EASTERN HEMLOCK
ITS RELATIONSHIP TO THE
SILVICULTURAL POLICY OF THE HARVARD FOREST

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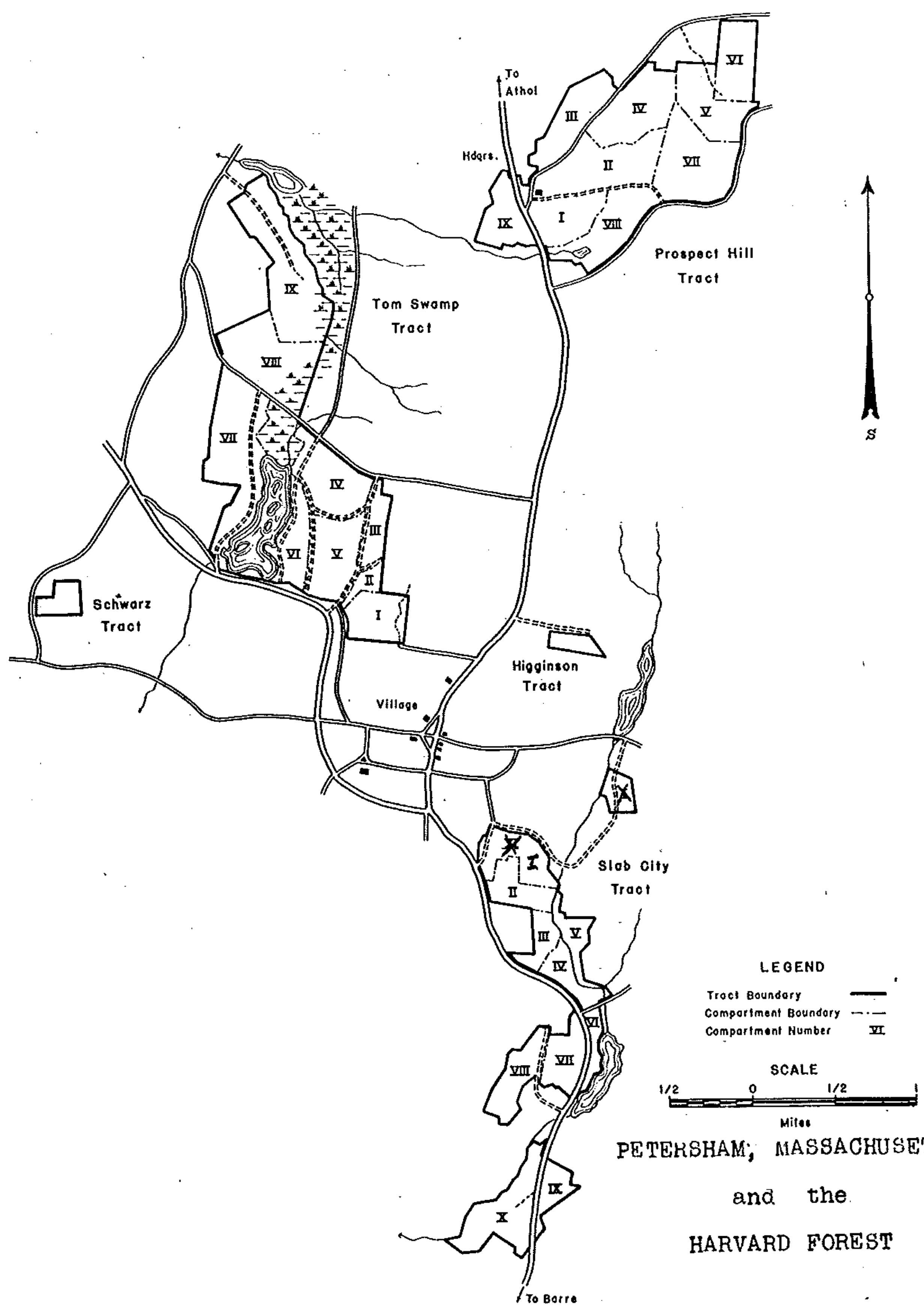

PETERSHAM, MASSACHUSETTS

and the

HARVARD FOREST

Willett Rowland

INTRODUCTION

Eastern Hemlock, *Tsuga canadensis* (L.) Carr., can be considered a problem in our forests. The ability of hemlock to exist for long periods of time as a supressed tree has long been known. This habit in itself is to our advantage and disadvantage. Hemlock is increasing in many of our stands as an understory species. This is the crux of our problem: if we remove the overstory, will the hemlock come through and form the next crop? If so, shall we discriminate against hemlock with the hope of bringing another species through as the dominant species in the next rotation? Even if this is desirable, can we afford to remove the understory in quantities large enough to permit the regeneration of other species? If we can afford the preceding operation, would it be advisable from a biological standpoint?

There are many reasons for the distribution pattern of a species. Some of these extend back to the orogeny of the area, which in turn was followed by the erosion cycle that existed during the intervening time. The pleistocene with its various advances and retreats of ice which scoured the surface and dropped till, and added outwash and in many cases deposited loesses in immediate postglacial times, all of which was modified by the frost action of a periglacial climate.

These factors along with the various climates all affected the topography, soils, slope, drainage and various other physical features. Vegetation of many kinds has during the intervening years added its quota of change to the area in the various successions which have passed or are passing. The natives of the region made no important changes with the exception of fire. The actual extent to which they affected the vegetation cannot be determined at this late date as it is not easy in many cases to distinguish where fire was present before or after colonization. In some cases there are records written in the older trees of fire scars which occurred before the earliest known settlers had arrived. This may have been due to lightening or some other natural cause, or it may have been the aborigines. Many other phenomena, such as ice storms, hurricanes, heavy wet snows, extreme wet or dry periods, all left their mark on the vegetation of the area. Insects, fungi, and other diseases also did their part.

All of these modifying factors are of little importance in our present stands compared to the white man with his ax, plow, cattle, sheep, fire, and his need of the forest to supply him with many necessities and conveniences which were only obtainable from the forest, plus the fact that the forests were in his way.

These are some of the problems which have a bearing on why a stand of hemlock is located in a given spot. As can be seen these problems cannot be solved by one person or by the men of one profession, but rather by the combined efforts of the geologist, the economist, the anthropoligist, the chemist, the physicist, and the many facets of biology.

The bearing that this problem has on the Harvard Forest is a direct one, as in the last few years while marking stands for thinning, the problem has arisen as to how to treat the hemlock understory and large individual trees. It could be thinned with the hope of making space for upper canopy species to reproduce or come in as seedling sprouts, or it could be left to come through as a crop of hemlock.

Leopold (1949) remarks, "Some species of trees have been 'read out of the party' by economic-minded foresters because they grow too slowly, or have too low a sale value to pay as timber crops: white cedar, tamarack, cypress, beech and hemlock are examples." Others such as Merill and Hawley (1924) go to the other extreme and advocate the change of many types of stands to hemlock. Although our problems are basically long term, the overall pattern will give us an insight into the problems of today. We must then handle our stands in a manner which will most nearly approach the natural succession and with the least amount of economic compromise to keep a forest business in operation. Another important item is the closely related problem of keeping an area in controlled production. This may be thought of in terms of Hosmer's plan (1948) for a pilot plant in the field of forest industry. The whole foundation for this idea is dependent on the ability of a given area of land to produce a continuous crop which is economically valuable.

Objects and Methodology

This work was undertaken to present the available data on eastern hemlock in such a way that it will be available and useful in silvicultural operations. The idea originated in the summer of 1948 when the problem of marking stands containing considerable hemlock were encountered. It is the writer's intention to locate some of the significant data which have been written in the past and interpret some of the stands and records of the forest in the light of these data.

