at

Table 3.--Growth in natural white pine-hemlock stands, site I

(Mortality deducted)

Growing stock per acre	Annual growth per acre	Growing stock per acre	Annual growth per acre	Growing stock per acre	Annual growth per acre
Cubic feet	Cubic feet	Tons	Tons	Board feet	Board feet
200	24	5.3	0.6	1,000	80
400	34	10.5	.9	2,000	120
600	43	15.8	1.1	3,000	160
800	51	21.1	1.3	4,000	200
1,000	59	26.3	1.6	5,000	237
1,200	66	31.6	1.7	6,000	275
1,400	72	36.8	1.9	7,000	313
1,600	78	42.1	2.1	8,000	351
1,800	84	47.4	2.2	9,000	389
2,000	89	52.6	2.3	10,000	427
2,200	94	57.9	2.5	11,000	464
2,400	99	63.2	2.6	12,000	497
2,600	104	68.4	2.7	13,000	525
2,800	108	73.7	2.8	14,000	560
3,000	110	78.9	2.9	15,000	575
3,200	110	84.2	2.9	16,000	580
3,400	109	89.5	2.9	17,000	580
3,600	107	94.7	2.8	18,000	570
3,800	105	100.0	2.8	19,000	540
4,000	102	105.3	2.7	20,000	505

Converting factor: 38 cubic feet = 1 ton.

Ricketts Glen, for example, has volumes as high as 40,000 board feet per acre.

The number of merchantable-sized trees per acre is generally satisfactory. However, the number of trees 0.6 to 3.5 inches d.b.h. is extremely low in the older stands. Reproduction, too, is poor in these stands. This is due to the closed canopy formed by the trees as they reach saw-timber size. This reduces the amount of light that is necessary for the successful establishment of reproduction.

Table 4.--Mortality per acre in white pine seedling-sapling stands, site I, by species and diameter class

Species	D.b.h. class (inches)				Total	
	0.25	1	2	3		
	Number of stems	Number of stems	Number of stems	Number of stems	Number of stems	Percent
White pine	430	900	90	--	1,420	60.4
Hemlock	50	--	--	--	50	2.1
White oak	20	--	--	--	20	.9
Black birch	490	90	--	--	580	24.7
Gray birch	20	40	--	--	60	2.6
Aspen	60	140	--	--	200	8.5
Chestnut	--	10	--	--	10	.4
Witch hazel	--	10	--	--	10	.4
All species	1,070	1,190	90	--	2,350	100.0

The percentage of volume in trees of poor form is not high (tables 6-11). Since neither white pine nor hemlock sprouts, the percentage of trees having sprout origin is also low, and of course is limited to the hardwood species.

Cull and mortality seem to have no great significance in the older stands. However, mortality of white pine in the seedling-and-sapling stage is highly significant. Ninety percent of the stems that die are in the 0.25 to 2.0 inch diameter classes, and 60 percent of these are white pine (table 4).

Growth rates within the white pine - hemlock forests exceed those of any other type in the region. An annual increase of more

than 500 board feet per acre may be expected in stands containing more than 12,000 board feet per acre. The amount of annual increase, of course, depends upon the volume of growing stock. Table 3 shows the amount of annual growth that may be expected for stands of various volumes after deducting for mortality.

MEASURES NEEDED TO IMPROVE PRODUCTIVITY

One of the outstanding problems is to increase the proportion of white pine in the second-growth stands. This, the most valuable species, has been cut heavily in the past with little consideration for its regeneration. Original stands were heavily stocked with white pine, but logging practices have created conditions that favor the shade-tolerant hemlock, so that hemlock now almost completely dominates the young stands (5) (6). The percentage of white pine in the total mortality is higher in the younger stands than in the older ones. The following tabulation shows the distribution of white pine mortality according to the stand-size class:

	Mortality (Percent)
Saw-timber stands	5
Pole-timber stands	8
Seedling-and-sapling stands	60

Moreover, this mortality of white pine in seedling-and-sapling stands is extremely high in the lowest diameter classes (table 4). All these factors tend to eliminate white pine from the young age classes, and to favor the hemlock and hardwoods. In fact, this transition has progressed so far that the present seedling-and-sapling stands contain very little white pine.

Another silvicultural problem is the need for partial cuttings to increase growth rates and to promote good development of suppressed tolerant species. This is indicated by the high proportion of low-vigor trees (table 2).

