

HARVARD FOREST

BULLETIN No. 8

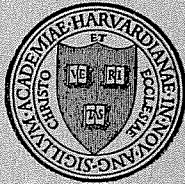
RICHARD T. FISHER, *Director*

MIXED WHITE PINE AND HARDWOOD

BY

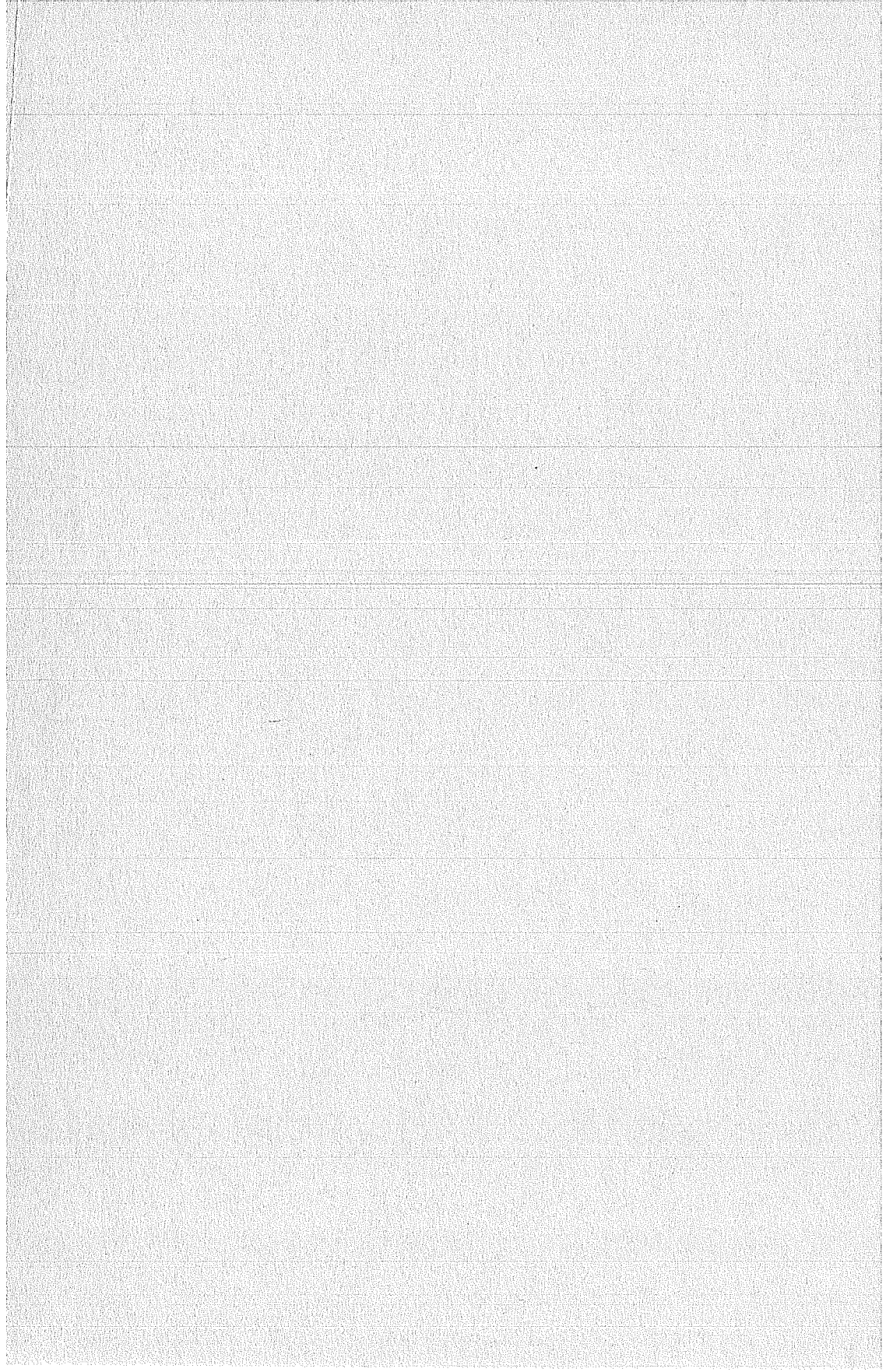
A. C. CLINE AND C. R. LOCKARD

WITH AN INTRODUCTION BY R. T. FISHER



HARVARD FOREST, PETERSHAM, MASS.