The data will be brought to bear on several of the important characteristics of eastern hemlock with special emphasis placed on the Prospect Hill stands of the Harvard Forest in an attempt to point out some of the various problems. A number of photographs will be included to further clarify various points. Prospect Hill was chosen as the most suitable area because of the complete coverage of type, soil, land use and hurricane damage maps. The 1946 type maps were made by use of areial photographs, with a close ground check; and in this way the area and composition of the stands were very closely mapped. From these data the composition of the various stands could be evaluated before making extensive field checks.

The field and reference work was carried out during the spring of 1949. The Harvard Forest library and records were extensively used. The following libraries of Harvard University were consulted; the Library of the Arnold Arboretum, Biological Laboratories, Gray Herbarium, Library of Economic Botany, Widner Library, Library of Anthropology. The Library of the Horticultural Society, in Boston, Mass. was also consulted.

REVIEW OF THE IMPORTANT LITERATURE

Many of the early writers discuss eastern hemlock in relation to its medicinal properties and its ornamental value. The writers of the latter part of the nineteenth century usually predicted an early elimination of hemlock as an important species in our northeastern forests. This was based on the apparent lack of reproduction and the wasteful method of logging that was carried out by the tanning industry. The value of hemlock lumber was quite low at the time, therefore, the trees were cut and peeled, the bark removed, and the logs left to rot in the woods. Walsh (1896) states that the tanning industries' use of hemlock bark was on the decline at this time. After 1899 the average price of hemlock lumber rose from $11.84 / M bd. ft. to #32.65 / M bd. ft. in Massachusetts (Steer, 1948). The price quoted by a lumber dealer in Athol, Massachusetts was $70.00 / M bd. ft. lumber tally in the summer of 1949.

Sargent (1898) gives the silvical features of eastern hemlock and sums up some of the earlier uses, such as medicinal and ornamental values.

The diseases of hemlock, both physiological and pathalogical, are discussed by Spaulding (1914). He considers wind shake, drought and sunscorch to be the most important dangers.

Frothingham (1915) sums up most of the early literature and organizes it in useful form. Some excerpts from his paper gives us interesting ideas as to various phases of the history and utilization of hemlock. "Compared to pine, hemlock has been lumbered for only a short time..." Speaking of the utilization of hemlock, "Small quantities of hemlock lumber were produced in the northeast during the early days, but not until the bulk of the pine had gone was it able to find a wider market".

Boardman (1883) discusses the position of hemlock in the forests of Maine as follows: "The distribution of hemlock in this state appears not to be a matter of latitude, so much as it is a matter of soil. And it is not the elevation of the land, so much as it is the character of the land on which it succeeds best. On high land — what we term our highest hills — the hemlock does not attain so large a growth, as on lower, (not the lowest), land of forest growth. The hemlock that grows on high land, differs materially from that growing on the lower soils, or on what we term the 'natural hemlock lands'. The trees on the high locations grow tall and slim, and have a finer, thinner, white bark: while those growing on the lower ground are shorter bodied, and have a coarser, thicker bark, one which contains a large percentage of 'gum', on which account it is more highly valued for tanning purposes."

Three general sets of silvicultural practices have been advanced in the literature. All of these suggestions are based on restricted areas and in some cases a different objective was in mind for the practice.

Merrill and Hawley (1924) advanced six general rules from which they are admittedly trying to increase hemlock in the sprout hardwood stands of Southern New England. They are as follows:

1. Afford continuous protection from fire.
2. In all cuttings, preserve young hemlocks even though overtopped by other trees.
3. When thinning and improvement cuttings are made, select the trees for removal in such a way as to encourage the development of overtopped hemlock.
4. In cutting stands of mixed hardwoods and hemlock, leave one to ten thrifty hemlocks per acre. These trees while providing the seed for starting a crop of hemlock seedlings, will grow rapidly in diameter and height.
5. When stands, containing hemlock or with hemlock seed trees adjacent, are to be cut, heavily graze the area for several years before and after cutting.
6. When pure stands of hemlock are to be reproduced, a shelterwood cutting, if the stand is evenaged, or a group selection cutting if unevenaged,

should result in starting abundant reproduction. Black birch and possibly other hardwoods will become established at the same time. If the treatment listed under point five is carried out, the black birch and other hardwoods may be kept down sufficiently for establishment of another pure hemlock stand.

Marshall (1927) worked out a series of marking recommendations in Petersham, Massachusetts on what is now a part of the Harvard Forest. The soil is light and well drained and the area has always been in woods, probably pine and hemlock. Based on an intensive study, Marshall recommended for this area, a group selection cutting with the following main points:

1. Removal of small patches of timber and avoidance of anything resembling clearcutting will protect the soil from serious injury and exposure.

2. Dense reproduction is easy to obtain. The small area cut, even if it has no advanced growth of hemlock, will seed in from the side. Dense reproduction will result in high volume, good quality, and rapid growth.

3. The advantages of suppressing hemlock are:

(1). Good quality - limbs pruned.

(2). In the long run the suppressed tree will make better growth.

(3). Suppressed hemlock will make a good pruner in a mixed stand.

(4). Overlapping rotations. The reproduction can be established several generations before the old crop is ripe.

4. The group selection method is well adapted for a forest managed for sustained yield.

5. Fire danger is less in a group selection system because large unbroken areas of reproduction and slash are not present.

6. Group selection is practical from a logging standpoint. The area cut may be large enough to avoid difficulties in felling while the cost of operation may be kept as low as by any system except clearcutting. Only relatively large timber is cut and this saves expense in felling, hauling and milling.

Graham (1943) shows the effect of exposure on hemlock after cutting and gives some reasons why hemlock does not take over large areas and form pure stands. The reasons given are sudden exposure and subsequent fungal and insect attack. The following are some of his rules for marking a stand of hemlock in northern Michigan, but these basic rules can be generalized.

1. Hemlock cannot stand severe exposure.

2. Nothing is to be gained by leaving merchantable

trees that are likely to die before they can be removed in the next cut. Therefore, if silvicultural or economic conditions demand the removal of exposure resistant species that are sheltering hemlock the latter should be marked for cutting. (Except on northern slopes when trees have heavy crowns and are on a good site).

3. Do not expose hemlock regardless of crown from the south and west.

4. All hemlock with short narrow crowns should either be marked for cutting, or if reserved, sheltered from the south and west sides.

Kellogg (1931) in his book lists various physical properties of hemlock wood in comparison with other species. Brown and Panshin, (1940), give a detailed description of the structure, identification, properties, and uses of hemlock.

Harlow and Harrar (1941) sum up the botanical features and give a good description of the species with photographs of the gross morphology of the tree and include a range map of the species. Harlow (1942) describes some of the wood-craft and wildlife uses of eastern hemlock.

Hough and Forbes (1943) in discussing a virgin forest on the high plateaus of Pennsylvania give us an insight as to the role of hemlock in a virgin forest and some reasons for its limited area of pure stands. They trace the history of some trees back at least 420 years.

Baldwin and Heermance (1949) show the volume of hemlock saw timber in New England by states. These data are contained in their study of the function of forestry in the New England economy. The paper goes on to say that as important as forestry and the forest-based industries are now, they can become more important in the future if our methods of forest management are improved.

BIOLOGICAL FACTORS

The following factors are discussed and in some cases documented to provide a background of data for the conclusions which have been drawn from the literature and field observations. This is by no means a complete review of the factors, but only the ones which are deemed most important within the scope of this paper.

Hemlock in the Pre-Colonial Forest.

Eastern hemlock has been a constituent of the Petersham forests since primeval times, as shown by Whitney (1793). He writes of Petersham, "....On the highlands the growth of wood is oak, more chestnut, and a great deal of walnut (hickory) of later years. In the swamps and lowlands there is beech, maple, oak, elm, and hemlock." Writing of Athol he says, "....Oak, chestnut, ash, beech, birch, hemlock, and maple constitute the principle growths of wood." The data cited above when viewed from the standpoint of the date 1793 will show that hemlock was a relatively minor species in the pre-colonial forest and did not form pure stands over large areas, or such a discerning writer as Peter Whitney would have noted this fact.

