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CUT-OVER OLD FIELD PINE LANDS IN CENTRAL NEW ENGLAND

A REGIONAL STUDY OF THE COMPOSITION AND STOCKING OF THE ENSUING VOLUNTEER STANDS

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FOREWORD

One of the most valuable contributions of the late Director Richard T. Fisher to the practice of silviculture is his carefully developed plan for improving the young volunteer stands which follow the clearcutting of "old field" white pine. The details of the method were worked out during the past twenty-seven years, largely on the Harvard Forest, and under the conditions of soil and growing stock which exist there. A series of bulletins and articles dealing with this subject, and either written by him or prepared under his direction, provide an unusually complete and solid foundation for further investigations.

Within the central New England region several hundred thousand acres of old field white pine have been cut off during the past fifty years. Nearly all of this area has been restocked by volunteer stands, composed chiefly of hardwoods, which, except in a few cases, have received no cultural treatment whatever. The present study was undertaken as a means of determining the silvicultural condition of these stands and their susceptibility to profitable treatment, as influenced by the various factors of age, soil, and stand history.

There is a special timeliness in such a regional survey, for it is evident to those familiar with present day forest exploitation that wood lot owners are inclined to look upon all immature hardwood stands, no matter how good their composition and quality, as cordwood crops, to be harvested as soon as the trees reach fuel wood size. This attitude undoubtedly results in part from the prominence of merchantable old field white pine during the recent

past, and to a corresponding scarcity of hardwood of saw log size. The indiscriminate clearcutting of the young and middle-aged hardwood stands now so prevalent on the cut-over pine lands may, in many cases, destroy potentially valuable sawtimber crops at the very age when they are making their best growth, and, in any event, it gives rise to a stump sprout generation of marked inferiority to the parent stand. There is an unmistakable need at present for a better understanding of those factors of composition and stocking which aid in determining the best policy of management for the individual stand.

To ensure a reliable appraisal of the present growing stock conditions on the cut-over old field pine lands of the region and to bring conclusive evidence to bear on questions of susceptibility to cultural treatment, the authors covered a sizeable section of country and examined 225 individual stands. The section extended far enough north and south to include the full width of the transition zone and to penetrate the northern forest and central hardwood forest zones proper.

This study received the support and guidance of Director Fisher during the course of its prosecution in the field and its presentation in manuscript form. For this, and his manifest approval of the completed work, the authors are deeply grateful.

A. C. CLINE.

Petersham, Massachusetts
May 1, 1935.

INTRODUCTION

LAND HISTORY AND ITS INFLUENCE ON FOREST SUCCESSION

THIS study covers a rectangular-shaped area of about fifteen hundred square miles extending from Worcester, Massachusetts, on the south to Keene, New Hampshire, on the north, and from Wachusett Mountain on the east to Millers Falls, Massachusetts, on the west (Fig. 1).

Within the area the earliest recorded settlement was in the town of Brookfield, Massachusetts, in 1673. From Brookfield, which lies on the southern border, northward to Keene, the date of settlement becomes progressively later. In the towns of Brookfield, Paxton, and Spencer land clearing was undertaken prior to 1700; while twenty-five miles farther north in the towns of Athol, Templeton, and Westminster it did not start until some thirty years later; and in the northernmost towns of Keene, Peterboro, and Harrisville, New Hampshire, not until 1735 to 1765. Likewise, the intensiveness of the early occupation and land clearing in general decreased from south to north.

The original forests consisted in the main of mixtures of hardwoods and softwoods, with a predominance of hardwoods. Further, there was an unusually large variety of species, owing to the fact that the region lies in a transitional belt between the northern forest and the central hardwood forest. The protected sites in the northern part of the zone favor the growth of a number of "northern" species, including hard maple, beech, yellow and paper birch, red spruce, and balsam fir; while the more exposed sites to the south are favorable for

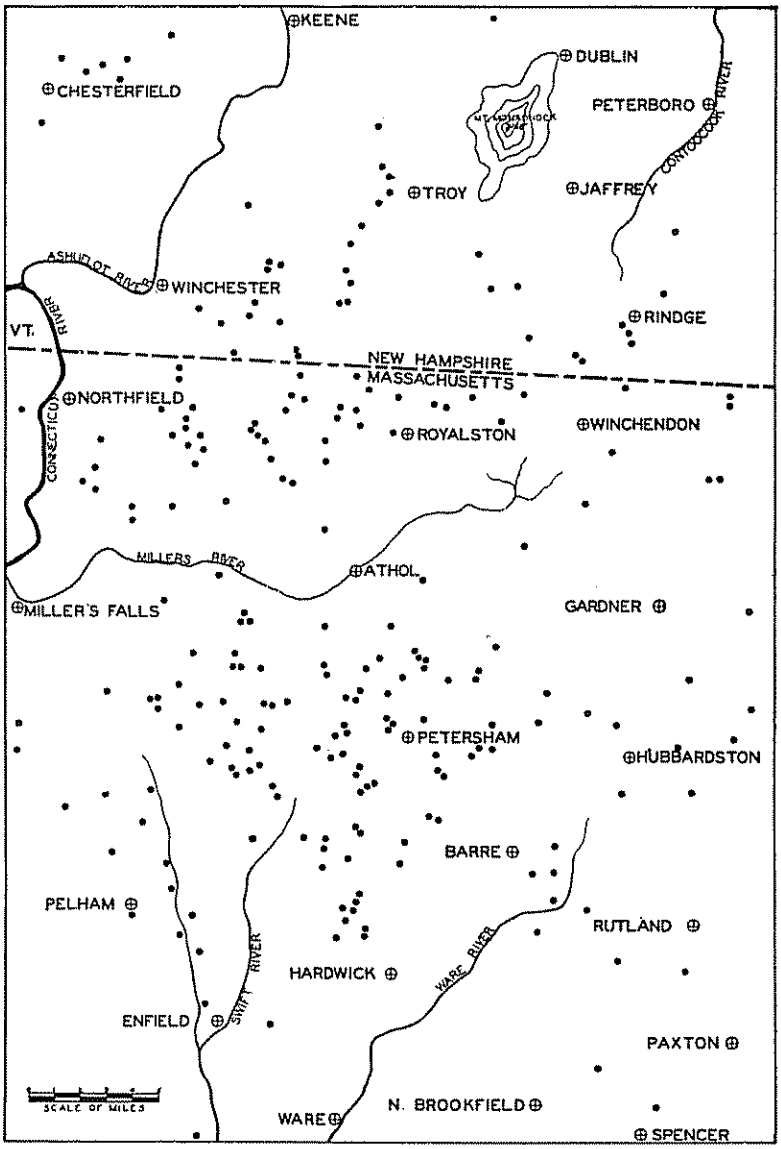

FIGURE 1. THE AREA COVERED IN THE STUDY, AND THE LOCATION OF THE CUT-OVER OLD FIELD PINE LOTS SAMPLED.

The extreme northern and southern portions of the area include stands truly representative of the northern forest and central hardwood forest, respectively. The remaining portion, about thirty miles wide north and south, contains stands which represent a commingling of the conditions of both, and is known locally as the transition zone. The Harvard Forest is situated near the center of this zone

such "central" species as red, white, and scarlet oak, hickory, chestnut, and pitch pine. Intermediate locations are characterized by an intermingling of these species, and, in addition, by several species which have a fairly wide north-south range of distribution and cannot be classed as being typically either northern or central, among them white pine, hemlock, white ash, black cherry, and red maple. For the most part white pine occurred singly or in groups among the hemlocks and hardwoods. Pure white pine, including more or less pitch pine, formed a permanent type only on the sand plains, and a transient type on burns or blowdowns where hardwood competition was temporarily reduced. Spruce was present in appreciable amounts only in the northern portion of the region, particularly at the higher elevations in the Monadnock region of New Hampshire.

Excellent as were the original forests in variety and quality of timber, to the first settlers they were obstacles to progress which must be removed by whatever means available, even fire. In the southern towns during the period from 1700 to 1850 no less than eighty per cent of the land was cleared for tillage and pasturage. Some miles to the north, in northern Worcester County, the percentage cleared probably was nearly seventy-five, while in the mountainous sections of northern Cheshire County, New Hampshire, it was considerably less. For the region as a whole fully sixty-five to seventy per cent of the land was at one time cleared, and under some form of agricultural use.

Farming reached its full development about 1830. With the building of the transcontinental railroads, the opening of the West to settlement, the discovery of gold in California, and the Civil War the era of farm abandonment in central New England was ushered in. The collapse of farming has been progressively more extensive from south to north. Even today well over fifty per cent

of the land area of the southernmost towns in the region covered is being farmed, or at least is open, while in the central and northern towns the percentage is not more than thirty.

Throughout the region fields and pastures, when abandoned, were soon seeded to white pine, with hardwoods forming a minor proportion. Usually there were enough old pines along the fences or in nearby woodland to produce an abundance of seed; and, since sod and grass land furnish an especially favorable seed bed for pine, each successive seed year marked the beginning of scores of new stands, generally well stocked and invariably even-aged. The young stands were exceedingly dense, and very little undergrowth or ground cover could become established during the first thirty to forty years. Then, as the canopy rose, providing increased light and room beneath and making conditions more favorable for animal life, hardwoods began to come in to form an understory, so that when the pine had reached merchantable size, at sixty to seventy years, a dense hardwood thicket was present.

The first old field pine cuttings on any considerable scale took place about 1890, and for the next thirty years large quantities were removed annually. Portable mills and clearcutting were the order of the day. Reports show that the peak of pine production in Massachusetts was reached in the period 1906 to 1909. During recent years production has fallen off, because of the decline in the wooden box business, low priced lumber brought in from other regions, and the inferior quality of the remaining old field pine stands.

It is altogether likely that, when the first pine lots were cut, little thought was given to the presence of the hardwood advance growth, and no concern felt over the ability of the pine to reestablish itself. Indeed, quantities of pine did start when lots were cut in good seed years, but

on all except the poorest soils the hardwoods grew so fast that the pines were overtopped, and either completely suppressed or reduced to scattered individuals or groups. Nearly everywhere hardwoods formed the bulk of the new stand, a long step in the process of reversion from a purely temporary coniferous type to the original mixed composition in which hardwoods predominated.

However, though such a reversion unmistakably is in the direction of the more permanent and stable composition which marked the original forests, the present stands exhibit a substantial difference by way of the addition of a hardwood weed element found only occasionally in old growth. In the absence of cutting and fires a few generations would serve to eliminate it; but such a time-consuming process will take place but rarely, since the tendency is for woodlot owners to cut their hardwood stands at an early age. In fact, repeated clearcuttings are tending to reduce all stands to a similar form and composition, regardless of whether they are on land which has never been cleared or on land which has reverted to forest after a period of agricultural use. There is every assurance that the next predominating phase in the man-made forest succession will be sprout hardwoods composed of the rankest growing individuals of the most aggressive species.

STATEMENT OF THE PROBLEM

There are hundreds of cut-over old field pine lots in central New England which are now covered with some sort of hardwood, or pine and hardwood growth, chiefly in the sapling and pole stages. Such samples as have been dealt with on the Harvard Forest contain both desirable and undesirable elements in all manner of mixtures, and it has been shown that the proper sort of treatment administered at the right time materially af-

fects their production, both silviculturally and financially. But just what the conditions of composition and stocking are throughout the region, and how these are affected by factors of site and stand history, have never been shown in a quantitative way. Obviously, a better knowledge of these factors is necessary in determining forest policies, and should be made available while the bulk of the stands are still in the formative period. Twenty-seven years of management on the Harvard Forest have provided a comparison in the matter of susceptibility to improvement and of potential stocking whereby these stands may be judged in terms of possible silviculture.

REVIEW OF RELATED STUDIES

As far as the present writers are aware, Thoreau (1863) was the first to discover the underlying causes for the white pine-mixed hardwood succession in central New England, and, in particular, to explain the means whereby the hardwood advance growth becomes established under the pine canopy. To quote from his address to the Middlesex Agricultural Society at Concord, Massachusetts, ". . . I suspect that I can throw some light on the fact that when hereabouts a dense pine wood is cut down, oaks and other hardwoods may at once take its place.