Protection from fire and grazing is necessary for successful timber production by this forest type. Although the fire hazard is very low, complete fire protection is required. Grazing should be prevented. Trampling of seedlings and compacting of soil decreases the possible yields.

The forms of management recommended in this report can also be used for pure hemlock stands. Efforts should be made to introduce into these stands more valuable species. These management methods will be beneficial to the propagation and maintenance of wildlife. The partial cuttings will perpetuate a constant overstory of conifers, which afford excellent cover for most animal species.

SAW-TIMBER STANDS

Any form of management applied to this forest type should have a threefold objective: it should assure establishment and development of white pine; it should increase the growth rates of all high-quality species and maintain the stands in a thrifty condition; and it should encourage development of high-quality hardwood associates. To accomplish these the shelterwood system of cutting is best for saw-timber stands (5). This is a partial cutting that allows seedlings to become established under a light overstory of large trees. This cutting method is desirable because of the characteristics of these stands:

1. Reproduction is not adequate.

2. The stands are even-aged.

3. White pine needs a mineral seedbed for establishment and a fair amount of light for development (8).

4. Hemlock and white pine reproduce better under light cover than in the open (6) (16).

5. Suppressed hemlock must be exposed gradually in order to minimize damage from sunscald and from excessive drying of soil (14).

6. Hemlock is shallow-rooted and may windthrow if left isolated on wet areas.4/

7. Isolated hemlocks over 16 inches d.b.h. develop "shake".5/

Cutting methods of several degrees of intensity were considered (table 5). In estimating yields under the different cutting methods, it was assumed that the white pine - hemlock growth rates will correspond closely to those for the white pine type, for which Dana (4) found an increase of about 12 percent after release cutting. It was also assumed that the culmination point of 16,000 board feet per acre for natural stands (table 3) will be raised to 20,000 board feet under good forest management.

Clear-cutting.--The present practice of cutting all trees down to 2 inches d.b.h. should be discontinued. It is undesirable for these reasons:

4/ Wood, O. M. Windfirmness of hemlock left after logging. Allegheny Forest Expt. Sta. Tech. Note 2. 2 pp.; illus. 1940.

5/ Bratton, Allen W. Hardwoods, the bigger the better; hemlocks just get bigger. Northeast. Forest Expt. Sta. Forest Economics Note 2. 3 pp., illus. 1946.

Figure 1.--Saw-timber stand, site I.

1. It yields less volume over a given number of years than any of the partial cutting methods.

2. It yields a greater proportion of low-quality material than any of the partial cutting methods.

3. Conversion to hardwoods is encouraged, since the conifers are unable to sprout.

4. The fire hazard is increased because of large amounts of slash left after logging.

5. The site is exposed to soil erosion and drying-out, thus destroying the watershed-protection qualities of the forest and adding to the ever increasing threat of floods.

6. It favors invasion of light-seeded, intolerant, noncommercial species such as ironwood, aspen, and gray birch.

The heavy cut.--Since the average saw-timber stand is already at silvicultural maturity, a high volume can be removed immediately as a seed cut. This is a cutting that removes everything but well spaced seed-bearing trees of desirable species to ensure reproduction and to afford protection to the area while the seedlings are becoming established. About 12,000 board feet per acre can be removed in this first

Table 5.--Comparison of four methods of cutting white pine - hemlock saw-timber stands, site I[1/]

Year	Item	Clear-cut[2/]	Heavy cut	Moderate cut	Light cut
		Board feet	Board feet	Board feet	Board feet
1946	Present volume	18,400	18,400	18,400	18,400
	Amount removed	18,400	12,000†	5,000*	2,000*
	Remainder	0	6,400	13,400	16,400
1951	Expected volume	--	--	--	19,900
	To be removed	--	--	--	3,000*
	Remainder	--	--	--	16,900
1956	Expected volume	--	10,500	19,700	20,400
	To be removed	--	9,500x	5,000*	3,000*
	Remainder	--	1,000	14,700	17,400
1961	Expected volume	--	--	--	21,000
	To be removed	--	--	--	12,000†
	Remainder	--	--	--	9,000
1966	Expected volume	--	--	21,000	--
	To be removed	--	--	12,000†	--
	Remainder	--	--	9,000	--
1971	Expected volume	--	--	--	13,000
	To be removed	--	--	--	12,000x
	Remainder	--	--	--	1,000
1976	Expected volume	--	--	13,000	--
	To be removed	--	--	12,000x	--
	Remainder	--	--	1,000	--
1981	Expected volume	1,000	--	--	--
	To be removed	--	--	--	--
	Remainder	--	--	--	--
Total volume removed		18,400	21,500	34,000	32,000

1/ Growth rates shown in table 2 were used. They were increased 12 percent when applied to partially cut stands.