Peter Whitney's writings, as shown by Raup and Carlson (1941), were accurate. Raup and Carlson also indicate that Petersham was settled in 1733 and up to the year 1791 only small areas were cleared for subsistance agriculture. This amounted to 1.2% for tillage and 11.8% for meadows, mowings, and pasture by the year 1791. This shows that 87% of the land was still woodland when Whitney's account was written; and the woods he described would have existed before the large scale clearing was carried out to feed the mill towns, that sprang up as a result of the industrial revolution after 1800.

Scudder (1948) cites the following types which contained hemlock in the pre-colonial forests of central New England:

> "Pitch Pine plains,.....this type verged rather gradually into the white pine and white pine-hemlock type. These types occurred on gravelly and sandy well-drained soils usually of outwash origin.
>
> The Ravine type, which was very similar to the hemlock northern hardwood type of the uplands further north, consisted of hemlock, red and sugar maple, black and yellow birch, beech, ash, and some white pine. This type usually was found on cold rocky north facing ravines.
>
> The hemlock-northern hardwood type was found over large areas of uplands in the northern part of the region and in considerable variation. Cline and Spurr (1942), found that in its virgin state in the Pisgah tract it consisted,.......primarily of hemlock, beech, and sugar maple, with black birch and white ash as other major components and yellow birch and red spruce as species of minor importance.
>
> The white pine-hemlock type was found by Cline and Spurr (1942) on the upper slopes and ridges in the Pisgah tract. In addition to the pine and hemlock there were lesser amounts of beech, black birch and red maple. This is fundamentally the same type as the white pine-hemlock described under the pine plains."

The foregoing represents an attempt by man to force a biological problem into a category. The types, as may be expected, graded into each other; and many possibile combinations of species were in all probability found. This is true today in that they only keep a sharp identity in extremes, while there are all stages of gradation between types.

Land Use as a Factor.

The land use history map and the 1946 type map of the Prospect Hill tract show a distinct relationship. The following four different classes of hemlock stands were determined from the type map:

1. Hemlock in a pure stand or as a dominant member.
2. Hemlock as the second most important crop.
3. Hemlock as a relatively minor species.
4. Hemlock as a dominant member of the understory.

By superimposing the land use map on the type map we see that 14 of the 19 stands in the Prospect Hill tract falling in class 1 and 2 lie wholly or in part in the area which has always been in woods. (see plate 1). The remaining 5 areas of the first two classes have a varied history, although the land use studies do not show that they have always been in woods; two of the areas were created by the death of the American chestnut (Plate IV). These are all shown as having been in pasture which may or may not have had scattered wood-lots or individual trees while being pastured. Merill and

Hawley (1924) point out, "Grazing animals have the effect of reducing ground cover and litter, which is likely to encourage hemlock reproduction. Further, and more important, the animals browse upon the hardwood seedlings and sprouts, but do not injure the hemlocks. The reduction of competition in this way between hardwoods and hemlock is frequently the decisive factor in enabling the hemlock seedlings to gain ascendancy."

Another interesting comparison which can be shown between the type map and the land use map is the complete lack of hemlock in sufficient quantity to type on areas which were cultivated. This, or course, may be due to the fact that the only land cultivated was land that did not support large amounts of hemlock in the pre-colonial forest.

The type maps of the Tom Swamp and Slab City tracts, (Plate II and III), are included. The hemlock stands are classified in the same manner as the ones in Prospect Hill. The apparent observation is the increasing amount of hemlock which is coming in as an understory species. Slab City X, shows a relationship between what may have been pastured terraces in a wood lot and the position of hemlock in the stand. There are a number of places where several large hemlock trees are located on very rough stony slopes, which may be the front of a stone-banked terrace. On the terrace proper, or the area that would have been pastured, there is an understory of young hemlocks fanning out from the several large trees which are the apparent seed source.

Seedling Characteristics.

Frothingham (1915) states that a hemlock usually bears cones when it is from 20 to 40 years old and from 15 to 25 feet in height. The cone begins to develop during the first part of July, and by October the cone is mature. These cones are sensitive to moisture, and a small amount causes the scales to close rapidly. If there is considerable moisture the cone closes completely usually within 10 to 20 minutes. This is a decided advantage in the dissemination of the seed, because with the alternate opening and closing of the cone scales, the tree is able to spread its seeds in many directions. This seed dispersion is carried out from autumn to spring. The seeds have an attached wing of a delicate and transparent material which makes it suitable for wind dissemination.

According to Betts (1945), abundant seeds are produced every 2 to 3 years, and the seeds germinate readily. Ordinarily only 30 to 60 percent of the seeds are fertile, and they germinate in the spring from March until the end of May.

Reproduction and Establishment

Reproduction is of paramount importance in all silvicultural problems. Frothingham (1915) makes the statement, "...Too much or too little shade will kill hemlock seedlings." Based on observations in central Massachusetts, this generally seems to hold true. In old fields, hemlock does not seed in as readily as white pine; and even in the larger clearings in the forest hemlock does not seem to be reproducing to its fullest extent, even where a seed source is available. On the other extreme, under the dense shade of a hemlock stand, the reproduction — which to a large extent is hemlock — is relatively sparce and not as vigorous as can be found in semi-open areas. This area is shown in Plate IV and Table #1. The area shown above was operated in 1946 whan an improvement and salvage cutting was carried out on about one acre. The opposite is found in a small opening near a stand of several large hemlocks where the species has shown a remarkable ability to reproduce. This reproduction is on the edge of a blowdown which is partly sheltered by deciduous trees on one side and near the large hemlocks on the other side. (See Plate V and Table #2).

Hough and Forbes (1943) sum up this problem by saying, "The controls influencing the periodicity of hemlock in the virgin forest are not alone the large scale climatic or other catastrophies affecting mature trees. Success or failure of hemlock reproduction during given periods in the life of the forest also depends on a complex of microhabitat factors. Among these are the presence of viable seed, a substrate suitable for germination and establishment, light, soil moisture, and mineral salts sufficient for survival and growth. Due to the shallow rooting which creates severe root competition in the upper soil layers, dense low shade, and dry acid litter, a young, fully-stocked stand of hemlock may practically exclude any further reproduction from seeds during long periods. The long gaps in the occurance and the peak of establishment of hemlock in other periods are in a large measure consequences of the silvical characteristics of hemlock."

The chart, as shown in Figure #1, is adapted from one of Hough and Forbes (1943), showing the periodicity of hemlock establishment. Their data were collected in a virgin stand in northwestern Pennsylvania.

Tolerance and Growth

Hemlock has long been known as one of the most tolerant species in the northeastern United States. Because of this feature, hemlock will stand suppression for many years as an understory species; and when released by the removal of the overstory, either naturally or by cutting, the hemlock will respond to the release with vigorous growth. There have been documented cases of this, such as Marshall (1927) and Smith (1948). Merill and Hawley (1924) point out, "..,When the hardwood upperstory is cut the understory of hemlock occupies the ground and develops into a pure stand of hemlock."

The work of Marshall (1927) on the Harvard Forest states, "Suppressed hemlock shows a remarkable increase in growth when released." He based this on 362 trees, which showed a ratio of 1 to 5½ increase in 40 years — on a comparison period of 40 years before release and 40 years after release. He also points out, "The response of hemlock stands to release is influenced by their density, the well-stocked stand showing greater acceleration in growth than poorly stocked stands." He goes on to say that a good, well-stocked stand will produce better formed trees; and then when they are released, their growth and form will be better than if they were open grown.

Influence of Hemlock on the Forest Community

Eastern hemlock has played its role, in the past, as an intermediate or suppressed member of the forest community, by hastening the natural pruning process of associated species. Baker (1934) says, (hemlock)....... "Will play its most important part as an understory tree, forcing pine and hardwoods to good quality increment and contribute to the full stocking of the area."