"Apparently there were only pines there before. They are cut off, and after a year or two you see oaks and other hardwoods springing up there, with scarcely a pine amid them, and the wonder commonly is how the seed could have lain in the ground without decaying. But the truth is that it has not lain in the ground so long, but is regularly planted each year by various quadrupeds and birds.

"In this neighborhood, where oaks and pines are about equally dispersed, if you look through the thickest pine wood . . ., you will commonly detect many little oaks, birches, and other hardwoods, sprung from seeds carried into the thicket by squirrels and other animals, and also blown thither, but which are overshadowed and choked by pines. The denser the evergreen wood, the more likely it is to be well planted with these seeds, because the planters incline to resort with their forage to the closest covert."

During the latter part of the nineteenth century ap-

parently little notice was taken of the steady decline of the pine woodlot and the rise of hardwoods. Even in the early part of the present century, when the logging of pine lots got under way on a large scale, the potentialities of the hardwood advance growth for crop production were seldom recognized. One of the early publications of the U. S. Bureau of Forestry entitled "The Natural Replacement of White Pine on Old Fields in New England" by Spring (1905) favored the replacement of pine with pine. In one of his conclusions the author states that, unless special measures are taken to assure the replacement of white pine following the logging of pine woodlots, the greater part of the land will be occupied by inferior species. In the earliest pine cuttings on the Har-

FIGURE 2. ADVANCE GROWTH OF MIXED HARDWOODS UNDER AN OLD FIELD PINE STAND SEVENTY YEARS OF AGE

Sprouts from the stools of this hardwood, which is cut out of the way in the course of logging the pine, form the bulk of the new stand.

vard Forest a similar tendency to favor pine reproduction was in force, though not to the exclusion of hardwood. In an account of the operations of 1908-09 Fisher (1911) recommended a method of handling which would result in a mixture of pine and hardwoods. He states, "There was already a large reproduction of well distributed hardwood seedlings on the ground (under the pine), of which white ash, black cherry, red oak, and chestnut were the chief species. Moreover, these seedlings were for the most part less than a foot high, and consequently not likely to be seriously injured in the logging. Reproduction of pine was practically wanting, as is usually the case in such heavy, dark stands, but the autumn of 1908 was marked by a very heavy fall of pine seed. It was therefore expected that by cutting the stand clear . . ., a reproduction of mixed pine and hardwoods would be secured." Frothingham (1914) was also among the first foresters to call attention to the presence and importance of the hardwood advance growth, and to advocate its use in the next crop, when of sufficient density and desirable composition.

It was not until 1918, however, that there appeared in print a detailed discussion of the hardwood advance growth and the stand which it formed once the pine overstory was removed. An article by Fisher, entitled "The Yield of Volunteer Second Growth as Affected by Improvement Cutting and Early Weeding," for the first time analyzed the composition and origin of the new stand, and pointed out the destructive competition which takes place between the various elements.

In 1920 Fisher and Terry in "The Management of Second Growth Pine in Central New England" advanced the general knowledge of the cut-over pine lands by including in their study an examination of fifty-four pine cuttings in Worcester and Hampden Counties, Massachusetts, and Cheshire County, New Hampshire. Of

these, fourteen, or about twenty-five per cent, had been cut in pine seed years, most of them having a good catch of pine reproduction. But especially significant was their finding that, for the first ten years after logging, 60 to 70 per cent of the area studied was satisfactorily stocked with better hardwoods, thus disclosing for the first time the extensiveness of the reversion to hardwoods of sawtimber species.

Spaeth's work (1920) on the growth and yield of second growth hardwoods has an important bearing on the present study in that it recognized two qualities, or types, of hardwood mixtures on cut-over pine land, depending on the age of the previous stand at the time of cutting. The one was made up of "better hardwoods" which followed the cutting of pine stands over fifty years of age (the approximate age at which hardwood advance growth becomes established); the other, of "inferior hardwoods," which followed the cutting of stands under fifty years of age. Furthermore, the stands falling in the better hardwoods type were divided according to two site qualities, designated I and II; and for the first time a table of mixed hardwood composition according to site was presented.

The work of Patton (1922), though dealing essentially with only two species, red oak and white ash, contributed much to the present work by pointing out inherent differences in the growth habits of these leading species. Red oak is shown to be more aggressive than white ash: it demands space and struggles to obtain it, while ash will accept a subordinate position where it must endure suppression and the crowding of its crown. For these characteristics Patton gave the terms "space-demanding" for oak, and "crowd-enduring" for ash. He classified basswood, beech, and chestnut as oak-like; hard maple, black cherry, red maple, black and yellow birch as ash-like.

Averill, Averill, and Stevens (1923) in their survey of seven towns in northern Massachusetts corroborated Fisher and Terry's (1920) findings in regard to the reclaiming of pine cuttings by hardwoods. They found that pine, after clear cutting, is followed by nearly pure hardwoods on 75 per cent of the acreage classified under "heavier" soils. This is slightly higher than the percentage determined by Fisher and Terry.

Cline and Lockard (1925) made a further analysis of even-aged mixed white pine and hardwoods, chiefly on cut-over pine land, and showed the relative height growth of the several elements composing the stand,—white pine, better hardwoods direct from seed, better hardwoods from stools of various size classes, and inferior hardwoods which seed in after logging. It was determined that all hardwoods of sprout origin, and certain of the inferior species of seed origin, grow more rapidly at the start than the better hardwoods direct from seed; and that all hardwoods, regardless of species or origin, outgrow the pine for a period of several decades.

Griffith, Hartwell, and Shaw (1930) investigated the soil changes which accompany the old field white pine-mixed hardwood succession. They found that during a life time of eighty years pine impoverished the soil to a marked degree, reducing the enriched, dark-brown top layer from eight inches or more to less than two inches. Conversely, after the pine is cut and the hardwoods come in, a striking improvement takes place. The thick layer of pine needles is soon decomposed, and the depth of the enriched top layer is steadily increased.

CUT-OVER OLD FIELD PINE LOTS: CONDITIONS IMMEDIATELY FOLLOWING LOGGING

Except to the trained eye a recent pine cutting presents a picture of complete forest devastation, with long, rib-like windrows of slash extending up and down the slope, scraggly hardwoods left scattered here and there over the area, one or more large piles of sawdust, and a sticking ground littered with the remains of the lumber piles. Clearcutting and the use of horses in logging led to the method of felling the trees in strips, windrowing, so that the slash and the logs lie in alternate rows running with the slope, a practice which greatly facilitates hauling. The windrows of slash usually occupy one-third or more of the ground area and have every appearance of being able to prevent any new growth from starting within their borders.

All except the very best hardwoods are commonly left standing on the lot after the pine is logged, some of them remaining alive for decades. They consist of occasional old pasture trees much older than the pine, scattered trees which seeded in with the pine, and strips or clumps of red maple and other swamp hardwoods along the streams and in the low, wet places.

Despite a general impression of bareness, close examination of the ground the first growing season after logging reveals that in the open lanes between the rows of slash innumerable shoots of hardwood are starting up, chiefly from small stools under an inch in diameter. Also, around the margins and in the thin portions of the slash piles other sprouts are pushing through to supple-

FIGURE 3. A CUT-OVER OLD FIELD PINE LOT IMMEDIATELY AFTER LOGGING.

The principal features are the windrows of slash, the scattered hardwoods (residuals), and the sawdust pile at the millset.

in width according to the age of the stand, the unit of measure being the square chain, or one-tenth acre. For the most part, in stands under fifteen years of age a sample strip one-half chain wide was used; in older stands, a strip one chain wide.

SITE CLASSIFICATION

The basis chosen for site determination was the commonly used Site I, II, III classification,* in which Site I includes the most favorable situations with moist, dark-colored soils, high in humus content, of mull structure, and located chiefly on the lower slopes; Site II, a broader division including the moderately fertile situations with somewhat drier and less humus-rich soils, though also exhibiting the mull structure, and usually found on the upper slopes and ridge tops; and Site III, a comparatively uncommon site for the region covered, including the least favorable situations with dry, sandy or gravelly soils, light in color and coarse in texture, occurring chiefly in the valleys.

Because of the very limited number of cut-over lots found on Site I, samples taken on this site were grouped together with those on Site II under the designation "Site II and Better." This is comparable with the terms "better sites" and "heavy soils" frequently used in other Harvard Forest publications. Secondly, as the field work progressed, it was decided to set up a new site, intermediate between Site II and Better and Site III, to be designated as "Site II Minus." This was considered necessary in order to provide for the comparatively dry and exposed upland situations commonly found in the

* Used first with pine yield tables. Site III for pine is a very poor site for hardwoods, and local yield tables for hardwoods include only Sites I and II. Using height at age 50 as an index to site, Site I for even-aged, mixed hardwoods is indicated when the height of dominants and codominants ranges between 65 and 75 feet; Site II, between 55 and 65 feet.

southern part of the region studied, sites occupied chiefly by oaks, chestnut, and hickory, plainly poorer than Site II but not so dry and sterile as Site III.

THE PREVIOUS STAND

The previous stand affects the present stand principally in two ways: first, the advance growth hardwood originates chiefly from seed produced by hardwoods growing with or near the pine; second, it does not become abundant until the pine has reached fifty years of age. In order to determine what hardwoods formed part of the previous stand, an individual tally was made of the hardwood residuals (trees left standing after logging) and of the stumps of all main stand hardwoods cut with the pine. Ring counts on pine stumps were made to determine the age at which the previous stand was cut, but this record necessarily was limited to cases where the stumps were still fairly sound.

DEFINITION OF TREE CLASSES

The individual stands, all of them even-aged, were analyzed as potential forest crops, and the elements composing them, as dealt with in silviculture, were separately observed. Thus, each stand was divided into (1) those trees suitable for forming the final crop, the *crop trees;* (2) those interfering with the growth of the crop trees, *the weeds;* and (3) those forming the subordinate element, *the trainers.*

Crop Trees

Crop trees were taken to include only potential sawtimber trees of desirable species, namely, of red oak, white ash, paper birch, black birch, hard maple, black cherry, yellow birch, beech, white oak, scarlet oak, hick-

ory, white pine, hemlock, and red spruce. Due to the possibility of rot in multiple-stemmed trees, especially those from large stumps, the selection of crop trees was further limited to single-stemmed individuals, thus assuring the inclusion of only those trees which had originated either from seed or as sprouts from very small stools. In this connection Leffelman and Hawley (1925) working on cut-over areas in Connecticut found that 28 per cent of the four-year-old sprouts from large stumps had traces of decay, whereas no decay was noted in the single-stemmed seedling sprouts. These authors showed that the two desirable growth forms, seedlings and single seedling sprouts, were free from decay and maintained a good physical condition.

To bring out the effect of competition between weeds and crop trees, and to show what degree of improvement in crop tree stocking could be effected as the stand progressed in age, crop trees were divided into two classes, *free-to-grow* and *overtopped*. The former included individuals which occupied a dominant position; the latter, those which were overtopped by weeds but still vigorous enough to recover and gain a dominant position, if released. Furthermore, trees so tallied were limited to those overtopped by weeds, since to include crop trees overtopped by other crop trees would lead to false conclusions.

Weeds

Weeds are trees of inferior species, form, or condition which are overtopping trees desirable for the crop. They fall into two main classes: fast growing individuals of inferior species, and sprouts from large stumps of nearly all hardwood species. The following were considered as inferior species: gray birch, pin cherry, poplar,* and red

* In some parts of New England, poplar is a valuable tree for pulp and excelsior.

maple. Stump sprouts are the rankest of all weeds because of their extremely rapid growth, poor quality, and susceptibility to heart rot. Occasionally, trees of desirable origin and species must also be considered weeds because of defectiveness or poor form. Squirrels, birds, insects, snow and ice, fungi and other agencies are responsible for damage to trees which otherwise might be favored for the crop.