1925



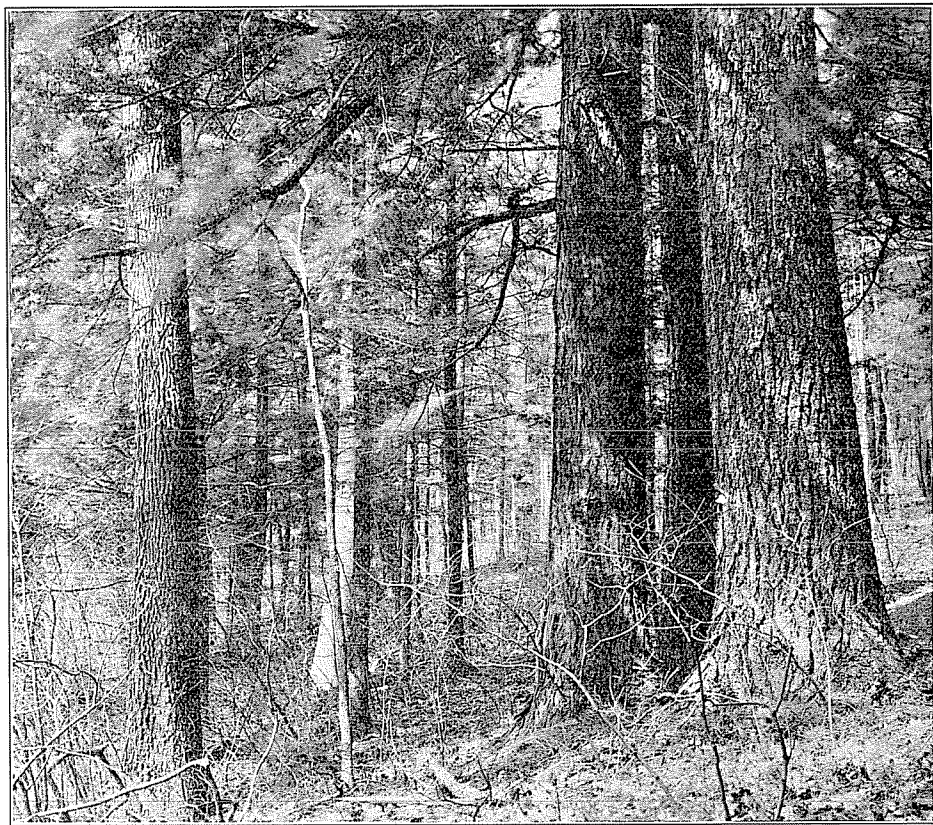


FIG. 1. CULLED STAND OF MIXED OLD GROWTH ON THE HARVARD FOREST
The original forest of central New England was largely mixed

Photographed by A. C. Cline

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PREFACE

THE study of Mixed White Pine and Hardwood, though it led the authors for many months by numerous highways and byways over a large portion of northern Massachusetts and southern New Hampshire, had its inception and consummation within the Harvard Forest — a forest and an institution which, in the minds of the present writers, is inseparable from its director and counselor, Professor R. T. Fisher. His help and advice in the prosecution of this study have been of inestimable value.

Following Professor Fisher's introductory chapter is the authors' principal contribution. This chapter on the life history of wild pine-hardwood stands is based very largely upon field work started in the fall of 1923. The chapter on management is little more than selected pickings from the Harvard Forest records and publications. Several prominent European foresters were written to for advice and suggestions regarding the management of pine-hardwood stands, particularly even-aged stands. Their replies were most reassuring, since in nearly every case they corroborated the existing silvicultural policy of the Forest, more specifically the segregation of the pine and hardwood into groups. The next chapter, which deals with the expectable yields and returns from managed pine-hardwood stands, indicates anew the profitableness of what is commonly referred to as intensive silviculture. Finally, in order still further to strengthen the cause of the mixed stand, the authors searched out opinions of eminent European foresters on the subject of pure *versus* mixed stands.