Reference to Plate VI and VII will show two red oaks which have grown with an understory of hemlock. Plate VI is a red oak which is located in Prospect Hill II and is growing in an unthinned stand, while Plate VII is an oak in a stand which has recently been thinned in Prospect Hill VII. The reason usually advanced for the pruning effect of hemlock on other species is that the shade tends to keep the branches small. They are then broken off by actual friction between the trees.

Tarbox (1924) describes the effect of hemlock on white pine in mixed stands, "White pine shows excellent quality where the individual tree is shut off from contact with others of the same species by intervening species."

This is well demonstrated in Slab City X of the Harvard Forest where there are pure stands of pine which are course and limby, while pines of about the same age that are grown in a mixture with hemlock and hardwoods are straight and clear.

The roots of hemlock are massed in the upper soil as shown by Daubenmire (1934). This fact coupled with the dense shade produced by a closed canopy of hemlock will result in a very low percentage of forest floor herbs under hemlock. As may bee seen in Plate IV the reproduction of tree species is also quite sparse.

Plate VIII shows a hemlock understory, in an unthinned stand, which will form the next crop when the overwood is removed, unless some control is exerted to reduce the quantity of hemlock. An understory of hemlock in a thinned stand is shown in Plate IX. Here the understory appears rather sparse, but over the stand as a whole it creates a satisfactory picture and fills a definite need in the protection of the site and the stocking of the stand.

Case History of a Prospect Hill II Stand

The summary sheet of the 1909 forest inventory shows this area (See Fig. #2) to have been hemlock-transition hardwood. The volume at that time was about 8,000 bd. ft. per acre and had been cut about 1850. From the data available it appears that the area has always been in woodlands since pre-colonial times.

Cole (1909) examined the area for a proposed cordwood cutting and recorded the following observations:

> "A low ridge of hardwoods and chestnut over hemlock, chestnut and hardwood reproduction. The ridge contains about 10 acres.
>
> The type may be described in general as mixed hardwoods and chestnut with an undergrowth of hemlock, scattered and in bunches. The species are as follows; chestnut, red maple, red oak, beech, black and white birch, hemlock, white pine, black ash, white oak and red spruce. Chestnut makes up from 1/3 tp 1/2 the stand. The hardwoods consist mainly of red maple, red oak, and black and white birch while beech and hemlock are numerous. In two 1/4 acre sections the trees 3" and up were divided as follows: chestnut 33%, red maple 15%, red oak 5%, black and white birch 10%, hemlock 15%, and beech 15%. The last two fugures ran nearly altogether in the small diameters and do not figure as much in the crop as the figures would indicate."

The forest inventory of 1923 showed that hemlock was still in the lower height and diameter classes of the stand (see table #3).

In 1931-32 an improvement cutting was carried out to release subordinate stands of hemlock, white pine, red spruce and paper birch from overtopping by poor hardwoods (see fig. #3). At this time the following data were recorded concerning the stands. The area had been cut twice before. About 120 years ago (1830) the chestnut and pine were taken out. Then about 50 years ago (1900) another cut, mostly chestnut, was carried out. The stand at the time, of this operation (1931-32) was made up of red oak, paper birch, red maple, white ash, yellow birch, and black birch overtopping hemlock and pine. The oaks averaged 85 years, and many had broken tops as a result of the ice storm of 1921. The stand remaining after the cut was hemlock, pine, red oak and paper birch, making about a 6/10 crown canopy with an average height of about 45 feet.

In 1931 thirty-six cords of red oak, red maple, white ash, black birch, paper birch, chestnut, and yellow birch were removed. The 1932 cutting was about the same as 1931 except the early cuttings seem to have been almost entirely chestnut. There was a heavy stand of pole-sized chestnut, killed by the blight, which was still standing in 1932. The cut consisted of 28 cords of red oak, red maple, white oak, gray birch, paper birch, and other minor species.

In 1940 a salvage cutting was carried out to remove the hurricane damage of 1938. Small groups of hardwoods and pines were destroyed, but where hemlock formed dense groups no windthrow occurred. Cutting was carried out only in the blowdown areas. The stand at this time was generally between 80 and 90 percent hemlock, with a few scattered red oak crop trees and practically no white pine. The advance reproduction was sparse.

A gale, from the east, during December 1941 caused considerable windthrow among the residual hardwoods, although the damage was mostly on the windward margin of the openings. The height at this time was 50 to 70 feet.

A salvage operation in 1949 was carried out for chestnut, and this operation adjoined the one of 1931-32 to the north. (See Fig. #4).

This work completed the operations to date on the area, and the various stands making up the area show hemlock dominating in all cases (see plate I). The stand has been converted to hemlock by the removal of the overstory, which contained various hardwood species with scattered pines. The death of the chestnut and the improvement cuttings were the primary factors, but windthrow also played an important part.

Two views of the interior of the stand show hemlock dominating almost to the exclusion of other species (see plates X and XI). Plate VI is a view of a red oak which is also located in this stand.

Inimical Agencies of Eastern Hemlock

Perley Spaulding (1914) compiled a list of the diseases of eastern hemlock. The most important type he describes as physiological diseases. Lumber men and foresters who have had experience with hemlock are inclined to suspect any mature (20" and up)* hemlock of shake. The fault known as shake has been attributed to wind in its twisting and bending action on the sharply defined annual rings. Another theory is the change in growth that ensues after a release and causes a differential tension; and then when a sudden strain is exerted, as by the wind, a parting or a tearing along the ring occurs. The shake itself is bad because the lumber which is sawn from a shaky tree will not hold together and thus becomes worthless.

During the spring of 1949 a small stand of hemlock was cut near the Harvard Forest, which ran from about 10" to about 20" in DBH. The mill operator who bought the timber disclosed that relatively little shake was present. The few trees that were around 20" gave indication that shake was present, by an examination of the stumps.

Drought and Sunscorch.

As has been shown previously the roots of hemlock

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* Foster and Kirkland, 1949.

are located in the upper layer of soil, and this fact makes them susceptible to drought. This dryness can either be due to natural causes or to the opening of the forest to such an extent the surface soil is dried out and simulated drought conditions exist. Hough and Forbes (1943) point out, "Any prolonged or severe drought, such as that of 1929-30 in the eastern United States is particularly damaging to tree growth. The periodic occurrence of such drought, especially on shallow soils and steep slopes, results in heavy mortality among shallow rooted tree species such as eastern hemlock and yellow birch."

Graham (1943) states in his summary, "A clear relationship exists between amount of exposure to sunlight and mortality rate, the greatest mortality occurring in trees exposed to the southwest."

Windthrow

Windthrow is of slight importance to eastern hemlock because of its habit of growing in mixed stands. The hurricane of 1938 did not fail to throw hemlock any more than it did any species that was exposed. Trees affected with shake or heart rot are often broken by heavy winds (Spaulding, 1914).

Winter Injuries

Snow and ice do relatively little damage. The flexible growth allows the snow and ice to slide off before damaging the tree.

The new growth usually does not appear until after the late frosts, so no spring damage is found; and the species also seems to be resistant to early fall frost. Frost cracks, as a rule, are not frequent.

Fungal and Insect Attacks

Eastern hemlock is comparatively free from parasitic fungous diseases. Spaulding (1914) includes a rather complete list of species found on both living and dead hemlock.

The hemlock borer, *Melanophila fulvoguttata* Harr., and the fungus, *Armillaria mellea* (Vehl.) Quel., are both considered as secondary causes of mortality by Graham (1943). The hemlock looper or spanworm, *Ellopia fiscellaria* Guan., may have been a primary cause of death in the lake states.

Fire

The shallow habit of root growth of hemlock makes it susceptible to fire as well as drought. A very hot ground fire can be fatal to mature hemlock trees as well as to younger trees and seedlings.

Mammals

Deer will eat the buds, leaves, branches, and bark of hemlock, and deer damage is apt to be serious in both natural stands and plantations when deer populations are high (Clepper, 1931). Deer damage has been observed on the Prescott Peninsula in Quabbin Reservoir, where all hunting is prohibited.