Trainers

The trainers consist of those trees which have fallen behind the weeds and crop trees, and have been suppressed to such a degree that they cannot be made available as part of the main crop. Both desirable and undesirable species make up this element, which plays a very important rôle in improving the quality of the crop trees by restricting the growth of lower branches and hastening pruning.

METHOD OF RECORDING BY TREE CLASSES

A tree-by-tree tally of the crop trees was made by species and freedom for growth (free-to-grow or overtopped) for each linear chain of sample strip. Five columns permitted a tally of a quarter- or a half-acre sample on each field sheet, the size depending on the width of strip; and underneath space was provided for general notes on origin, and form and quality. Since only single-stemmed trees were included, observations as to origin necessarily were limited to young stands in which it was possible to distinguish between sprout and seed origin. Form and quality was rated as *very good, good, fair,* or *poor,* as judged on the basis of the general appearance of the trees, particularly the straightness and clearness of their boles.

No tree-by-tree tally was made of the weeds, since their

destructive action would be disclosed by the crop tree tally; that is, all crop trees tallied as "overtopped" were overtopped by weeds. Just how many weeds there were per acre seemed to have little significance. However, in order to show the longevity, or persistence of the various weed elements in relation to species and origin, the weeds in each stand were listed by species under two classes,—*single-stemmed* and *multiple-stemmed* weeds. Thus, all weeds from very small stools or direct from seed fell in the single-stemmed class, and all those from the larger stools in the multiple-stemmed class.

The record of trainers was limited to listing the various species present in this class, using the stand as a unit.

GROWTH IN SLASH PILES

Since a previous study had been made of the relation of slash to the composition and density of young stands on cut-over pine land, notes were of a general nature, and dealt particularly with the amount of slash present under the older stands (twenty years and over) and its evident effect on the density of stocking.

ANALYSIS OF DATA

DIVISION INTO TYPES

THE first step was to subdivide the stand record sheets on the basis of whether the previous stand was cut during a pine seed year. Seed year cuttings commonly result in large quantities of pine reproduction along with the hardwood, while cuttings made in off years give rise to stands composed wholly of hardwoods. The great majority of the stands fell in the latter division.

Further inspection of the records for the areas which were cut in non-seed years showed the necessity of grouping according to hardwood types. A comparatively small number of stands situated in the northern part of the area covered contained a high proportion of paper birch, beech, and hard maple, and were therefore assigned to the northern hardwoods type. In the south, a like minority had a composition strong in red, scarlet, and white oak, and these were placed in the oak type. All other stands, situated chiefly in the central part of the area covered and evidently transitional in their make-up, were placed under the transition hardwoods type.

Although the area covered in the study included a rather weak representation of the northern hardwoods and oak types, characteristic of the northern forest and the central hardwood forest, respectively, it was considered worth while to refer to whatever data were available in order to bring out at least general comparisons with the transition hardwoods type of the so-called transition zone, within which the Harvard Forest is located.

DISTRIBUTION OF THE STANDS STUDIED

The distribution of stands by number and acreage, shown in Table 1, may be considered fairly representative of the region, except that some recent cuttings on Site II and Better, transition hardwoods type, were passed by in order that more time might be had for studying the older stands. Also, the central and southern portions of the region were covered somewhat more intensively than the northern.

Only a rough estimate can be made of the total acreage of old field pine cuttings within that portion of the region covered. If it is assumed that the sample strips represent twenty-five per cent of the total area of the cuttings examined, and that roadside cuttings constitute ten per cent of the total, there are 80,000 acres of cut-over old field pine lots which have been logged in the last forty-five years. This is believed to be a conservative estimate.

Both in point of number of stands and acreage, the transition hardwoods type greatly exceeds the northern hardwoods and the oak types. The relative scarcity of pine cuttings now supporting northern hardwoods is due to the less intensive settlement and land clearing in the northern part of the region, and to the fact that abandoned farm land seeded to red spruce, or pine and spruce, as well as to pure pine. In the oak type a similar scarcity is accounted for chiefly by the earlier and more intensive settlement and use of the land in the southern portion of the region. Not only was a comparatively large portion kept under cultivation or pasturage from the start, but those pine stands which did come in as a result of farm abandonment were cut comparatively early, and the succeeding hardwood reached cordwood size and was cut some years ago. Today most of the stands are hardwood coppice which has followed the clearcutting of hardwood rather than pine.

TABLE 1

THE NUMBER AND AREA * OF THE STANDS SAMPLED, ACCORDING TO TYPE, SITE, AND AGE CLASS

Age Class	Northern Hardwoods Type						Transition Hardwoods Type						Oak Type					
	Site II and Better		Site II Minus		Site III		Site II and Better		Site II Minus		Site III		Site II and Better		Site II Minus		Site III	
	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres	Number of Stands	Acres
1-2	..	..	..	..	.	.	9	87	4	71	4	57	..	..	.	..	.	..
5	.	..	3	19	.	.	13	158	13	82	8	95	.	.	3	24	..	.
10	2	25	1	5	2	21	10	117	11	97	3	22	1	3	.	5	.	..
15	..	..	..	.	.	.	15	151	5	33	5	45	1	10	2	15	.	..
20	..	..	..	.	.	..	6	53	5	52	1	7	1	4	.	..	.	..
25	3	29	..	.	.	.	19	148	4	32	2	17	.	.	1	10	2	24
30	..	.	.	..	.	.	17	114	6	51	2	14	.	.	2	12	..	..
35	..	..	..	..	.	.	15	107	..	.	2	11	.	.	1	20	..	..
40	..	..	..	..	..	.	14	123	.	.	.	.	1	5	.	..	.	..
45	1	11	.	..	.		5	37	.	.	.	.	.	.	..	.	.	.
Total	6	65	4	24	2	21	123	1095	48	418	27	268	4	22	9	86	2	24
Grand Total	12 Stands 110 Acres						198 Stands 1781 Acres						15 Stands 132 Acres					

* Area includes only that portion of the lot of which the sample is typical.

The distribution of stand areas according to site class is also significant. In the northern and transition hardwoods types the largest acreage is classed under Site II and Better, while in the oak type it falls under Site II Minus. Thus, the proportion of better soils on cut-over pine lots is higher in the northern and central parts of the region than in the southern.

The distribution of stands according to age class, in the transition hardwoods type, shows a greater number in the age classes above 20 than in those below. This is very likely due to the rather sharp falling off in pine lumber production since 1910. In that year the cut for Massachusetts fell to 155 million board feet from a total of 222 million the preceding year, and since then the decline has continued, except for the period of the World War. The comparatively large number of stands in age class 25 coincides with the peak of pine production during the period 1906 to 1909.

Table 2 shows the relationship between site quality and elevation. It will be noted that the great majority of the stands on the better sites occur at elevations ranging from 600 to 1200 feet, or, in other words, on the slopes

TABLE 2

DISTRIBUTION OF THE STANDS ACCORDING TO ELEVATION

Elevation above Sea Level * (Feet)	Percentage Distribution of Stands		
	Site II and Better	Site II Minus	Site III
400– 600	5%	5%	42%
600– 800	23	30	29
800–1000	33	34	10
1000–1200	33	18	19
1200–1400	6	11	
1400–1500		2	
Basis	133 Stands	62 Stands	31 Stands

* Taken from U. S. Geological Survey Quadrangle Maps.

and ridge tops; whereas, most of the stands on the poorest site are found at elevations under 600 feet, in the valley bottoms where glaciers deposited the bulk of their load of sand and gravel.

Transition Hardwoods Type

Composition of Hardwoods in the Previous Stand and Relation to Occurrence and Distribution of Species in the Present Stand

Frequent mention has been made of the hardwoods which form a minor part of every old field pine stand. From the tally of hardwood stumps and residuals, Table 3 has been constructed to show the composition of the hardwood element; but it should be recalled that the tally applies to high ground only and not to swales or stream courses, where hardwoods predominate.

TABLE 3

HARDWOODS PRESENT IN OLD FIELD PINE STANDS

Species	Average Number of Trees per Acre		
	Site II and Better	Site II Minus	Site III
Red Oak	2	3	1
White Ash	4	1	
Paper Birch	2	1	
Black Birch	3	1	
Hard Maple	1	1	
Black Cherry	2	1	2
Yellow Birch	1		
Beech	1	1	
White Oak		1	1
Red Maple	22	19	8
Gray Birch	2	5	6
Chestnut	3	4	4
Poplar	1	1	1
Total	44	39	23
Basis	41 Stands	27 Stands	15 Stands

It is noteworthy that red maple leads on all sites, with gray birch in second place. Many of the better hardwoods, such as white ash, hard maple, and paper birch, while present on the better sites, are entirely absent on Site III. Not only are there fewer species represented on the poorest site, but fewer individuals as well. Evidently, old field pine stands are more nearly pure when growing on the light, sandy soils. In addition to the species listed in the table, several others, such as hickory and butternut, appear occasionally.

An inspection of the crop tree tallies for present stands on Site II and Better showed certain general tendencies in distribution of species commonly found as advance growth under pine which might be correlated with the occurrence of hardwoods in the previous stand. For this purpose the five-chain sample strip was used as the areal unit, and only stands in age classes 5, 10, and 15 were included, since beyond this age many of the hardwood stumps have rotted and disappeared. Where a given species consistently was found to be present in large numbers on only a fractional part of the sample, its distribution was considered group-wise, or patchy; whereas, if it was present in approximately equal amounts on each of the five chains, its distribution was considered uniform, or stem-wise.

With regard to the stand records for Site II and Better only, red oak is present in appreciable amounts in 97 per cent of the samples. Although the number of crop trees varies by stands, there is no well defined tendency towards patchiness. In fact, the uniform distribution of red oak has been one of the outstanding observations in the present study, a finding which, in view of the scarcity of oaks in the previous stand, an average of only two per acre, substantiates the conclusions of other authors that the dissemination of its seed is accomplished chiefly by birds and rodents.

Black cherry, although found in only 50 per cent of the sample strips, shows an oak-like uniformity of distribution within the strips where it does occur. That the wide dissemination of its heavy seed is largely due to the activity of animals is beyond doubt, since cherry stumps or residuals occur in only 10 per cent of the strips in which cherry of the new generation is recorded.

White ash and hard maple are present in 85 and 67 per cent of the samples, respectively. In contrast to red oak and black cherry these species exhibit a distribution which may be characterized as patchy, and which, in all probability, is due to their much greater dependence on wind and gravity for dissemination. This is evidenced by the fact that in about one-half of the samples where white ash, and one-quarter where hard maple crop trees are abundant, stumps or residuals of the respective species are also present.

Black birch is recorded in slightly more than one-half of the samples. In three-quarters of the cases it occurs but scatteringly, while in the remainder it is decidedly group-wise. The latter is the more conspicuous tendency of the species. A close relation between trees in the previous stand and groups of reproduction in the new stand is shown by the presence of one or more residuals or stumps in 80 per cent of the group areas. This bears out the general observations made on the Harvard Forest that black birch advance growth of high density occurs only in the proximity of seed trees, despite the lightness of its seed.

The distribution of black birch contrasts with that of paper birch, a species which does not occur as advance growth under pine, but which seeds in following logging. Paper birch is present in 80 per cent of all the samples and shows a generally uniform distribution. Undoubtedly, the openness of the cutting area immediately after logging combined with the lightness of the seed accounts

for such a distribution. Apparently, black birch does not possess an equal ability to seed in fresh cuttings.

No definite relationships between trees in the previous stand and those in the new can be shown in the cases of yellow birch and beech, since they occurred very infrequently.

The above observations deal only with the crop tree species. The composition and distribution of the weeds and trainers also bear a relationship to the hardwoods in the previous stand, but the present study cannot give this quantitative expression. The fact that red maple is the most common hardwood species in the previous stand unquestionably accounts for its predominance in the weed and trainer classes in the new stand.