2/ Removes all stems down to 2-inch d.b.h.

*Preparatory or improvement cut. †Seed cut. xFinal cut.

Figure 2.--Pole-timber stand, site I.

operation. Slash should be piled and burned to facilitate seedling establishment in the mineral soil bed. Ten years later the remaining overstory of trees should be removed as a final cut. Two or three cleanings should follow at 5-year intervals to release white pine from competition by hemlock and hardwoods.

This type of cut is recommended for stands that have already attained their maximum volume and possess well developed seed trees. It is particularly designed for inaccessible extensive forests where large volumes are necessary to meet logging costs.

The material removed will find a good market. Most of it can be utilized as saw timber. The poor-quality hemlock and hardwoods can be sold as mine props. And, in addition, if the logging takes place in the spring of the year when bark is easily peeled, the hemlock bark may be marketed at a profit.

The moderate cut.--This method requires two light cuts to prepare mineral seedbeds and to develop large-crowned seed trees before the seed cut is made. It is designed for areas that need preparatory work of this nature, where cull is excessive and improvement work is needed, or wherever the owner desires rather frequent returns. About 5,000 board feet per acre can be removed immediately from the average saw-timber stand, and another 5,000 board feet 10 years later Then, after a 10-year period, the seed cut can be made, followed by the final cut as

outlined previously. It will be necessary to conduct cleanings as with the heavy cut method.

Hawley (9) found that systematic thinnings resulted in the establishment of an abundance of white pine seedlings and small quantities of hardwood and hemlock seedlings. In view of this it may be possible to eliminate the seed cut in stands where reproduction becomes adequately established following the first two preparatory cuts.

The light cut.--This method is designed for areas on which cull is excessive and improvement work is needed. Preparatory cuts are used to condition the site for seedling establishment and development of seed-bearing trees. This method is especially suitable for farm woodlots where owners who can find time to do their own woods work during months when farm work is slack can capitalize on their own labor and equipment that would otherwise be idle. By carefully distributing the annual cuts over a tract an owner can sustain yearly employment and realize yields of high-quality sawlogs. Three light cuts of 2,000, 3,000, and 3,000 board feet per acre respectively should be made at 5-year intervals preparatory to the seed cut and final cut as previously outlined. It is not likely that these light operations will promote the establishment of white pine reproduction, since the species is rather intolerant to shade and the openings created will be small. Therefore the seed cut will be relied upon entirely for regeneration of white pine.

Any one of the above cutting methods can be successfully used; the method selected depends upon the desires of the owner and on economic and silvicultural factors. The yields estimated (table 5) apply only to the average saw-timber stand as found in this study, but the same procedures can be applied to any stand. Growth rates indicate that the 1,000 board feet per acre left after the final cuts will have attained sufficient volume in 30 or 40 years to allow initial cuts in the second rotation. These cuts must be carefully planned so that the amount removed will be less than the periodic growth. This will allow the growing stock of high-quality trees to increase gradually until the culmination point of about 20,000 board feet per acre is reached, at which time the harvest cuts can be made. It is important that the cutting plans be kept flexible so that all cutting and timber utilization can be constantly correlated with market conditions and demands.

POLE-TIMBER STANDS

The average pole-timber stand was marked for removal of 400 cubic feet or 10.5 tons per acre of material in a thinning operation. Deformed or defective red oak, white oak, red maple, and yellow birch make up a small portion of it; but the bulk of it is in sound densely grown hemlock that should be removed to release selected crop trees. This work should be done as soon as possible in order to speed up the growth rate on the best-quality stems. Practically all of the volume removed

Figure 3.--Seedling-and-sapling stand, site I.

in such a thinning could be sold as mine props. A few fundamental principles must be borne in mind. Thinnings should not be excessively heavy, because both hemlock and white pine are susceptible to sunscald on sudden exposure (7) (10). Also, in order to realize high yields it is necessary to leave a large volume of growing stock.

It must be recognized that, although hemlock may appear to be of low vigor in the present stands, it has remarkable ability to recover from years of suppression. The response seems to be in direct proportion to the length of time suppressed (11). The reverse is true of white pine. Suppressed and small-topped pines very seldom respond to release. They should be salvaged before they become decadent. Selected white pine crop trees should be rather vigorous, possessing lateral limbs to some degree.