Porcupines will also damage hemlock to the extent of ruining individual trees. The branches are broken and the tree is pruned repeatedly until it eventually dies. Most of these trees are located near the rocky dens of porcupines.

UTILIZATION

The utilization of eastern hemlock has been held back by the presence of species, such as white pine and the western conifers, which have wood that is easier to work and season; and have been present in volume and in longer, clearer lengths.

MacConnell (1948) in discussing resources and uses of hemlock points out the fact of its tolerance, ..."And it is a component of the northern forest, and the readiness with which it reproduces in mixed, unevenaged stands makes it ideally suited to conditions where the selective system of forestry can be advantageously applied. Conditions are optimum in Southern New England and Pennsylvania for the management of hemlock as an important component in a mixed forest."

Some Physical Properties of Eastern Hemlock

The following physical properties were listed to show the comparison of eastern hemlock with white pine and red oak and also to compare it with the averages of the important commerical species of the United States. It must be kept in mind that these figures are all obtained from small clear pieces of wood and that many factors will modify them, such as growth, site, and length of fiber. They have all been obtained from Kellogg, (1931), except the data concerning nail holding capacity.

Specific gravity. (Vol. when green, Wt. oven dried).

EH	0.38	(Eastern Hemlock)
WP	0.36	(White Pine)
Avg. softwood	0.41	
RO	0.56	(White Pine)
Avg. hardwood	0.56	

Modulus of rupture

EH	6,700
WP	5,300
Avg. softwood	6,305
RO	7,700
Avg. hardwood	7,817

Ratio of bending strength to weight.

EH	176
WP	147
Avg. softwood	153
Ro	138
Avg. hardwood	152

Crushing strength. (Lbs./sq. in parallel to grain).

EH	3,270
WP	2,720
Avg. softwood	3,053
RO	3,200
Avg. hardwood	3,293

Shearing strength. (Lbs./ sq. in.)

EH	880
WP	640
Avg. softwood	814
RO	1,120
Avg. hardwood	1,165

Modulus of elasticity. (Lbs./Sq. in.)

EH	1,120,000
WP	1,070,000
Avg. softwood	1,158,000
RO	1,290,000
Avg. hardwood	1,186,000

Toughness. (Inch.-pounds/cu. in.)

EH	6.8
WP	5.9
Avg. softwood	6.8
RO	11.5
Avg. hardwood	12.7

Resistance to impact. (Ht. in. a 50# hammer, cause breakage).

EH	20
WP	18
Avg. softwood	24
RO	41
Avg. hardwood	41

Hardness. (Lbs. required to indent specimen).

EH	410
WP	300
Avg. softwood	402
RO	950
Avg. hardwood	812

Nailholding capacity of eastern hemlock in lbs.
(Markwordt and Gahagan, 1929).

EH End grain 225; Flat grain 230.

WP End grain 220; Flat grain 225.

RO End grain 466; Flat grain 422.

Uses of Eastern Hemlock

Lumber has been the chief use of hemlock over the years, and as shown previously, it has been cut since the early days of settlement. The amount was small, however, until the bulk of white pine was gone. It has been used, in part for building construction, framing, sheeting, subflooring, roof boards, and for the manufacturing of boxes and crates. Hemlock lumber is selling at present in Athol, Massachusetts from $65 to $75 / M. Table #4 will give a more complete list of the uses of eastern hemlock.

Betts (1945) shows an early figure for pulpwood in 1905 when 375,000 cords were used. In 1927 a maximum of 818,00 cords were used, and it then leveled off at about 420,000 cords through 1945. Professor S. O. Heiburg, of New York State College of Forestry, quoted hemlock peeled pulp selling roadside for $12.50 a cord, while white pine pulp brought only $10.50 under the same conditions. The tract in question was near Warrensburg, New York. The Great Northern Paper Company will accept hemlock pulpwood at $25.00 per cord delivered to their plant in Maine.

Hemlock pulp is used principally in the manufacture of news and wrapping papers and has a minor use in the manufacture of books and printing papers. The sulfite process is generally used in pulping eastern hemlock. According to the Forest Products Laboratory the data which are available on western hemlock can be applied to eastern hemlock because they are chemically almost the same.

The bark for tannin is usually obtained as a by-product of a pulpwood operation where the wood has to be peeled before selling. This is a more ecomonical method and less wasteful as compared to the old method of felling and peeling hemlock just for the bark.

Hemlock oil distilled from the needles and twigs is still made in some parts. The product is used in medicine.

In New York (Stout, 1949) and in Vermont (Hawes, 1912) hemlock has been used as a crude form or insurance. This is accomplished because hemlock is not considered a desirable species in the sale of the farm woodlot, so a very low price is offered. The farmers reserved the hemlock when selling their woodlot and in this way they had enough board footage on the ground to rebuild in case their barn or any outbuilding burned.

CONCLUSIONS

Hemlock existed in the pre-colonial forest, but not as pure stands. The associated species which have been shown to occur with hemlock in the mixed stands of this area are all present today, with the exception of the chestnut. A comparison of the pre-colonial species and those on the included type maps show that we have reached the same species composition as the pre-colonial forest. The question of form and spacing of this forest is still an open question.

The problem then of managing natural stands on the basis of the pre-colonial species, to a certain extent, has been realized. If we carry on thinnings where the poorly formed trees and the competing dominants and codominants are removed, then in many cases suppressed hemlock will be left as the understory. The result obviously will be an increased amount of hemlock as a dominant member of the community when the overstory is removed. In the next phase a pure stand or a stand running largely to hemlock will not reproduce to another pure stand unless some control is exerted, either naturally or by man.

A hemlock of 18 to 20 inches in diameter would be optimum size as dictated by the danger of "shake" and by the fact that large hemlocks do not increase in value in proportion to their increased size. When a stand containing hemlock is thinned or harvested the foregoing must be considered and the problem or removing overmature individuals must be satisfied.

A system of harvesting, for an evenaged stand, would be a group shelterwood, while a group selection system for an unevenaged stand would fill the requirements, in both cases, for protection from fire and exposure and would also provide a suitable seedbed for hemlock and other species. Both these systems have the advantage of exerting a control over the area until such a time as deemed proper to remove the complete overstory.

Hemlock, due to its tolerance, will often start under a canopy of other species and in this way the length of time required for a rotation can be shortened. The rapid growth of a hemlock when released and the good influence exerted on the other species cannot be overlooked.

A trend toward stablized forest industries will of necessity demand stabilization of forests to produce a continous flow of wood into these industries. The next important conclusion then is to found these industries on the natural vegetation of an area. When this is accomplished the next step is up to the forest managers. This is exemplified by the Harvard Forest as it has been managed in accord with the theory of natural succession. At present this is the obvious way to obtain the greatest good from a given area of land. We are forced to accept this theory if we subscribe to the axiom that we lack the ability to look into the future 50 to 100 years to see what the uses and the economic relationships of a species will be to a future economy. We know that it is dangerous to produce pure stands — either by planting or by silvicultural manipulations — from a physiological, pathological, or in some cases even from and economical viewpoint.

It seems probable that hemlock will never produce wood in the clear lengths, as do many of the species with which it must compete on the lumber market. The hackneyed thought must be kept in mind that in the future we do not know what methods of wood utilization may be possible. At present we are faced with the problem that as a species it is able to fill a definite place in our forest stands and though inferior in some qualities it will produce coniferous wood naturally in a region dominated by hardwood species.

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PLATE IV.

Prospect Hill Block, Compartment III
Harvard Forest, Petersham, Mass.

Hemlock stand showing lack of reproduction under a closed canopy.

PLATE V.

Prospect Hill Block, Compartment II
Harvard Forest, Petersham, Mass.