Density of the Stands

Table 4 shows the distribution of stands according to density of stocking. On Site II and Better all stands older than five years fall in density classes I and II. Those on Site II Minus are somewhat more open, and those on Site III are decidedly thin. Hence, the density of stocking varies directly with site quality. The older stands on the better soils are of special interest, since well over seventy-five per cent of them fall in the highest density class. Thus, over three-quarters of the young stands attain a condition of full, or nearly full stocking within twenty years after the pine logging. Actually, on the very best sites full stocking often is reached within ten years. A number of young stands on the Harvard Forest contain upwards of five thousand stems per acre.

Composition of the Stands (Previous Stand over Fifty Years Old and Cut in a Non-seed Year)

Pine stands cut before hardwood advance growth has become established are followed by an inferior growing stock originating largely from seed disseminated after

TABLE 4

DENSITY OF STOCKING ACCORDING TO SITE AND AGE

Age Class	Percentage Distribution of Stands: Site II and Better, Density Class * I	II	III	Site II Minus, Density Class I	II	III	Site III, Density Class I	II	III
1–2	30%	50%	20%	..	50%	50%	..	..	100%
5	25	42	33	23	62	15	14	29	57
10	71	29		14	57	29		100	..
15	83	17		50	50			..	100
20	83	17		67	33			100	..
25	89	11		50	50			..	100
30	93	7		80	20			100	..
35	77	23		..	..			100	
40	90	10							
45	80	20							..
Basis	108 Stands			41 Stands			20 Stands		

* Class I—75 to 100 per cent of a full canopy.
Class II—50 to 75 per cent of a full canopy.
Class III—less than 50 per cent of a full canopy.

logging, while stands cut later in life are followed by a much better stock composed of stems of both advance growth and post-logging origin. Since nearly all pine cuttings are made after the stands reach sixty years, the present study is concerned chiefly with well stocked stands in which trees of advance growth origin play a leading rôle.

Relation of the Number of Crop Trees to Site and Age. Figure 4 presents curved values for the number of crop trees per acre according to age of the stand, or number of years after logging, for Site II and Better. At the start there is a total of somewhat over 600 per acre, but during the next few years the number has increased to over 700. This is accounted for by the seeding in, after logging, of trees of light-seeded sawtimber species, notably paper birch. Of the stands in the youngest age

class 18 per cent, in point of area, contained from 230 to 500 crop trees per acre; 23 per cent contained from 500 to 750; and 59 per cent from 750 to 1050 per acre. Of the stands in the five year class, 8 per cent contained from 350 to 500; 49 per cent contained from 500 to 750; and 43 per cent from 750 to 1100 crop trees per acre. This is

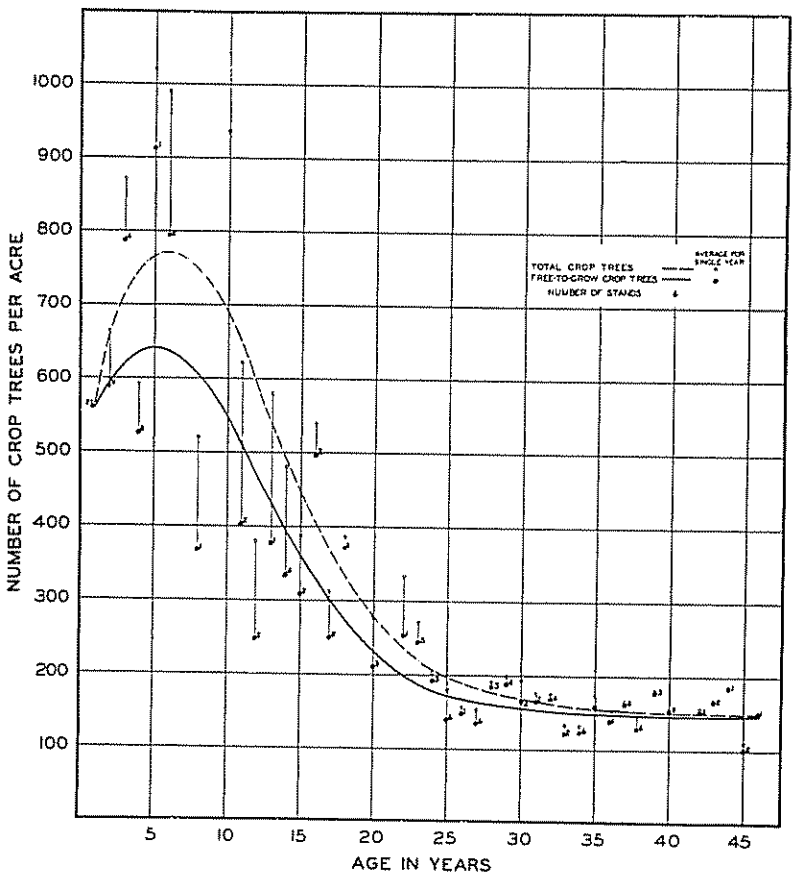

FIGURE 4. THE NUMBER OF FREE-TO-GROW AND OVERTOPPED CROP TREES PER ACRE, SITE II AND BETTER.

The curves, based on 126 stands, show the general trends in crop tree stocking on cut-over old field pine land during the period of from one to forty-five years after logging. Nearly all of the crop trees are of hardwood species, because the previous stands were cut in non-seed years.

abundant evidence that there is no dearth of crop trees in the beginning: even the poorest stands have more than enough to form a final well-stocked stand. From the five to the ten year age class there is a rather sharp falling off in numbers, due to the suppressing action of the weeds. In other words, it is not until five years after cutting that competition reaches an acute stage. From age ten to age twenty-five the struggle continues, with further heavy losses in crop trees until their number is reduced to slightly less than 200 per acre. At twenty-five years the leading elements in the stand appear to have accepted comparatively fixed positions, since during the next twenty years the number is reduced by only some 40 trees, making a total of about 150 at age forty-five. By the end of the first twenty-five years the stand evidently has closed in, and the period of greatest competition is past. It is indeed noteworthy that, in spite of unregulated competition, nearly enough good trees have survived to form a well-stocked final crop; that is, if each tree were fully developed and remained free to grow. Actually, a substantial portion of the main canopy space is occupied by weeds.

The difference between the number of free-to-grow trees (solid line) and the total number of trees (broken line) is the number of overtopped trees. It will be noted that the largest proportions of overtopped crop trees occur in age classes 10 and 15. The increase in overtopped trees after the first five years is at the expense of the free-to-grow trees, and thus attention again is called to this critical period in the struggle for dominance, extending from about the fifth to the twenty-fifth year and strongly marked at ten and fifteen years. At a point comparatively early in life, about thirty years, nearly all of the former overtopped crop trees are suppressed and must be classed as trainers.

Admittedly, there will be differences of opinion in

judging the ability of any given tree to respond to release and gain a place in the main canopy, and one may question the very evident placing of many subordinate trees between five and fifteen years of age in the trainer, rather than in the overtopped crop tree class. It is the experience of the Harvard Forest staff, however, that, in the densely stocked stands on the heavy soils, a tree once overtopped and forced to accept several years of subordination cannot overtake its free-to-grow neighbors.

The trends in crop tree stocking on Site II Minus (Fig. 5) are broadly similar to those on the best sites, but at substantially lower levels. The smaller number of crop trees is very definitely associated with the less fertile soil. At the start there is a total of about 300 crop trees per acre, and at ten years 400, as compared with 600 and 700, respectively, on Site II and Better. With advancing age this difference is narrowed considerably, owing to the

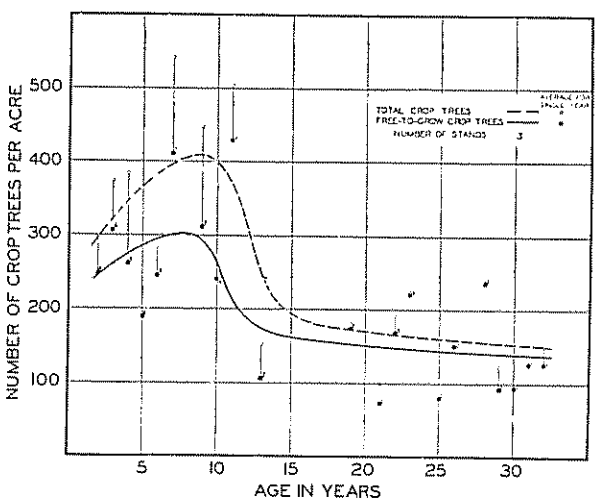

FIGURE 5 THE NUMBER OF FREE-TO-GROW AND OVERTOPPED CROP TREES PER ACRE. SITE II MINUS.

The curves, based on 44 stands, show the general trends in crop tree stocking on cut-over old field pine land during the period of from one to thirty-two years after logging. Hardwoods constitute a high percentage of the crop trees.

tendency of understocked stands to become more fully stocked as time goes on. The steeper downward trend of the curves, as compared with that in Figure 4, may be due largely to insufficient data. Another possible explanation is that on the poor sites there is a higher proportion of individuals accepted in the seedling stage as prospective crop trees and then rejected in the sapling stage, owing to coarseness caused by low density of stocking, than on the better sites.

The crop tree data for Site III show a very irregular trend (Table 5), probably due to the small number of stands included (twenty), but in general the stocking of crop trees runs true to expectations in that it is lower, especially in the younger stands, than on Site II Minus.

Relation of the Composition of the Crop Trees to Site and Age. *Site II and Better.* Table 5 shows the number of crop trees per acre according to species, site, and age. It will be noted that red oak is the leading species on all three sites in the transition hardwoods type. On Site II and Better it occupies first place in all ages after ten years. Starting with 241 trees per acre, or 39 per cent of the total stocking, this species with increasing age reveals its ability to dominate its associates, until at forty-five years it constitutes 75 per cent of all the crop trees. In fact, it outnumbers all other species combined in the age classes beyond 25.

White ash, like red oak, originates almost wholly as sprouts from the small stools of advance growth, and for the first five years these two species are the principal components of the young stand. Beginning with an average of 256 crop trees per acre, or 37 per cent of the total, ash decreases in numbers with advancing age until at forty years only 5 per acre remain. The table shows no ash crop trees whatever in age class 45, but incidental observations made in a few still older stands showed an

TABLE

CROP TREE STOCKING ACCORDING

Average Number

Age Class	Red Oak		White Ash		Paper Birch		Black Birch		Hard Maple		Black Cherry		Yellow Birch	
	F *	O †	F	O	F	O	F	O	F	O	F	O	F	O
Site II														
1-2	215	26	245	11	37	3	6		42	1	12	.	2	
5	268	26	130	23	51	5	38	2	32	4	46	.	15	
10	64	22	46	33	204	31	13	5	22	10		1		
15	121	13	66	26	95	14	17	6	24	10	1	1	7	2
20	104	15	61	19	31	1	1	1	41	8	1		28	1
25	88	7	11	5	45	5	8		3	4	1		3	1
30	133	4	12	4	15	3	5		2	2		.	1	
35	95	2	6	1	21	3	9		4	2			1	1
40	89	4	5		31	1	8		5	1	1	.	3	1
45	107	1	.	.	19	.	4	.	2	1	5	1	.	1
Site II														
1-2	112	27	120	19	6	.	13				42	1	.	
5	107	20	62	9	42	9	7	1	17	10	29	1	.	1
10	175	57	8	9	50	10	7	.	2	2	2	1	.	
15	70	6	3	3	25	13		.	3	2			.	
20	127	14		2	10	2	2	.	.	.	2		.	
25	124	5	2		7	7	1	1					2	3
30	123	3	2	5	13	.	3		1	3			.	
35				.	.	.	.	.	.	.	.	.	.	.
Site														
1-2	65			.	.		.		1		14	.	.	.
5	98	1		.	.		.	.			16	1	.	.
10	36	8				.	.					4	.	.
15	84	12		2	1		.			1	1	.	.	.
20	88	60	4		4	.	.			.		.	.	.
25	90	7	.	.	7		3		.			.	.	.
30	226		.	.			.	.				.	.	.
35	45	4	.	.	.	.	.	.	.	.	.	.	.	.