Pruning should be conducted on crop pine trees in conjunction with the thinning operation. Even though hemlock, because of its greater tolerance, has a natural pruning effect on white pine and markedly improves its quality, some artificial pruning may be necessary (15). It must be done carefully so that too many of the living branches are not removed. Helmers6/ states that one-third of the living crown can

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6/ Helmers, A. E. How heavily should western white pine be pruned? North. Rocky Mt. Forest and Range Expt. Sta. Res. Note 41.

be removed without lowering the growth rate, but removal of more than 50 percent of the live crown is apt to cause death within a few years.

SEEDLING-AND-SAPLING STANDS

In the average seedling-and-sapling stand white pine is gradually being crowded out by the more tolerant hemlock. This condition can be improved by cleaning the young stands to liberate the intolerant pines and allow them to get their crowns above their competitors. At least one treatment should be used, and in most stands one or more succeeding applications should be made at 5-year intervals. Cline (2) in a similar operation in the white pine - oak forest type found that one to three cleanings were necessary, requiring 12-30 man-hours of labor per acre. It is likely that the third operation of this nature will produce enough small salable material, either as fuel wood or mine lagging, to meet the costs. These cuttings, although they require expenditures with little or no immediate return, will improve the stand composition and will direct the growth to high-quality crop trees so that increased dividends will be realized ultimately.

LITERATURE CITED

(1) Burnham, C. F., Ferree, M. J., and Cunningham, F. E.
1946. Site class volume tables for merchantable timber in the Anthracite Region of Pennsylvania. Northeast. Forest Expt. Sta. Forest Management Paper 3. 16 pp.

(2) Cline, A. C.
1929. Forest weeding with special reference to young stands in central New England. Mass. Forestry Assoc. Bul. 20 pp., illus.

(3) Cook, Frederick.
1885. Journals of the military expedition of Major General John Sullivan against the Six Nations of Indians. 579 pp., illus. Auburn, N. Y.

(4) Dana, Samuel T.
1930. Timber growing and logging practice in the northeast. U. S. Dept. Agr. Tech. Bul. 166. 112 pp., illus.

(5) Frothingham, E. H.
1914. White pine under forest management. U. S. Dept. Agr. Bul. 13. 70 pp., illus.

(6) ----------
1915. The eastern hemlock. U. S. Dept. Agr. Bul. 152. 43 pp., illus.

(7) Graham, Samuel A.
1943. Cause of hemlock mortality in northern Michigan. Mich. Univ. School Forestry and Conserv. Bul. 10. 61 pp., illus.

(8) Graves, H. S.
1899. Practical forestry in the Adirondacks. U. S. Dept. Agr. Div. Forestry Bul. 26.

(9) Hawley, Ralph C.
1936. Observations on thinning and management of eastern white pine in southern New Hampshire. Yale Univ. School Forestry Bul. 42. 16 pp., illus.

(10) Huberman, M. A.
1943. Sunscald of eastern white pine. Ecology 24 : 456-471, illus.

(11) Marshall, Robert.
1927. The growth of hemlock before and after release from suppression. Harvard Forest Bul. 11. 43 pp., illus.

(12) Pearce, Stewart.
1866. Annals of Luzerne County: a record of interesting events, traditions and anecdotes from the first settlement in Wyoming Valley to 1866. Ed. 2. 564 pp., illus. Philadelphia.

(13) Pennsylvania Department of Forests and Waters.
1943. Pa. Dept. Forests and Waters Service Letter 14: 85.

(14) Stickel, Paul W.
1933. Drought injury in hemlock-hardwood stands. Jour. Forestry 31: 573-577.

(15) Tarbox, E. E.
1924. Quality and growth of white pine as influenced by density, site, and associated species. Harvard Forest Bul. 7. 30 pp., illus.

(16) Toumey, James W., and Neethling, Ernest J.
1923. Some effects of cover over coniferous seedbeds in southern New England. Yale Univ. School Forestry Bul. 9. 39 pp., illus.

A P P E N D I X

DEFINITIONS OF TERMS

The terms used in this report are defined below.

Forest Sites

Site I.--This site is characterized by moist, well drained, fairly deep soils frequently of alluvial origin. It usually is found in protected coves or along streams or bottom-lands that maintain moist, well drained conditions throughout the year. On northern exposures it ordinarily extends higher up the slope than on southern exposures because of more favorable soil moisture. Club moss, hydrangea, maidenhair fern, trillium, sphagnum moss, and fern-leaf moss are fairly good indicators.