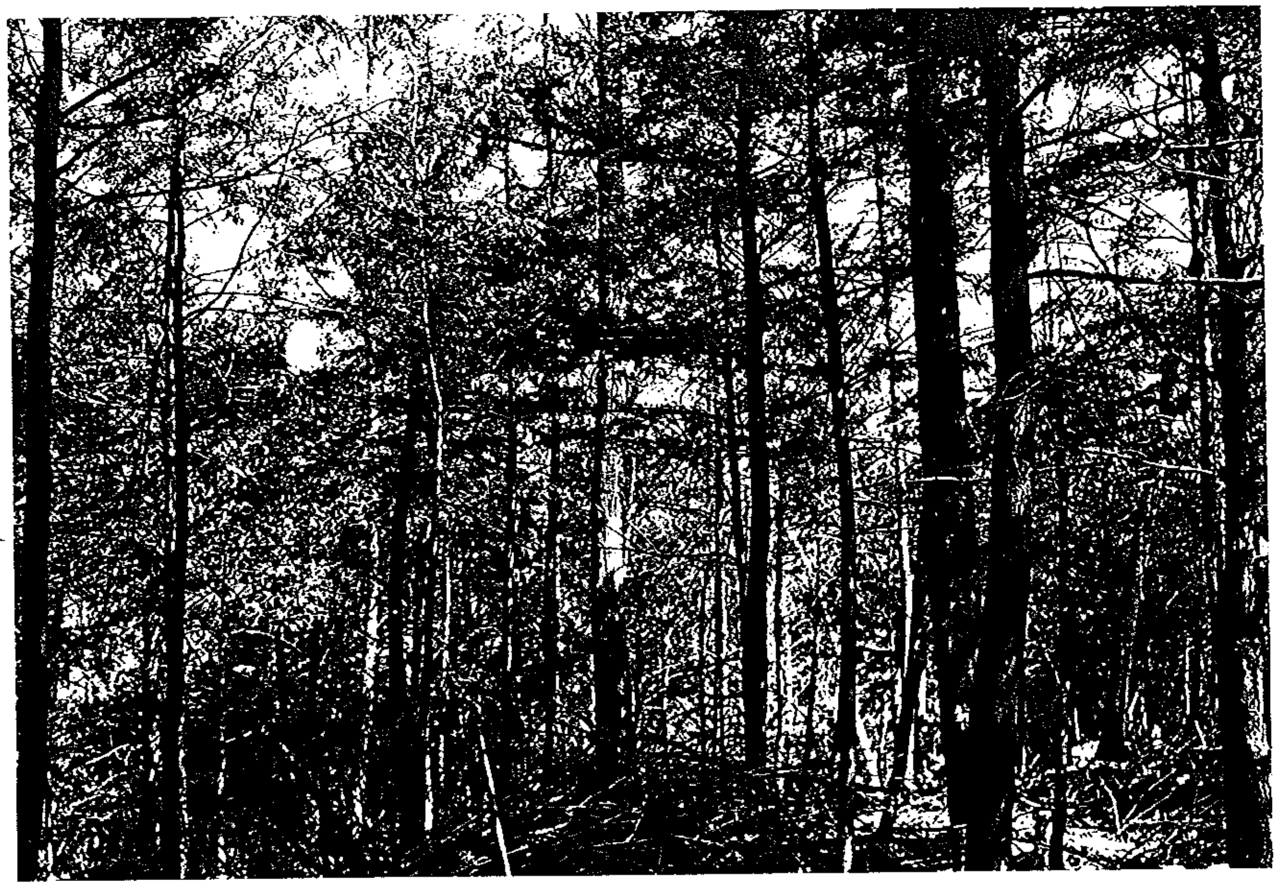
Hemlock reproduction in a semi-open area.

PLATE VI.

Prospect Hill Block, Compartment II
Harvard Forest, Petersham, Mass.

Red oak, center, showing good form when grown with a hemlock understory.

PLATE VII.



Prospect Hill Block, Compartment VII
Harvard Forest, Petersham, Mass.

Red oak, center, showing good form when grown with a hemlock understory.

PLATE VIII.

Prospect Hill Block, Compartment VII
Harvard Forest, Petersham, Mass.

Hemlock understory in an unthinned stand.

PLATE IX.

Prospect Hill Block, Compartment III
Harvard Forest, Petersham, Mass.

Scattered hemlock understory in a thinned stand.

PLATE X.

Prospect Hill Block, Compartment II
Harvard Forest, Petersham, Mass.

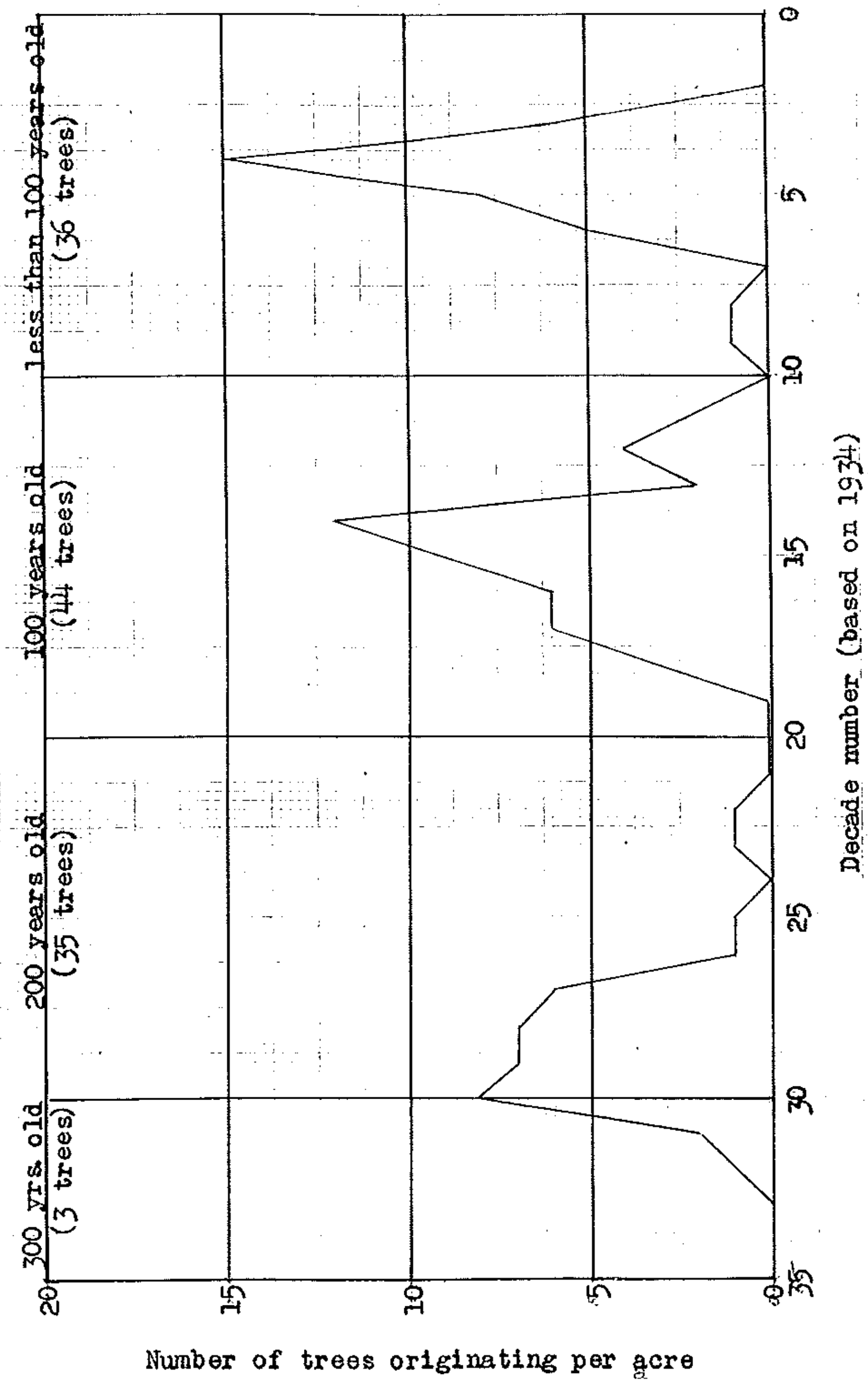
View of a stand, which has been converted to hemlock, (after a chestnut salvage operation in 1949).