* Free to grow.
† Overtopped.

[1] Based on 109 stands.
[2] Based on 41 stands.
[3] Based on 20 stands.

TO SPECIES, SITE, AND AGE

of Trees Per Acre

Beech		White Oak		Scarlet Oak		Hickory		White Pine		Hemlock		Total	
F	O	F	O	F	O	F	O	F	O	F	O	Free to Grow	Over-topped
and Better [1]													
1						2		15	2	1		578	43
						8		24	16	1		613	76
			1			4	1	5	18			358	122
		1	2					6	22	1	1	339	97
	1		1					3	7			270	54
1						1			2			161	24
				1		1			1			170	14
												136	9
				2					1		1	144	9
4												141	4
Minus [2]													
		1					1	5	2		1	299	51
				1	1	17	8	14	21	1	4	297	85
		2				4	20	9	21		1	259	121
								6	23			107	47
		3		5					1			149	19
		12	2	1		1						150	18
												142	11
II [3]													
		9		3				6				98	
		7		3				12	7			136	9
		2							8			38	20
		13	13					12	18			111	46
				24				12	12			132	72
		3						3	13			106	20
		2										228	
		33	3	45	2			8	5			131	14

occasional ash to be present. That such a high percentage of red oak and such a low percentage of white ash should be found in the older stands is due to inherent differences in growth habit. Patton (1922) has shown that red oak is space-demanding, while white ash is crowd-enduring. Corresponding terms more recently suggested are "aggressive" for oak, and "recessive" for ash. Ash trees which do succeed in gaining a place in the final crop are usually intermediates or codominants with comparatively small crowns and slender boles.

Paper birch, since it originates from seed disseminated after logging, shows a gain in numbers during the few years when the ground is still comparatively open, and before the sprout stems become too tall, but thereafter it undergoes a steady decline in abundance. Nevertheless, it ranks next to red oak in all ages after twenty-five, and, at least during the first fifty years, grows rapidly and exhibits an aggressiveness and crown development second only to that of the oak.

Black birch occurs in both the sprout and seedling form, though chiefly in the latter. It has a rate of growth and crown development similar to that of paper birch, but is not found in as large numbers at any age. The proportionate loss in numbers with age, however, is similar. Crop trees are most numerous in the five-year-old stands,—40 per acre. Forty-five years after logging the number has been reduced to only 4 per acre.

Hard maple and yellow birch, both largely dependent on the advance growth for their origin, and both shade-tolerant and long-lived, are not aggressive enough during the first forty-five years to secure a prominent place among the crop trees. Although never very abundant, they are represented at all ages. Even at forty-five years there is an average of 3 hard maples and 1 yellow birch per acre.

Black cherry is another species which is found most

FIGURE 6. A FORTY-YEAR-OLD STAND REPRESENTATIVE OF THE TRANSITION HARDWOODS TYPE ON CUT-OVER OLD FIELD PINE LAND, SITE II AND BETTER.

The leading crop trees are red oak and paper birch; the leading weeds, red maple and red oak stump sprouts. The trees are spindling and slow growing due to crowding.

commonly in the sprout form, though on recent cuttings there are individuals showing unmistakable evidence of seed origin. Five years after logging the number of crop trees averages 46 per acre, but within the next few years there is a very abrupt falling off in numbers, and beyond ten years only scattered crop trees are found. The heavy loss may be attributed in part to the tent caterpillar *(Malacosoma americana Fab.)* and black knot *(Plowrightia morbosa (Schw.) Sacc.)*

Beech occurred too infrequently to permit the discovery of any trend in abundance with age.

White oak, scarlet oak, and hickory, all of them originating very largely as sprouts from advance growth stools, appear sparingly as crop trees in the transition type, especially on the better sites, and no significant variations in numbers with age are evident.

White pine forms a very minor part of the crop tree stocking, the largest number occurring five years after logging, namely, 40 per acre; but, of these, 40 per cent are overtopped. With increasing age there are heavy losses until at twenty-five years only 2 crop trees per acre remain, and these are in the overtopped class. What few pines survive beyond this age generally are found in the trainer class.

Because of its limited occurrence and slow growth, hemlock plays an unimportant rôle among the crop trees. Up to and including age class 15 one to two crop trees per acre were noted, but scarcely a one in the older ages.

Site II Minus. The total number of crop trees for Site II Minus is substantially less than for Site II and Better (Table 5). Red oak is outstandingly the leader, with paper birch, white ash, hard maple, and black birch less common than on the better site. There are also differences in the case of yellow birch, which is seldom found as a crop tree on Site II Minus; of beech, which is entirely absent; and of white oak, scarlet oak, and hickory,

which are present in slightly greater numbers than on the better site.

Site III. On Site III the more exacting species, such as white ash, paper birch, black birch, and hard maple, are very poorly represented as compared with the better sites; and yellow birch, beech, hickory, and hemlock are entirely absent (Table 5). In contrast, white and scarlet oak are shown to be more plentiful on Site III than on either of the better sites. Especially noteworthy is the increased number of white pine crop trees present in the older ages, attributable to the comparatively slow growth and low density of the hardwoods.

Relation of Form and Quality to Site. Table 6 shows that there is a direct relationship between form and quality of the crop trees and site. In over four-fifths of the samples taken on Site II and Better, in stands twenty-five years of age and older, the crop trees were rated as *good* or *very good;* whereas, in every sample on Site III they were rated as *poor*. Intermediate between these extremes is Site II Minus with the ratings divided among *good, fair*, and *poor*. On account of the predominance of red oak in the older stands mention should be made of the tendency of the most vigorous individuals to

TABLE 6

FORM AND QUALITY OF THE CROP TREES IN RELATION TO SITE CLASS *

Site Class	Percentage Distribution of Stands			
	Very Good	Good	Fair	Poor
II and Better	33%	48%	17%	2%
II Minus		36	43	21
III				100

Basis—86 Stands, 25 years and over in age.

* Form and quality based chiefly on length, clearness, and straightness of bole of representative crop trees.

remain in a dominant position from the start, thereby becoming heavy-crowned and coarse-limbed, finally yielding a lower proportion of high grade lumber than trees in a managed stand.

Composition of the Multiple-stemmed Weeds. *Site II and Better.* Undoubtedly, the most damaging weeds are the multiple-stemmed sprouts, especially those from stumps of large hardwoods which formed a part of the previous stand. Figure 7 shows their frequency of occurrence expressed as a percentage of the number of stands in which a given species is found at progressively older ages. In stands five years or under in age there is a relatively large amount of growing space for each tree, and hence few trees are classed as weeds; but with advancing age the crowns close in and many of the inferior trees attain an overtopping position. The graph reveals that age class 15 marks the peak of occurrence of sprout

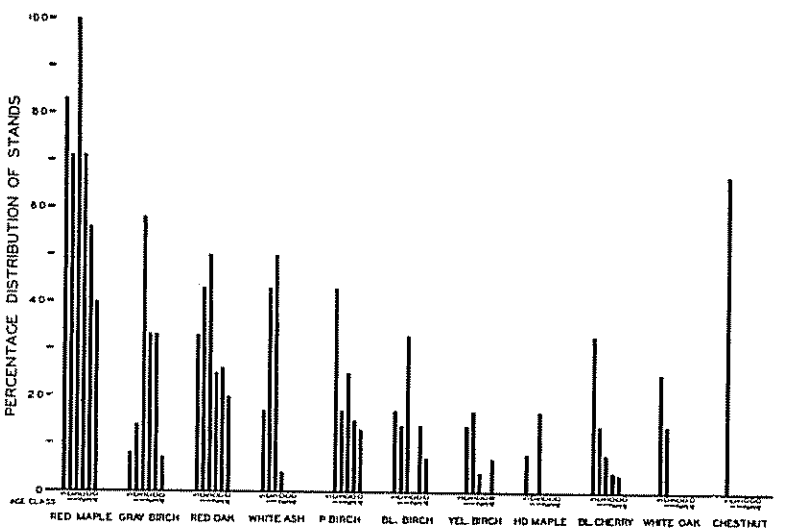

Figure 7. The occurrence of multiple-stemmed weeds, according to species and age class, site II and better.

Example: 83 per cent of the stands in Age Class 5 contained red maple.

weeds for several important species, that is, at 15 years the percentage of stands containing red maple, gray birch, red oak, and white ash weeds is in each case at its highest.

Red maple occurs more frequently at all ages than any other species. At fifteen years it is present as a weed in 100 per cent of the stands; and perhaps equally important, at forty years it still persists in 40 per cent of the stands. Red oak ranks next to red maple and exhibits a similar trend in occurrence.

Gray birch should be placed among the leading weeds because of its prevalence in sapling-sized stands, but it is subject to early decadence and death, in this respect differing from the longer-lived red maple and red oak. In the forty-year-old stands it retains an overtopping position in less than ten per cent of the cases.

The less aggressive nature of white ash is again demonstrated by its failure to attain dominance in the older ages. At twenty years it is present in about five per cent of the stands, and thereafter none whatever is recorded.

Paper birch, black birch, and yellow birch multiple-stemmed weeds, though generally less prevalent in the young stands than those species listed above, deserve mention because of their persistence throughout the entire period covered.

Hard maple and white oak, even when of sprout origin, evidently fall behind early in the life of the stand, since neither is present as a weed beyond the fifteen year age class. Black cherry sprouts make extremely rapid growth for a few years immediately after logging, but, like cherry crop trees, they lose vigor at a comparatively early age. No black cherry weeds were found in stands older than thirty years.

Chestnut was formerly an important species, but due to the chestnut blight successive generations of sprouts

FIGURE 8. A YOUNG STAND AT THE CRITICAL PERIOD, FIFTEEN YEARS OF AGE, WHEN MULTIPLE-STEMMED WEEDS REACH THE PEAK OF THEIR OCCURRENCE.

On the right a triple-stemmed red oak sprout clump is overtopping well-formed oak and ash saplings desirable as crop trees.

are killed before reaching large sapling size. The records show chestnut to be commonly present in the weed element only during the first seven years.

Certain miscellaneous species, notably alder, beech, and amelanchier, occur occasionally as multiple-stemmed weeds in age classes 5 and 10, but not thereafter.

Site II Minus. The number of stands included under Site II Minus, forty-three, is too few to warrant other than general comparisons with Site II and Better. Table 7, showing the frequency of multiple-stemmed weeds for this site, is presented in place of a graph.

Red maple still leads in occurrence, but its leadership is somewhat less outstanding. Gray birch shows some gain, especially in the early ages, and contends with red oak for second place.

Black cherry and white oak occur more frequently on

TABLE 7

THE OCCURRENCE OF MULTIPLE-STEMMED WEEDS ACCORDING TO SPECIES AND AGE CLASS, SITE II MINUS

Species	Percentage Distribution of Stands Age Class				
	5	10	15	20	30
Red Maple	85%	90%	100%	44%	17%
Gray Birch	23	50	40	33	33
Red Oak	30	40	20	44	67
White Ash	23	..	40	..	..
Paper Birch	..	20	20	22	17
Black Birch	23	20	20		
Yellow Birch		10			
Hard Maple	..	..	..		
Black Cherry	54	50	20	..	..
White Oak	15	40	20	11	17
Chestnut	36				
Miscellaneous	8				

Basis—43 Stands

Example: 85 per cent of the stands in Age Class 5 contained red maple.

the poorer site, and paper birch, white ash, and yellow birch less frequently. Another exacting species, hard maple, is completely lacking on Site II Minus.

Site III. Twenty-three stands were sampled on Site III, and with this small number only the most conspicuous tendencies are worthy of mention. The influence of the poor site is evident in that such species as white ash, yellow birch, and hard maple are entirely absent as weeds; while red oak and paper birch have a much lower frequency than on the better sites. Those species which show a decided increase are gray birch, white oak, and black cherry. Red maple still occurs in a high percentage of the stands, and shares the leadership with gray birch. Scarlet oak was recorded as a weed for the first time, being entirely absent on the better sites.