In the northern counties where northern hardwoods surround the white pine - hemlock type the principal associated species are black cherry, basswood, yellow birch, northern red oak, and red maple. In the southern counties where the oak types prevail, red oak, white oak, yellow poplar, and red maple occur as the chief associates.

In the mature stands the dominant and co-dominant species will produce 3 or more 16-foot logs per tree. Conifer dominants and co-dominants will produce $3\frac{1}{2}$ or more 16-foot logs.

Site II.--The white pine - hemlock type occurs to a limited extent on site II. Site II areas are characterized by soils intermediate in moisture, depth, drainage, and fertility. They will dry out for only short periods during the year. Usually they are slope types located between the ridges and the coves or bottom-lands. Poorly drained bottom-lands may be of site II quality. Ordinarily the site reaches nearly to the ridge tops. It reaches higher on slopes with northern exposure than on slopes with southern exposure. Trailing arbutus, ground pine, aster, goldenrod, bracken fern, and sheep laurel usually indicate site II.

In mature stands the dominant and co-dominant hardwood species will produce 2 to $2\frac{1}{2}$ 16-foot logs per tree, while the conifers will yield $2\frac{1}{2}$ to 3 16-foot logs.

Site III.--The white pine - hemlock type rarely occurs on site III. This site is characterized by shallow, rather dry, stony or compact soils characteristic of ridges. It will produce hardwood trees having less than two 16-foot logs at maturity. On southern exposures it may extend down the slope for a considerable distance, because of

unfavorable soil moisture conditions. Dense mountain laurel ground cover or a preponderance of lichens often indicate site III conditions.

Forest Stand-size Classes

Saw-timber stands.--Stands bearing a minimum volume of 2,000 board feet per acre. Saw-timber volume is measured in conifers in the 9-inch d.b.h. class and over, and in hardwoods in the 11-inch d.b.h. class and over.

Pole-timber stands.--Stands bearing a minimum volume of 5 standard cords per acre in trees in the 4-inch d.b.h. class and over, and less than 2,000 board feet of saw timber.

Seedling-and-sapling stands.--Young growth areas of forest land that have less than 5 standard cords of wood per acre in trees in the 4-inch d.b.h. class and over.

Tree Vigor Classification

In this study tree vigor is an expression of the present growth rate of a tree as conditioned by density, size, and position of the crown plus the general health of the tree as determined from its age and the presence or absence of diseases or mechanical injuries. Four vigor classes are recognized. Trees in these classes meet the following conditions:

Vigor class 1.--These trees have large dense crowns. Usually they are dominant or co-dominant with at least one-half of their crowns exposed. They are free from diseases or mechanical breakage tending to reduce the crown surface (butt rot and small mechanical injuries on tree trunks do not affect the vigor classification). They are free from old-age stagnation as evidenced by dead limbs in the crown, and they have a general healthy and thrifty appearance.

Vigor class 2.--These trees have fair-sized crowns of moderate density or large crowns of light density. Usually they are co-dominant with less than one-half the crown exposed, but with more than the tip in the open in well stocked uncut stands. They are free from diseases or mechanical breakage tending to reduce the crown surface, and are free from old-age stagnation. They may be trees that are dropped from vigor class 1 because of injury, disease, or old age.

Vigor class 3.--These trees have small dense crowns with just the tips exposed and are free from diseases and mechanical injuries tending to reduce crown surface. They have not reached old-age stagnation. They may be trees that are dropped from vigor classes 1 or 2 because of injury, disease, or old age.

Vigor class 4.--These trees are growing under obvious handicaps, such as suppression, injury, disease, or old age.

Tree Origin

Seedling.--Any tree that at present shows no union with a stump or other tree and can be silviculturally treated as a single tree.

Sprout.--Any tree that is joined to a stump, other tree, or clump of trees.

Tree Form

Good form.--Any tree that at present has a clear straight bole and is a potential saw-timber tree.

Poor form.--Any tree that is so deformed that its potential use would not exceed that of mine prop.

Other Terms

Ingrowth.--Volume of small-sized trees that have grown up into the merchantable classes during the past 10 years.

Mortality.--Number and/or volume of trees that have been lost through natural causes such as insects, windfall, disease, or suppression during the past 10 years.