PLATE XI.

Prospect Hill Block, Compartment II.
Harvard Forest, Petersham, Mass.

View of a stand, which has been converted to hemlock, (after a chestnut salvage operation in 1949).

FIGURE # 1



Periodicity of Hemlock Establishment - By Decades

East Tionesta - Plot #8

Based on 1 acre
(118 hemlocks)
In Northwestern Pennsylvania

After Hough and Forbes (1934)

PROSPECT HILL II.
1947

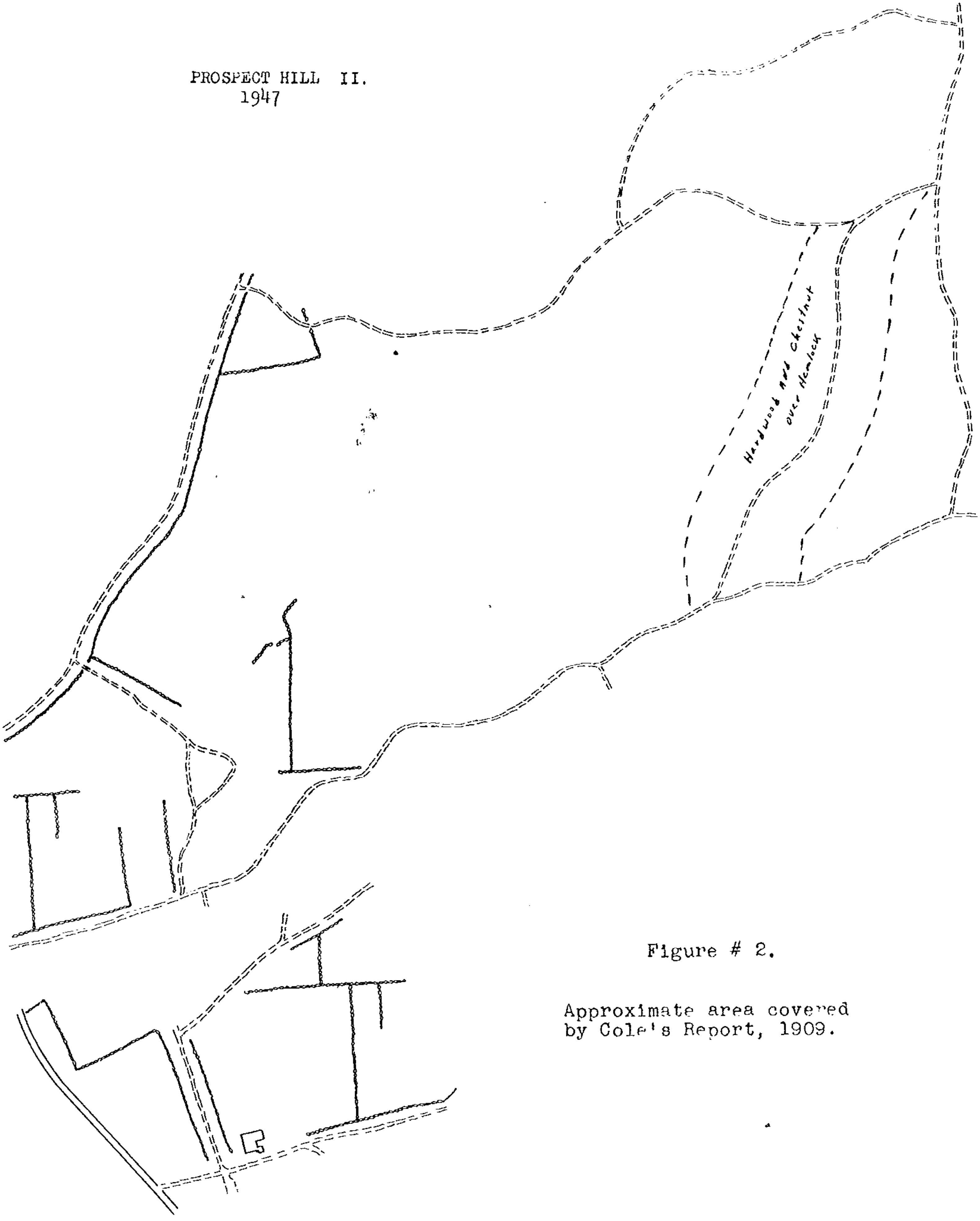


Figure # 2.

Approximate area covered
by Cole's Report, 1909.

PROSPECT HILL II.
1947

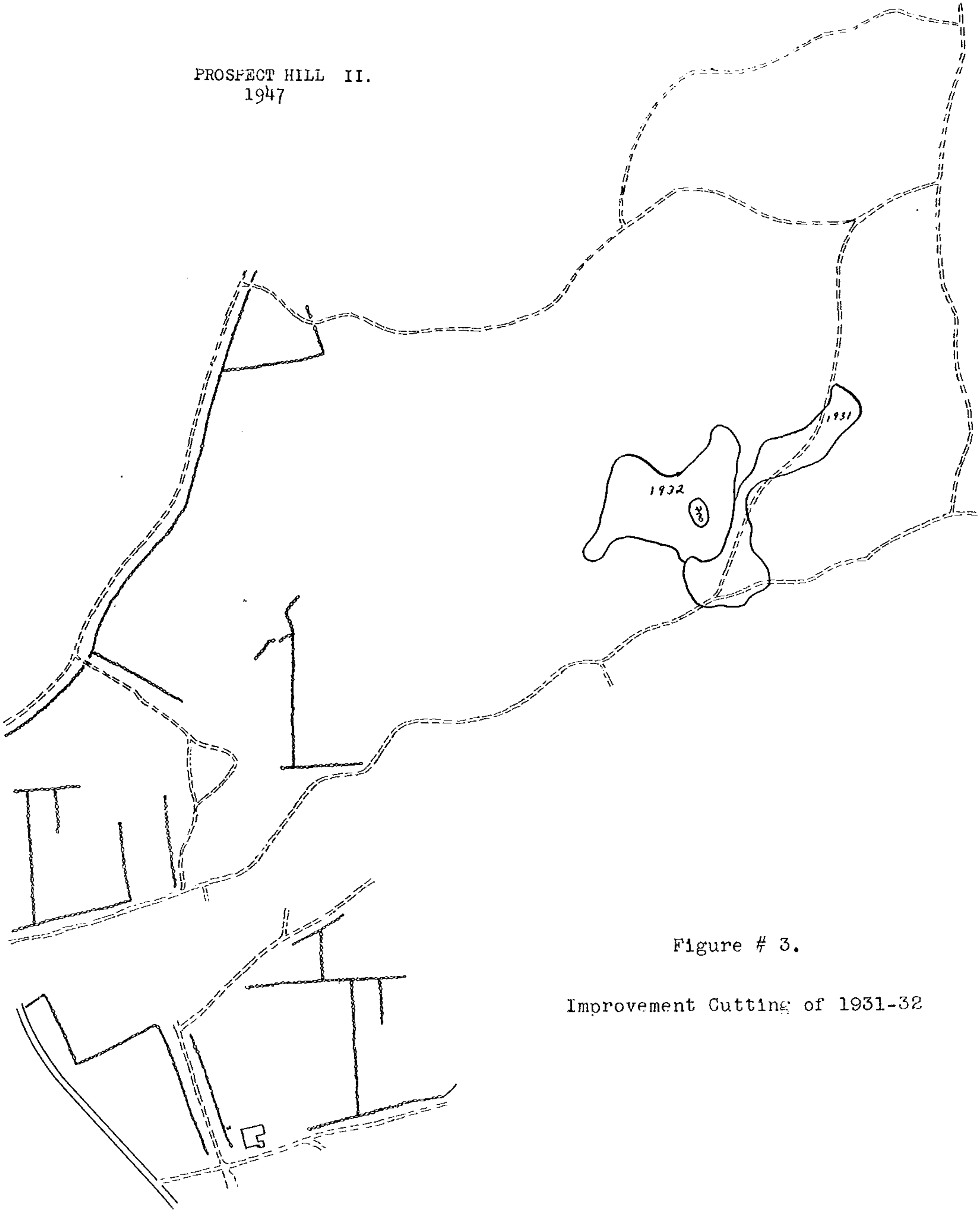


Figure # 3.