Composition of Single-stemmed Weeds. *Site II and Better.* The composition of the single-stemmed weeds

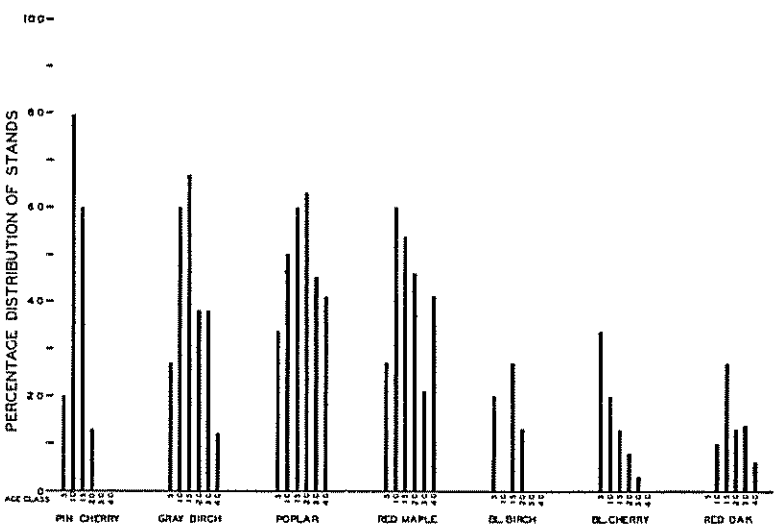

Figure 9. THE OCCURRENCE OF SINGLE-STEMMED WEEDS, ACCORDING TO SPECIES AND AGE CLASS. SITE II AND BETTER.

Example: 20 per cent of the stands in Age Class 5 contained pin cherry.

differs from that of the multiple-stemmed in that poplar and pin cherry occur only in the single-stemmed form; beech, yellow birch, hard maple, and chestnut, only in the multiple-stemmed form. Figure 9 shows the frequency of occurrence of the single-stemmed weeds. Unlike the multiple-stemmed weeds, there is no well defined peak at 15 years for a majority of the species.

WEEDS OF SEEDLING ORIGIN ONLY

Gray birch, poplar, and pin cherry are the outstanding weed species which owe their origin to seed which is disseminated, or at least germinates, after logging. Although all three are commonly referred to as being short-lived, differences are to be noted in this regard. Pin cherry is the shortest-lived, as evidenced by its disappearance after the first thirty years. Gray birch is somewhat more lasting, occurring in a small percentage of the 40 year stands, while poplar is present in 40 per cent of the stands in the oldest age class.

WEEDS OF SEEDLING OR SEEDLING SPROUT ORIGIN

Red maple, black birch, and black cherry, although single-stemmed, may originate either direct from seed or from very small stools, both kinds of origin being noted in the field. Red maple far exceeds the other two in its prevalence, and shares leadership with poplar and gray birch.

In the younger stands certain dominant black birches, probably from small stools, were so far ahead of neighboring trees that they were classed as weeds; but the fact that none is recorded as a weed in stands beyond twenty-five years indicates that the rapid early growth rate is not maintained.

Black cherry, which in its early life has a tendency towards extremely rapid growth similar to that of black birch, is present as a weed in stands up to thirty years of

age. For some reason its early superior position as regards height and crown size is not maintained. Similar losses with age were noted under crop trees and multiple-stemmed weeds.

Certain red oaks also were noted as single-stemmed weeds, on account of their super-dominant position and excessively large, spreading crowns. Thus, red oak may be grouped with black birch and black cherry as a desirable crop tree species which, none the less, not infrequently must be classed as a weed because of individuals with wolf tree tendencies.

Mention should be made of certain species found occasionally and not included in Figure 9, namely, white oak, paper birch, white ash, hornbeam, and amelanchier.

Site II Minus. The occurrence of single-stemmed weeds on Site II Minus is shown in Table 8. The same species are present as on Site II and Better, with the exception of white ash, hornbeam, and amelanchier. There is a noticeably higher frequency of occurrence of white

TABLE 8

THE OCCURRENCE OF SINGLE-STEMMED WEEDS ACCORDING TO SPECIES AND AGE CLASS, SITE II MINUS

Species	Percentage Distribution of Stands Age Class				
	5	10	15	20	30
Pin Cherry	46%	50%	80%		17%
Gray Birch	23	90	80		50
Poplar	46	10	80	33	33
Red Maple	15	80	60	11	17
Black Birch		30	40		
Black Cherry	36	20			
Red Oak	15	10	40	22	
White Oak	6	40	20		
Paper Birch		10			

Basis—43 Stands

Example: 46 per cent of the stands in Age Class 5 contained pin cherry.

oak and gray birch on the poorer site, but for the other important weeds there is little or no convincing evidence of significant differences. As on Site II and Better, leadership is divided among poplar, gray birch, pin cherry, and red maple.

Site III. The most reliable observation which can be made from the data for Site III is an increase in the occurrence of poplar, gray birch, and white oak, and a decrease in red maple and pin cherry, as compared with Site II Minus. Gray birch and poplar quite definitely take the lead over red maple and pin cherry on the poorest site.

Composition of the Trainers. *Site II and Better.* Figure 10 shows the frequency of occurrence of the trainers. The five year age class has been omitted, owing to the fact that differentiation has not reached the point where it is possible to identify the trainers. No separation according to origin was made in the field notes, but,

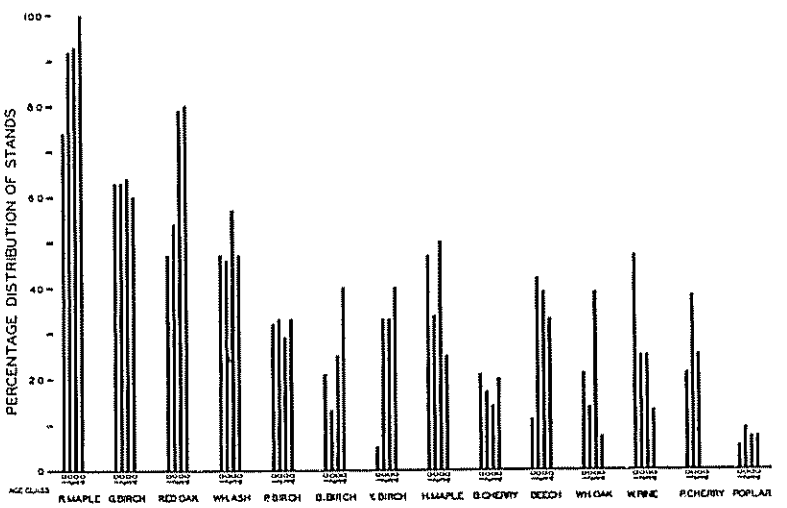

Figure 10 THE OCCURRENCE OF TRAINERS, ACCORDING TO SPECIES AND AGE CLASS, SITE II AND BETTER.

Example: 74 per cent of the stands in Age Class 10 contained red maple

in general, the trainers were single-stemmed, and they originated either direct from seed or from very small advance growth stools.

The predominance of red maple is at once evident: it is found more frequently at all ages than any other species.

Gray birch, red oak, and white ash are next in order, with the three birches, hard maple, cherry, and the several remaining species at still lower levels of occurrence. Out of fourteen species listed in the graph, pin cherry is the only one which drops out before forty years. It is somewhat surprising to find that gray birch, a light-demanding and short-lived species, is present as a trainer in nearly sixty per cent of the age class 40 stands. The occurrence of poplar as a trainer is extremely low, and as a weed extremely high. This is explained by its extraordinarily rapid early growth, which places it in a dominant position from the start. Only the most vigorous stump sprouts of other species have an early growth rate equal to that of poplar.

It is noteworthy that many of the better hardwoods, such as white ash, hard maple, and yellow birch, which are very poorly represented among the crop trees in the older stands, occur quite commonly as trainers, thus furnishing further proof of their inability to compete with the more aggressive species. It may also be noted that white pine shows a downward trend with age. This is most certainly due to its gradual elimination through suppression by hardwoods.

Other species found too seldom to warrant including in the graph are hickory, striped maple, and amelanchier.

Site II Minus. The data for trainers on Site II Minus are not presented, but it may be stated by way of general comparison that the better hardwoods either occur less frequently than on Site II and Better, or are entirely absent. Red oak, white ash, black birch, and beech fall

in the former group; hard maple, paper birch, and yellow birch in the latter. On the other hand, white oak and the weed species—red maple, gray birch, poplar, and pin cherry—are more prevalent. As might be expected, white pine trainers are more common than on the better site. This is in keeping with the record of the crop trees, which also shows an increase in the pine with a lowering of the site quality.

Site III. The majority of the stands on Site III come under age class 5, and are, therefore, too young to have developed trainers. However, in the few (seven) older stands sampled, the influence of poor site is unmistakably shown by a preponderance of white oak and the presence of scarlet oak, a species not found on the better sites. Red maple and gray birch rank next to white oak, and the only other species present as trainers are red oak, black cherry, white pine, and poplar.

Composition and Density as Influenced by Cutting the Previous Stand before Fifty Years of Age

The age of the previous stand could not be determined where the stumps had so rotted that it was impossible to count the annual growth rings. The following observations, therefore, are based on the more recent cuttings, under twenty-five years of age.

Only 13, or about eleven per cent of all the stands below twenty-five years of age followed the cutting of pine less than fifty years old. These are divided among the site classes as follows: Site II and Better, two stands; Site II Minus, three; Site III, eight.

With such a small number of samples no quantitative statement of the altered composition and density is possible. However, the general tendency toward poorer composition and lower density of stocking is unmistakable. Not only are the five stands on the two better sites notably lacking in the better hardwoods which have their

origin in the advance growth, but their density also is lower, ranging from density class II to III, as compared with I to II for the stands following the cutting of pine older than fifty years. Six of the eight samples on Site III show no appreciably poorer composition or lower density, but the other two are of particular interest. Both are in age class 15 and followed the cutting of pine forty years old. The tally shows not a single hardwood crop tree; only weed species are present,—red maple, pin cherry, gray birch, and poplar.

Composition as Influenced by Cutting the Previous Stand in a Seed Year

Out of a total of 226 stands examined, 38, or 17 per cent, contain a heavy stocking of pine which evidently has resulted from seed year cuttings. Of these, four have been weeded and two grazed, and they are therefore not included in the records. Twenty-one were found on Site II and Better; six on Site II Minus; and five on Site III. It will be noted that the percentage of occurrence is somewhat lower than that (25 per cent) found by Fisher and Terry (1920).

Table 9 shows rather wide variations in the amounts of free-to-grow and overtopped pines present even for a given site and age, but the well established tendency of pine to be overtopped by hardwoods early in life and reduced to a state of suppression is amply demonstrated. It will be noted that from age class 10 to age class 15, Site II and Better, there is a sharp dropping off in free-to-grow pines; and beginning with age class 25, four out of eight cases contain no trees above the suppressed class. At the same time, in some of the other cases small quantities of pine do remain free to grow up to forty years. Inspection of the field records reveals the specific reasons for the survival of pine in two of the stands in age class 40: in one the pines were concentrated in a

TABLE 9

THE PROGRESSIVE SUPPRESSION OF WHITE PINE REPRODUCTION RESULTING FROM CUTTING THE PREVIOUS STAND IN A SEED YEAR, ILLUSTRATED BY INDIVIDUAL STANDS

Class Age	Number of White Pines Per Acre					
	Site II and Better		Site II Minus		Site III	
	Free	Overtopped	Free	Overtopped	Free	Overtopped
5	260	440			70	290
	10	460				
	108	136	..	..	..	..
10	304	182	00	460	292	140
	220	176	432	444		
	24	202	..	..	..	..
15	56	300	40	100	30	180
	00	1099	8	152		
	00	285	124	776		
	44	108				
	28	36				
	4	24				
20	00	265			..	..
25	00	00			10	148
	00	28	..	..	..	..
30	12	151	3	270	120	100
	00	00				
35	..	..				
40	00	00				
	40	22				
	53	88				
45	00	00				
Basis	21 Stands		6 Stands		5 Stands	

group; and in the other the density of the hardwoods was unusually low. Incidentally, these represent the only conditions observed under which an appreciable amount of pine survives more than three decades. It is very evident that, on the better soils, the bulk of the pine reproduction is thoroughly overtopped by hardwoods at fifteen years. This corroborates Fisher's (1918) conclusion that "If a young mixed stand is to yield a substantial percentage of white pine, it must be treated for release and

FIGURE 11. A FORTY-THREE-YEAR-OLD STAND REPRESENTATIVE OF THE NORTHERN HARDWOODS TYPE ON CUT-OVER OLD FIELD PINE LAND, SITE II AND BETTER.