Table 6.--Saw timber, site I: number of trees per acre, by species and diameter

D.b.h. (Inches)	White pine	Hemlock	White oak	Red oak	Basswood	Yellow poplar	Black cherry	Red maple	Yellow birch	Black birch	Misc.[1/]	Total	Percent
1	16	88	--	8	--	--	8	88	40	--	264	512	64.0
2	16	24	--	8	--	--	--	72	8	--	72	200	25.0
3	8	16	--	--	--	--	--	32	16	--	16	88	11.0
Total	40	128	--	16	--	--	8	192	64	--	352	800	100.0
Percent	5.0	16.0	--	2.0	--	--	1.0	24.0	8.0	--	44.0	100.0	--
4	3.2	10.0	2.4	2.2	1.6	--	0.5	26.1	1.6	3.7	3.2	54.5	18.5
5	3.5	6.8	--	1.1	3.7	--	.8	11.1	1.6	1.8	3.7	34.1	11.6
6	3.2	11.8	--	1.3	2.4	--	2.4	8.2	2.4	.5	--	32.2	10.9
7	4.0	12.6	2.4	1.6	.8	--	.8	2.9	1.6	.5	1.3	28.5	9.7
8	3.2	6.5	2.4	3.7	--	--	.8	4.8	--	--	--	21.4	7.3
9	1.1	12.7	2.4	.8	--	--	.8	.5	.8	.5	2.1	21.7	7.4
10	1.5	8.0	8.0	4.3	1.6	--	--	.8	--	.5	.8	25.5	8.7
11	3.2	8.9	.8	--	--	--	--	.8	--	.5	--	14.2	4 8
12	4.0	2.9	1.6	1.3	--	--	--	--	--	--	.8	10.6	3.6
13	5.0	5.2	--	1.3	--	--	--	--	--	--	.5	12.0	4.1
14	.5	2.4	--	1.3	--	--	--	--	--	--	--	4.2	1.4
15	1.3	2.4	--	1.8	--	--	--	--	--	--	--	5.5	1:9
16	.8	2.1	--	--	--	--	--	--	--	--	--	2.9	1.0
17	.8	3.7	--	.5	--	--	--	--	--	--	--	5.0	1.7
18	1.9	2.1	--	--	--	--	--	--	--	--	--	4.0	1.4
19	2.1	--	--	.5	--	.5	--	--	--	--	--	3.1	1.0
20	.5	.8	--	1.0	--	1.0	--	--	--	--	--	3.3	1.1
21	2.1	--	--	1.0	--	--	--	--	--	--	--	3.1	1.0
22	1.1	--	--	1.1	--	--	--	--	--	--	--	2.2	.7
23	1.9	1.6	--	--	--	--	--	--	--	--	--	3.5	1.2
24	1.1	--	--	--	--	--	--	--	--	--	--	1.1	.3
25	1.1	--	--	--	--	.5	--	--	--	--	--	1.6	.5
28	.5	--	--	--	--	--	--	--	--	--	--	.5	.2
Total	47.6	100.5	20.0	24.8	10.1	2.0	6.1	55.2	8.0	8.0	12.4	294.7	100.0
Percent	16.2	34.1	6.8	8.4	3.4	0.7	2.1	18.7	2.7	2.7	4.2	100.0	--

1/ Includes noncommercial species (shadbush, dogwood, crataegus) totaling 296 stems under 4 inches d.b.h. and 1.1 stems over 4 inches d.b.h., and commercial species (chestnut oak, sugar maple, white ash, butternut, elm, aspen) totaling 56 stems under 4 inches d.b.h. and 11.3 stems over 4 inches d.b.h.

Table 7.--Saw timber, site I: volume per acre, by species, diameter, and tree form (1)