Improvement Cutting of 1931-32

PROSPECT HILL II.
1947

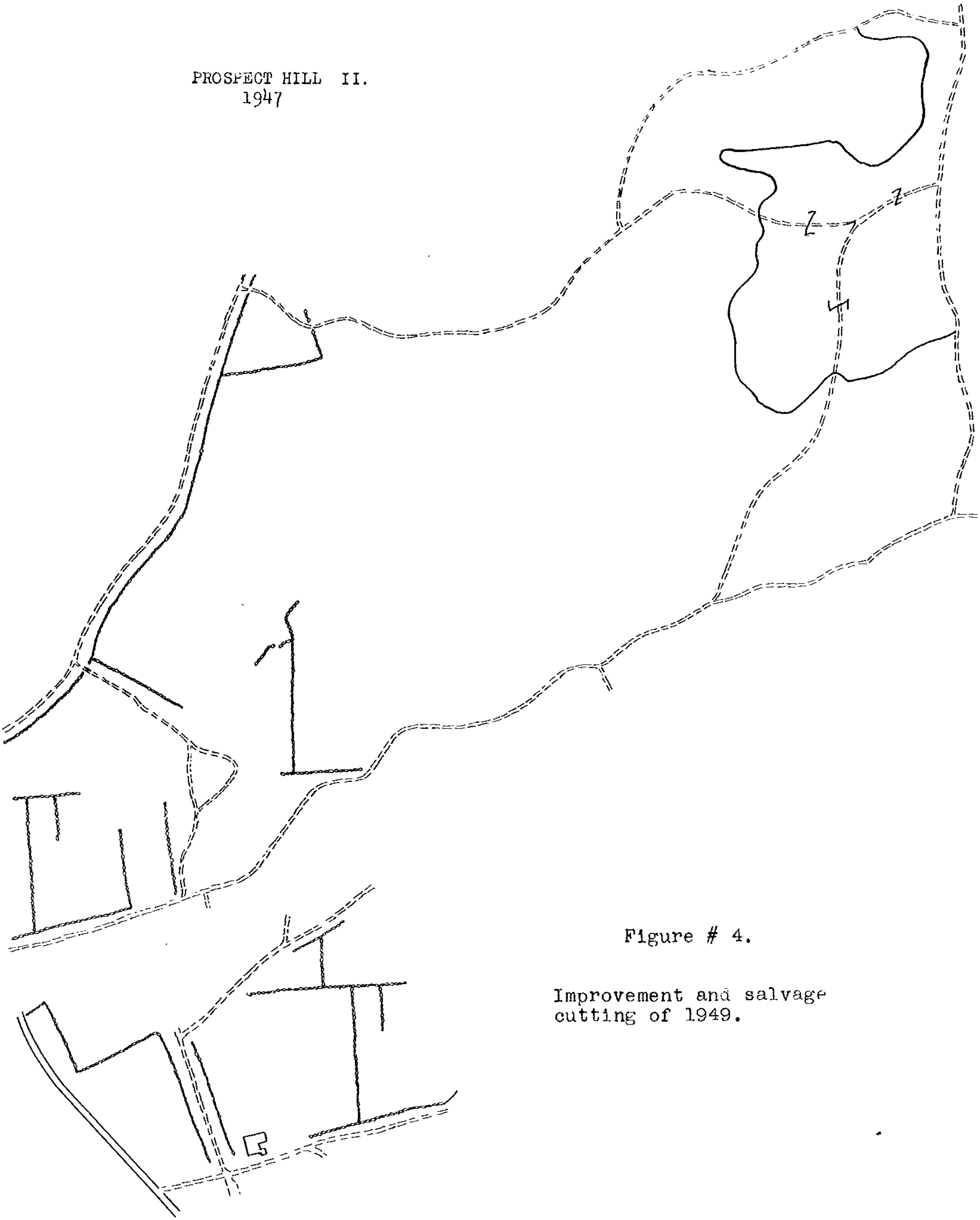


Figure # 4.

Improvement and salvage
cutting of 1949.

TABLE # 1

Reproduction under a Hemlock Stand (based on 1/5 acre plot).

Species	Hemlock		White pine		Red Oak		Black Birch		Red Maple		Others	
Diameter class	1/5 acre	per acre	1/5 acre	per acre	1/5 acre	per acre	1/5 acre	per acre	1/5 acre	per acre	1/5 acre (stripped maple)	per acre
Seedlings Sprouts	32	160	3	15	1	5	7	35	9	45	11	55
2"	1	5	-	-	-	-	-	-	3	15	-	-
4"	1	5	-	-	-	-	-	-	-	-	-	-
6"	6	30	1	5	-	-	-	-	2	10	- (yellow birch)	-
8"	4	20	-	-	-	-	-	-	2	10	1	5
10"	3	15	2	10	-	-	-	-	-	-	-	-
12"	6	30	2	10	-	-	-	-	-	-	-	-
14"	2	10	-	-	-	-	1	5	-	-	-	-

See Plate IV

Stand: PH II? $\frac{T}{RO-BB-PB}$ 60

By: E. E. Smith

TABLE # 2

Reproduction in semi-open area (based on 13.2' sq. plot)

Species	no. per 13.2' sq. plot	no. per mil-acre	no. per acre	Remarks
Hemlock	379	94.75	94,750	28 over 2' high
Black Birch	52	13.00	13,000	7 over 2' high
Stripped Maple	1	0.25	250	-
Red Oak	1	0.25	250	1 over 6' high
White Pine	2	0.50	500	1 - 3' 1 - 2'
Red Maple	20	5.00	5,000	-

By: E. E. Smith and A. C. Chable

Stand: PH II $\frac{\text{T 7C}}{\text{T-Be-RM-4-5-B}}$

See Plate V.

TABLE # 3

Hemlock and Hardwoods (based on ¼ acre strip)

Species	Hemlock	Chestnut	P. Birch	Beech	Maple	Red Oak
DBH						
3	10	-	-	6	-	-
4	20	1	-	2	4	10
5	7	1	2	5	4	8
6	13	2	2	2	4	11
7	8	3	1	1	4	7
8	4	5	-	-	1	2
9	-	2	1	-	-	2
10	1	1	1	-	-	1
11	-	-	-	-	-	-
12	-	1	-	-	-	-

Heights	Hemlocks	Hardwoods
3" -5"	30'	40'
6" -up	40'	50'

Stand: PH II (13.2 acres - hemlock and hardwoods)

By: Forest Inventory 1923 (Tally Sheet)

TABLE # 4

Eastern Hemlock used in the Manufacture of Wooden Products

Quantities in thousands of board feet, after Betts, 1945.

Classes of Products	1933	1940
Agricultural Implements	9	13
Boxes, baskets, crating	59,790	67,743
Car, construction and repair	8,084	8,740
Conduits, Pumps and wood pipe	-	30
Dairy,poultry and apiary supplies	200	-
Electrical equipment	-	416
Fixture	26	130
Furniture	19	559
Ladders	122	-
Machinery	30	95
Patterns and flasks	200	614
Plumbers' woodwork	-	50
Radio and phonograph cabinets	16	-
Refrigerators	128	231
Sash, door, general	980	2,410
Ship and boatbuilding	2	16
Signs, scenery and display	125	751
Sporting and athletic goods	-	96
Tanks	5	4
Toys	60	125
Vehicles, motors	10	100
Wooden wear and novelties	1	-
Total	69,807	82,323