Paper birch, hard maple, and beech occur more commonly than in the transition hardwoods or oak types; red maple is the leading weed, and beech is conspicuous among the trainers.

improvement not later than the twentieth year, and still earlier on good soils."

Under Site II Minus the presence of free-to-grow pines in all cases in age class 15 indicates that suppression proceeds at a slower rate on the poorer soil. The cases under Site III support such a tendency in that they show free-to-grow pines in all the stands examined, even at thirty years.

Northern Hardwoods Type

Because of the small number of stands (twelve) classified under the northern hardwoods type, it must suffice to point out the broader tendencies and to make only general comparisons with the other types.

Aside from a composition running more strongly to northern species, its most significant characteristic is the greater number of crop trees per acre, amounting roughly to fifteen per cent more than in the transition hardwoods type. This is considered to be due to the generally higher density of the northern forest rather than to any proportionate increase in the crop tree stocking at the expense of weeds and trainers.

Red spruce, balsam fir, and larch are found only in the northern type, while paper birch, hard maple, and beech are much more common than in the transition type; and such southern species as scarlet and white oak and hickory are entirely absent.

Red maple of the multiple-stemmed form is the leading weed, and to this extent the northern and transition types are similar; but otherwise a strong tendency towards the single-stemmed form, with pin cherry, poplar, and gray birch the chief representatives, is a distinctive characteristic of the former.

The principal trainers are red maple, gray birch, paper birch, beech, and poplar. The high frequency of occurrence of paper birch, beech, and poplar is in contrast to

FIGURE 12. A THIRTY-YEAR-OLD STAND REPRESENTATIVE OF THE OAK TYPE ON CUT-OVER OLD FIELD PINE LAND, SITE II MINUS.

Red, white, and scarlet oak predominate in all age classes, and in all tree classes,—crop trees, weeds, and trainers.

the minor rôle which they play in the transition hardwoods, and their infrequent occurrence in the oak type. Notably lacking are red, white, and scarlet oak, and hickory, which are commonly present in the other types, particularly in the oak.

Oak Type

Fifteen stands were classified under the oak type. A comparison of the crop tree stocking with that of stands in the transition hardwoods type reveals no consistent numerical difference in favor of either, which means that the generally lower density of the oak type stands, as shown by the record of stand density, must be due to a reduction in weeds or trainers or both. That the crop tree stocking shows up so favorably is due to the comparatively limited composition running strongly to red, white, and scarlet oak, all of which were considered crop tree species. In addition to the three species of oak, hickory is also frequently present. On the other hand, beech is entirely absent; and yellow birch, paper birch, and hard maple occur very sparingly. White ash, black cherry, and black birch also are less numerous than in the transition hardwoods type.

The weeds are largely multiple-stemmed, while in the northern hardwoods the single-stemmed form predominates. Another point of distinction is that red maple, the leading weed in the other types, is at least equalled by red, white, and scarlet oak. Next in order are gray birch, poplar, and black and pin cherry. Black birch, yellow birch, and white ash weeds occur occasionally; paper birch and beech not at all.

Red, white, and scarlet oak are the principal trainers, occurring more frequently than red maple, the leading trainer in the other types. Hickory, black and pin cherry, white ash, and poplar are found less frequently than in

the transition and northern hardwoods types; and yellow birch, beech, and hard maple are extremely rare.

INFLUENCE OF PINE SLASH ON THE STOCKING OF THE STAND

The following account of the relation of slash piles to the composition and density of the stand is based largely on Altpeter's (1926) findings for stands up to twenty years of age, together with general observations made in the older stands during the course of the present study.

Conditions Five Years After Logging

Around the margins of the windrows where the slash is thin, and in the thin spots within the piles themselves, sprouts are able to force their way through in sufficient numbers to give a density almost equal to that of the sprout growth in the openings between the rows. The composition of this element, therefore, varies with site and other factors in the same manner as does that of all advance growth. Very little growth is present in the thick portions of the piles. What does force its way through comes from the larger advance growth stools, or from the still larger stumps of hardwoods cut with the pine. As time goes on, this initial stocking is supplemented in the thin places and borders by seedlings of the hardwood species which commonly come in after logging. Pine seedlings, in the case of a lot cut in a seed year, come in around the edges of the piles, but never in the deepest parts.

The growth of the trees along the borders of the piles is somewhat faster than of those between the piles, presumably due to the effect of the slash in conserving soil moisture. The difference in growth rate is particularly marked in the case of white pine seedlings on Site III cuttings.

Ten Years After Logging

On the better sites and where the slash piles are narrow, the crowns are coming together over the piles, but the border trees are bushy, and trees growing in the deepest parts of the piles are inclined to be sickly. Under average conditions the slash piles still create large holes in the canopy. It is at about ten years that differences in height growth between border trees and those in the openings are no longer evident. Altpeter found that most of the seedling reproduction within the pile is in spots where the slash is less than one foot deep and loosely piled, especially at the very borders of the pile, and that the better hardwoods are fully as tolerant of slash as the inferior hardwoods. On the basis of sample plots taken within and without the slash piles, he determined that, per unit area, there are two-thirds as many trees of the better hardwood species, and one-half as many of the inferior hardwood species within the slash piles as in the openings between the piles; furthermore, that the percentage composition within and without the piles is substantially the same. The latter finding indicates that the same general methods of weed control may be employed throughout the entire cutting area.

Fifteen Years After Logging

Under the best conditions of stocking and site the canopy has closed over the slash piles at the end of this period. The relatively greater crown spread and poorer form of the trees along the edges of the slash are less marked than in the earlier stages.

Twenty Years After Logging

On a large percentage of the lots on the better sites it is not until twenty years after logging that the crowns form a closed canopy. Where the slash piles are narrow,

the effect of slash on the density of stocking is hardly noticeable. According to Altpeter, "On the dry sites, slash piles up to twenty-four years of age were found to create openings which showed no possibility of closing for years to come."

Twenty to Forty Years After Logging

In the present study 88 per cent of the twenty to forty-year-old stands on Sites II and Better and II Minus, combined, were apparently uniformly stocked, and showed little or no evidence of slash; whereas, on Site III the percentage was 67. Of the forty-year-old stands, all appeared to be lacking in evidence of either the presence or influence of slash from the previous stand. This, however, should not be taken as proof that pine slash has no effect whatever on the final form and quality of trees which formerly grew along the edges and in the interior of the windrows, since detailed observations of form and quality were not a part of the present study.

CONCLUSIONS

It has been shown that the cut-over old field pine lots in the region covered have been reclaimed largely by even-aged mixed hardwoods. In 83 per cent of the cases pine has been completely replaced by hardwoods, and in the remaining 17 per cent, comprising those lots cut in pine seed years, it will form only a minor portion of the final stand.

Eighty-eight per cent of the hardwood stands examined had a composition characteristic of the transition hardwoods type, and of these 62 per cent were on Site II and Better. Thus, the findings are concerned chiefly with stands on the better soils of the so-called transition forest zone of central New England, and the following conclusions will deal principally with them.

TRANSITION HARDWOODS TYPE

Site II and Better (Medium to Heavy Soils)

Material Available for the Crop

In the young stands valuable hardwood species are well represented, and the density of stocking is such as to make possible the development of a high quality saw-timber crop. Five years after the pine logging there is an average of over 700 crop trees per acre (Fig. 4), about seven times as many as are needed for the final stand, and in most cases the trainer element is sufficiently dense to insure very good form and quality (Table 4). The principal crop species are red oak, white ash, paper and black birch, and hard maple. With the exception of black

birch, these are species of high commercial value and undoubted desirability for use in forming the new crop. The only alternative is to plant conifers and repeatedly cut back the hardwoods to free the plantation, an operation which seldom can be justified on economic grounds.

Early Treatment of the Stand

The present findings clearly indicate the character and timing of weedings and improvement cuttings * necessary to control the weeds and save the crop trees. The weeds are most destructive during the first fifteen years. Not only are the highest percentages of overtopped trees found in the 5, 10, and 15 year age classes, but the sharp dropping off in crop trees as a whole, starting with age class 5, shows that within a period of a few years many are thoroughly overtopped and forced into the trainer class (Fig. 4). Unquestionably, the greatest improvement for the least outlay can be made by weeding the stand during this formative period.** It is also evident that, in order to develop the best possible crop, the first weeding must be made soon after age five, before there is an appreciable decline in the number of available crop trees.

Red maple of the multiple-stemmed form was found to be the most common weed in the region. Because of its abundance, excessive demands on space, and long life, it deserves special attention in all weeding operations. Other common multiple-stemmed weeds are gray birch and red oak, both of which are very destructive when the stems arise from large stools. By and large, all weeds of sprout origin are much more aggressive and persistent

* The term "weeding" applies to stands not past the sapling stage, while "improvement cutting" applies to stands beyond that stage.

** The technique of weeding mixed stands is discussed in "Forest Weeding" by A. C. Cline, a publication of the Massachusetts Forest and Park Association; also in "Mixed White Pine and Hardwood" by A. C. Cline and C. R. Lockard, Harvard Forest Bulletin No. 8.

than those direct from seed. Stump poisoning, girdling, and other promising methods of preventing large stools from sprouting, merit special consideration as means of reducing weeding costs where the multiple-stemmed form predominates.

Of the single-stemmed weeds, gray birch, poplar, and red maple are the leaders, with pin cherry in fourth place. Of these the birch and the maple are the most harmful. Birch is fairly long-lived, as evidenced by its presence in 12 per cent of the age class 40 stands (Fig. 9), besides which it tends to be limber, and much more subject to bending by snow or ice than the others. Red maple, though more rigid and therefore less harmful through whipping, is much longer-lived than gray birch, and is able to continue in a dominant position throughout a sawtimber rotation.* Poplar is rigid, tending to break rather than bend, and this quality combined with its open crown and light foliage serves to place it among the less destructive weeds, even though in point of longevity it generally exceeds gray birch. Poplar does not occur in the multiple-stemmed form, since the stools send up suckers from the roots rather than sprouts from the stump. Pin cherry was found to be the shortest-lived of all weeds, being entirely absent as early as age class 30. Because of its short life and light foliage, pin cherry may be considered the least harmful of the weeds.

It is evident that stands in which the weed element runs strongly towards the multiple-stemmed form will require earlier and more frequent weeding, and consequently, a larger expenditure for labor, than those in which the single-stemmed form predominates.

* The occasional red maples which are sufficiently well formed and free from black heart to make merchantable lumber are almost invariably of the single-stemmed form.

Treatment of Stands Past the Sapling Stage

Although the time for the most effective control of weeds is between five and fifteen years, stands which have recently attained cordwood size are still within the limits of profitable treatment. The crop tree record shows that at twenty years there is a considerable number of overtopped crop trees which could be made available by release cuttings (Table 5). During the next ten years, however, the crowns of the leading trees close in to form a complete canopy, and most of the former overtopped crop trees are forced back into the trainer class. By thirty years the period of strongest competition for dominance is definitely past, and thereafter the number of overtopped crop trees is so small that no release treatment is warranted. Improvement and release cuttings, to be most effective and well within the range of profitableness, should be undertaken before the stand is thirty years old.