Item	Poor form	Good form	Total		Poor form	Good form	Total	
	Cubic feet	Cubic feet	Cubic feet	Percent	Board feet	Board feet	Board feet	Percent
Species:								
White pine	4.6	1,641.8	1,646.4	38.7	--	8,743	8,743	47.4
Hemlock	99.5	1,254.0	1,353.5	31.8	367	5,795	6,162	33.5
White oak	.6	201.7	202.3	4.7	--	168	168	.9
Red oak	25.2	525.3	550.5	12.9	--	2,177	2,177	11.8
Chestnut oak	--	11.9	11.9	.3	--	46	46	.2
White ash	11.5	--	11.5	.3	--	--	--	--
Basswood	4.1	34.9	39.0	.9	--	--	--	--
Yellow poplar	41.4	147.8	189.2	4.5	221	791	1,012	5.5
Black cherry	9.2	17.4	26.6	.6	--	--	--	--
Sugar maple	18.9	1.1	20.0	.4	--	--	--	--
Red maple	67.7	61.3	129.0	3.0	--	48	48	.3
Yellow birch	21.7	3.8	25.5	.6	--	--	--	--
Black birch	24.9	2.0	26.9	.6	25	--	25	.1
Elm	16.0	--	16.0	.4	62	--	62	.3
Aspen	7.6	--	7.6	.2	--	--	--	--
Butternut	4.8	--	4.8	.1	--	--	--	--
Misc. 1/	.5	--	.5	--	--	--	--	--
Total	358.2	3,903.0	4,261.2	100.0	675	17,768	18,443	100.0
D.b.h.: (Inches)								
4	18.0	6.6	24.6	0.6	--	--	--	--
5	20.8	21.9	42.7	1.0	--	--	--	--
6	38.8	44.9	83.7	1.9	--	--	--	--
7	36.0	82.3	118.3	2.7	--	--	--	--
8	23.8	114.7	138.5	3.3	--	--	--	--
9	56.9	130.3	187.2	4.4	50	251	301	1.7
10	44.5	267.7	312.2	7.4	33	373	406	2.2
11	7.7	215.1	222.8	5.2	25	891	916	4.9
12	25.8	192.6	218.4	5.1	106	823	929	5.1
13	--	305.4	305.4	7.3	--	1,409	1,409	7.6
14	--	125.3	125.3	2.9	--	589	589	3.2
15	--	196.4	196.4	4.6	--	970	970	5.3
16	20.6	101.7	122.3	2.9	110	548	658	3.6
17	23.9	217.1	241.0	5.7	130	1,179	1,309	7.1
18	--	226.4	226.4	5.3	--	1,289	1,289	7.0
19	--	206.3	206.3	4.8	--	1,166	1,166	6.3
20	41.4	205.1	246.5	5.8	221	1,129	1,350	7.3
21	--	255.8	255.8	6.0	--	1,455	1,455	7.9
22	--	200.2	200.2	4.7	--	1,120	1,120	6.1
23	--	358.6	358.6	8.4	--	2,125	2,125	11.5
24	--	129.1	129.1	3.0	--	757	757	4.1
25	--	213.0	213.0	5.0	--	1,207	1,207	6.5
28	--	86.5	86.5	2.0	--	487	487	2.6
Total	358.2	3,903.0	4,261.2	100.0	675	17,768	18,443	100.0
Percent	8.4	91.6	100.0	--	3.7	96.3	100.0	--

1/ Noncommercial species: shadbush, dogwood, crataegus.

Table 8.--Pole timber, site I: number of trees per acre, by species and diameter

D.b.h. (Inches)	White pine	Hemlock	Pitch pine	White oak	Red oak	Black cherry	Red maple	Yellow birch	Black birch	Gray birch	Misc. 1/	Total	Percent
1	25	127	--	--	--	--	12	--	--	--	12	176	25.2
2	1	161	--	--	--	--	25	17	--	--	--	204	29.2
3	27	225	--	12	--	--	--	43	--	--	12	319	45.6
Total	53	513	--	12	--	--	37	60	--	--	24	699	100.0
Percent	7.6	73.4	--	1.7	--	--	5.3	8.6	--	--	3.4	100.0	--
4	11.8	170.6	--	6.4	2.5	--	18.1	26.9	2.5	16.7	19.2	274.7	35.1
5	32.7	102.4	--	5.0	5.8	13.4	9.2	22.1	2.5	3.3	11.7	208.1	26.6
6	9.3	71.1	--	7.5	--	1.7	10.0	4.8	--	--	2.5	106.9	13.6
7	10.3	81.0	--	2.5	6.7	1.7	2.5	1.7	--	--	--	106.4	13.6
8	7.9	27.6	2.5	2.5	2.5	--	1.7	1.7	--	--	--	46.4	5.9
9	8.1	12.5	--	--	2.5	--	--	--	--	--	--	23.1	2.9
10	5.8	8.6	--	--	--	--	--	--	--	--	--	14.4	1.8
11	--	1.7	--	--	--	--	--	--	--	--	--	1.7	.2
12	--	2.5	--	--	--	--	--	--	--	--	--	2.5	.3
Total	85.9	478.0	2.5	23.9	20.0	16.8	41.5	57.2	5.0	20.0	33.4	784.2	100.0
Percent	11.0	61.0	0.3	3.0	2.6	2.1	5.3	7.3	0.6	2.6	4.2	100.0	--

1/ Includes noncommercial species (shadbush, crataegus) totaling 12 stems under 4 inches d.b.h. and 24.2 stems over 4 inches d.b.h., and commercial species (hickory, black oak, aspen) totaling 12 stems under 4 inches d.b.h. and 9.2 stems over 4 inches d.b.h.

Table 9.--Pole timber, site I: volume per acre by species, diameter, and tree form (1)

Item	Poor form	Good form	Total		Poor form	Good form	Total	
	Cubic feet	Cubic feet	Cubic feet	Percent	Board feet	Board feet	Board feet	Percent
Species:								
White pine	45.2	315.2	360.4	21.5	--	561	561	37.3
Hemlock	105.6	818.7	924.3	55.1	109	834	943	62.7
Pitch pine	--	12.7	12.7	.8	--	--	--	--
White oak	28.9	33.9	62.8	3.7	--	--	--	--
Red oak	49.7	28.8	78.5	4.7	--	--	--	--
Black oak	--	3.0	3.0	.2	--	--	--	--
Black cherry	8.4	18.4	26.8	1.6	--	--	--	--
Red maple	78.2	--	78.2	4.6	--	--	--	--
Yellow birch	40.6	39.7	80.3	4.8	--	--	--	--
Black birch	--	4.9	4.9	.3	--	--	--	--
Gray birch	13.2	--	13.2	.8	--	--	--	--
Hickory	--	2.2	2.2	.1	--	--	--	--
Aspen	1.2	7.8	9.0	.6	--	--	--	--
Misc.1/	19.5	--	19.5	1.2	--	--	--	--
Total	390.5	1,285.3	1,675.8	100.0	109	1,395	1,504	100.0
D.b.h. (Inches)								
4	60.4	44.1	104.5	6.2	--	--	--	--
5	103.1	123.3	226.4	13.5	--	--	--	--
6	111.1	134.6	245.7	14.7	--	--	--	--
7	46.6	329.7	376.3	22.5	--	--	--	--
8	11.9	259.1	271.0	16.2	--	--	--	--
9	42.4	162.0	204.4	12.2	52	469	521	34.6
10	15.0	158.2	173.2	10.3	57	597	654	43.5
11	--	25.3	25.3	1.5	--	107	107	7.1
12	--	49.0	49.0	2.9	--	222	222	14.8
Total	390.5	1,285.3	1,675.8	100.0	109	1,395	1,504	100.0
Percent	23.3	76.7	100.0	--	7.3	92.7	100.0	--

1/ Noncommercial species: shadbush, crataegus.

Table 10.--Seedling and sapling, site I: number of trees per acre, by species and diameter

D.b.h. (Inches)	White pine	Hem-lock	White oak	Red oak	Red maple	Black birch	Gray birch	Aspen	Misc. 1/	Total	Per-cent
0.25	10	1,370	30	20	20	980	20	--	--	2,450	35.2
1	100	590	--	10	--	1,420	60	40	50	2,270	32.6
2	650	120	10	10	10	490	100	10	20	1,420	20.4
3	600	40	--	--	--	120	20	40	--	820	11.8
Total	1,360	2,120	40	40	30	3,010	200	90	70	6,960	100.0
Percent	19.5	30.5	0.6	0.6	0.4	43.2	2.9	1.3	1.0	100.0	--
4	100	20	--	--	--	40	--	40	--	200	57.5
5	40	--	--	--	--	10	--	--	--	50	42.5
Total	140	20	--	--	--	50	--	40	--	250	100.0
Percent	56.0	8.0	--	--	--	20.0	--	16.0	--	100.0	--

1/ Noncommercial species: witch hazel, shadbush, sassafras.

Table 11.--Seedling and sapling, site I: volume per acre by species, diameter, and tree form (1)

Item	Poor form	Good form	Total	
	Cubic feet	Cubic feet	Cubic feet	Percent
Species:				
White pine	5.0	101.0	106.0	63.4
Hemlock	--	6.2	6.2	3.7
Black birch	10.0	25.0	35.0	20.9
Aspen	5.0	15.0	20.0	12.0
Total	20.0	147.2	167.2	100.0
D.b.h.: (Inches)				
4	20.0	76.2	96.2	57.5
5	--	71.0	71.0	42.5
Total	20.0	147.2	167.2	100.0
Percent	12.0	88.0	--	100.0