The question naturally arises as to what treatment, if any, may be applied to stands which have been neglected until thirty or more years of age, and what outcome may be expected where no treatment whatever is applied. It has been shown that in the oldest stands studied, 45 years, there is an average of nearly 150 free-to-grow crop trees per acre and that the number of overtopped crop trees is practically nil. With little or no opportunity for improving the composition of the crop tree element as such, it follows that thinning is the only treatment to be considered. The great majority of the stands past thirty years of age are densely stocked (Table 4, Fig. 6) and give every assurance of progressively increased congestion as time goes on. Spaeth (1920) has shown that well stocked hardwood stands at forty-five years contain an average of about 800 trees per acre two inches and over in diameter, or about 170 trees of seven inches and over

in diameter. By sixty years the number in the latter size range has increased to 400 per acre. When it is realized that, for a rotation of 60 to 70 years, less than 150 fully developed crop trees will completely occupy one acre of space, it is evident how much overstocked untreated stands are.

While the details of thinning cannot be discussed on the basis of the present findings, there can be no doubt but that the growth rate and final value of the existing crop trees can be materially increased, and the stands eventually be brought to a fairly good condition as regards density and volume, even though they failed to receive treatment before thirty years of age. But such an outcome is possible only with a lengthening of the rotation, besides which one must be content with a main crop made up largely of red oak of a quality lower than that obtainable through early treatment. In this region such a high proportion of oak must be considered a serious risk, on account of the increasing prevalence of the gipsy moth (*Porthetria dispar*). In the absence of any treatment whatever, only the most vigorous individuals will produce logs comparable in size with those from a managed stand. For the most part, the untreated stand will contain small-crowned, spindling trees ill suited to manufacture into high grade lumber.

The finding that, in spite of 45 years of unregulated competition, about 150 crop trees per acre have succeeded in holding or gaining a dominant position in the stand, should be a source of encouragement to owners of cut-over pine land and a strong argument against clear-cutting middle-aged stands for cordwood. It should be recalled in this connection that the authors accepted only single-stemmed trees of good form as crop trees. The inclusion of the best multiple-stemmed individuals of desirable species would have shown the effects of unregulated competition to be even less disastrous.

The Influence of Specific Growth Habits on the Control of Composition

With regard to the growth characteristics of the most important crop tree species and their influence upon weedings and improvement cuttings, special reference should be made to red oak. This species alone constitutes 75 per cent of the crop trees in the oldest stands studied, as compared with 39 per cent in the youngest, thus demonstrating its aggressive habit and its ability to attain leadership by suppressing its associates. Chief among the losers in the struggle is white ash, one of the most valuable species in the region, and, unfortunately, one of the most recessive in habit. The inability of ash to compete successfully with the other crop tree species stands out as one of the most important findings of the study. In the youngest stands it was fully as well represented as red oak, but in the oldest (45 years) scarcely a single dominant individual was recorded. Weedings and improvement cuttings offer the only means of bringing through any appreciable quantity of good white ash on the cut-over pine lands of this region.

In view of the increasing prevalence of insect pests and fungus diseases in the Northeast, foresters are now thoroughly convinced of the dangers which attend the growing of pure stands. Mixtures of species offer the only hope of adequate crop security. The extremely high proportion of red oak in untreated stands of the transition hardwoods type furnishes an additional and compelling reason for early silvicultural treatments to control composition.

It has been implied that red oak will take care of itself. This is true in so far as its superior ability to maintain a dominant position is concerned, but many of the oaks tallied as crop trees, especially in the less heavily stocked portions of the stands, exhibited wolf tree form. Large

branches or branch scars furnished ample proof of knotty wood in the bole. The red oak portion of the crop could be materially improved by the early selecting and favoring of the best formed individuals.

Paper birch ranks next to red oak as a leading crop tree species in the older stands. Like oak it often exceeds its neighbors in height, but the inherent tendency of its crown to be rather narrow and compressed generally prevents even conspicuously dominant individuals from being classed as wolf trees. Black birch also exhibits a tendency towards extra rapid growth and the attainment of dominance early in life, particularly marked in certain vigorous individuals, together with a similar amelioration of its relationship with its neighbors as time goes on. In the weeding of young stands greater consideration should be accorded super-dominant paper and black birches than young red oaks of similar development.

The findings in regard to white pine show that this species, to an even greater degree than white ash, cannot successfully compete with its associates; it can be saved only by timely weedings. Attempts to save pines which have been overtopped for more than twenty years generally have met with failure, chiefly because of their extreme susceptibility to breaking or bending with heavy snow or ice loads. Furthermore, little success has attended efforts to grow white pine in stemwise mixtures with hardwood on cut-over land, owing to the wide difference between the early growth rates of the two elements. Under the silvicultural policy of the Harvard Forest the pine is encouraged only where it occurs in sizeable groups, and then special care is taken to prevent the encircling hardwoods from overtopping and suppressing the marginal trees (Cline and Lockard, 1925).

Because of a high mortality in early and middle life, it appears advisable not to place too much dependence on otherwise promising black cherries to form good

sound crop trees in the final stand. In the weed and trainer classes no black cherries were recorded beyond age class 30, and representatives among the crop trees for the same period are too few to warrant much consideration.

Hard maple and yellow birch often exhibit excellent growth and form on the best sites; and, since neither tends to acquire the attributes of a wolf tree, the elimination of any individuals in the course of weeding usually will be on account of poor form or defectiveness rather than over-development. The same observations apply to basswood.

Site II Minus (Light to Medium Soils)

Site II Minus supports stands which have a generally lower density of stocking than those on Site II and Better (Table 4, Fig. 5), their composition running more strongly towards the central hardwoods, with white and scarlet oak and hickory replacing some of the northern hardwoods. However, red oak and paper birch continue to lead among the crop trees (Table 5). A substantial excess in crop trees over the minimum number required to form a final stand leaves no doubt as to the possibility of attaining a fully stocked volume, but the comparatively low density of stocking early in life, particularly of the trainer element, will exert an adverse influence on the final form and quality of the crop trees. Although Site II Minus will not produce as high quality sawtimber as the better sites, it would appear more desirable to develop existing young stands for sawtimber rather than for cordwood. Trees cut as soon as they attain a good size for cordwood will sprout prolifically from the stumps, thus giving rise to a new generation of low grade coppice; while those cut at sawtimber age are much less subject to stump-sprouting. Moreover, a desirable advance

growth reproduction can be established by this age, which makes possible the start of another sawtimber crop.

Site III (Very Light Soils)

The transition hardwoods type on Site III has been shown to be wholly unsuited to the growth of hardwood sawtimber (Tables 4, 5, and 6). Except where pine reproduction is present in sufficient amounts, there is no opportunity to develop a profitable volunteer sawtimber stand of any sort. In most cases the light, sandy soils must either be planted or allowed to grow cordwood.

NORTHERN HARDWOODS TYPE

The twelve stands classified under the northern hardwoods type show a generally higher density of stocking and a smaller proportion of weeds of the multiple-stemmed form than those in the transition hardwoods and oak types. Less weeding will be required, owing to a weed population which tends more towards the single-stemmed form; but, on the other hand, the higher density of stocking makes the matter of thinning more important. There seems to be good ground for the belief that the prevalence of fungus diseases in northern hardwoods is associated with dense stocking and the attendant condition of high atmospheric moisture and slow growth. The cutting or girdling of weed trees and, later, the periodic opening of the canopy in thinning should be conducive to healthier and more vigorous stands.

Paper birch, hard maple, white ash, red oak, and yellow birch occur most commonly among the crop tree species in the region covered, and well balanced mixtures of these give promise of a highly desirable crop. The northern hardwoods type on cut-over pine land is well adapted to the production of repeated sawtimber crops of first quality.

OAK TYPE

All stands classified under the oak type are situated in the southern part of the region covered, and, in general, they exhibit a lower density of stocking than those falling in the more northern types, this being attributed to a decrease in the trainers rather than in the crop trees or weeds. In fact, the number of crop trees per acre is somewhat higher in most cases than in the transition hardwoods type. This probably is due to the predominance of red, white, and scarlet oak, all of which were rated as crop tree species. Their predominance may also explain the decreased density of the trainer element. The comparative shade-intolerance of the oaks, particularly the white and scarlet, combined with the fact that oak regeneration seldom occurs in such high densities as are common with ash, maple, birch, and other species forming an important part of the trainer element in the other types, may well account for a scanty subordinate stand. Where the trainers are few, they cannot effectively carry out their function of pruning and shaping the crop trees, and the result is a crop made up of trees with relatively large crowns and short clear lengths of bole.

Owing to the less favorable conditions of soil, composition, and stocking, stands in the oak type cannot be expected to yield as high quality sawtimber as those in the transition and northern hardwoods types. Therefore, the choice between holding for sawtimber and cutting for cordwood is one which rests more largely on local market conditions. Where the decision favors growing sawtimber, timely weeding will be necessary in order to control vigorous multiple-stemmed oaks of poor form, and highly desirable as a possible means of enlarging the variety of species in the mixture, especially such species as are not favored food plants of the gipsy moth.

THE INFLUENCE OF SLASH LEFT FROM THE PREVIOUS CUTTING

The conclusions in regard to the effect of pine slash on the final stocking of stands on the better soils are such as to cast some doubts on the profitableness of slash disposal as a purely silvicultural measure. Too often, perhaps, it has been taken for granted that, because slash covers a third of the ground area at the start, it will reduce the stocking to a corresponding degree. While the present study does not provide any exact measurements of the effect of slash on final stocking, the fact remains that the oldest stands examined showed no noticeable evidence of variations in density of stocking attributable to slash. There can be no question of the worth of slash disposal as a protective measure, and, as a matter of accounting, the major portion of its cost might be charged against the removal of the old crop. Thus, while good management will demand slash disposal following clear cuttings of pine, it is to be emphasized that slash has not prevented a satisfactory volunteer restocking of the cut-over old field pine lands of the region.

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APPENDIX

LIST OF TREE SPECIES MENTIONED

Scientific Name*	Common Name
Abies balsamea (L.) Miller	Balsam fir
Acer pennsylvanicum L.	Striped maple
Acer rubrum L.	Red maple
Acer saccharum Marshall	Hard maple
Alnus incana (L.) Moench	Alder
Amelanchier canadensis (L.) Medicus	Amelanchier or shad bush
Betula lenta L.	Black birch
Betula lutea Michaux	Yellow birch
Betula papyrifera Marshall	Paper birch
Betula populifolia Marshall	Gray birch
Castanea dentata (Marsh) Borkhausen	Chestnut
Fagus grandifolia Ehrhart	Beech
Fraxinus americana L.	White ash
Hicoria glabra (Mill.) Sweet	Pignut hickory
Hicoria ovata (Mill.) Britton	Shagbark hickory
Juglands cinerea L.	Butternut
Larix laricina (DuRoi) Koch	Larch
Ostrya virginiana (Mill.) Koch	Hornbeam
Picea rubra Link	Red spruce
Pinus resinosa Solander	Red pine
Pinus rigida Miller	Pitch pine
Pinus strobus L.	White pine
Populus grandidentata Michaux	Poplar (Large-toothed aspen)
Populus tremuloides Michaux	Poplar (Trembling aspen)
Prunus pennsylvanica L.	Pin cherry
Prunus serotina Ehrhart	Black cherry
Rhus hirta (L.) Sudworth	Staghorn sumach
Quercus alba L.	White oak
Quercus borealis Michaux	Red oak
Quercus coccinea Muenchhausen	Scarlet oak
Quercus montana Willdenow	Chestnut oak
Salix spp.	Willow
Tilia glabra Ventenat	Basswood
Tsuga canadensis (L.) Carrière	Hemlock
Ulmus americana L.	Elm

* From *Check List of the Forest Trees of the United States: Their Names and Ranges* by George B. Sudworth. U. S. Department of Agriculture Miscellaneous Circular 92. 1927.