A. C. CLINE.

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PETERSHAM, MASS.

June 1, 1925.

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MIXED WHITE PINE AND HARDWOOD

INTRODUCTION

THE DESCENT OF THE WHITE PINE WOODLOT

THE passing of New England's primeval forests, now reduced to less than five per cent of their original area, is most commonly deplored in purely economic terms. The most obvious consequence has been the loss of the raw material, which is no longer available except by importation. But from the point of view of replacement, of the organization of production, this disappearance of the original forests has a much deeper and more important significance. The known figures for our initial and present supply and for current and expectable consumption sufficiently indicate the need for action; but what that action should be, what kind of forest production is most desirable, and how it is to be brought about can be soundly determined only by recognizing and interpreting the profound changes which human occupation has wrought upon the natural forest and upon the factors by which it was maintained. Timber is failing, and forest is increasing, but there is evidence that at present neither Nature nor man is growing timber crops of satisfactory permanence or value.

The original forest of central New England was largely mixed. Not only the records of the earliest travelers but also the scattered remnants of old forest that still remain indicate a prevailing mixture of hardwood with varying percentages of white pine and hemlock. Variations from this average composition were mainly related to changes in character of the soil and in the elevation above sea level. On the lighter, sandier soils there was a tendency to greater abundance of the softwoods, not only white pine, but also pitch pine and red pine, at the expense of the more exacting hard-

woods, which on these sites were unable to maintain their normal vigor. On the heavier soils, where clays predominated and moisture was abundant, the situation was all in favor of the hardwoods, which frequently attained such density and permanence as to exclude all softwoods except hemlock. A small percentage of the general forest area exhibited still other differences in make-up, such as the prevalence of spruce and fir on elevations above fifteen hundred feet, and an occasional strip of pitch pine on a sand plain; but in general the forest which the first white men entered was a varying mixture of the more enduring hardwoods, such as oak, maple, birch, ash, and chestnut, with white pine and hemlock.

One may picture this forest with the hardwoods and much of the hemlock forming a dense stand from eighty to one hundred feet high, above which, either by small groups or single trees, the white pines reached a height of one hundred and fifty feet or more. In general this mixture of species was self-maintaining; at least as regards the hardwoods and hemlock. A wide range of age was always represented, and the gaps occurring through decline or injury were imperceptibly filled by younger trees. To a lesser degree replacements among the pine came about in a similar manner, but its strongly groupwise distribution indicates that a larger opening was probably necessary both for the early development and ultimate survival of new generations. It is undoubtedly true, therefore, that over large areas, and considered in the aggregate, the composition of the primeval forest was for a given set of site factors permanent, but with respect to smaller areas, such as acres or parts of acres, there must have occurred considerable alternations of species. However, from the point of view of the soil it is plain that under such a continuous forest cover the tendency was all in the direction of improvement, and as regards the individual tree, especially the pines, there was a sustained vigor and longevity which little of the present second growth seems to promise.

In the first quarter of the eighteenth century, settlement began to penetrate beyond the coastal towns. Most of the upland towns of Massachusetts and southern New Hampshire were settled and incorporated between 1700 and 1750. Throughout the whole region the occupation of the land seems to have followed a similar progression. The better lands, both the valleys and the broad ridge-tops, were cut off and cleared for crops or pasturage. Such timber as was used thereafter was cut from the rougher, stonier areas, which were then allowed to reproduce as they would. At the worst the result was far better than occurs to-day, since only the larger, better trees were cut and there was an abundance of young ones to take their places. For more than a century this process of clearing and farming and of comparatively light cutting in the balance of the forest went on. It was a period of almost complete self-sufficiency on the part of the towns, and of extraordinary industry; cleared lands were kept clear, and such forest as still remained consisted mainly of the more valuable species and of large-sized timber. By 1830, in the region as a whole probably not less than fifty to sixty per cent of the total land area was clear and under some form of farming or grazing.

Soon after that the whole economic and social status of New England began to change. Beginning with the building of the railroads, and later accelerated by the discovery of gold, the Civil War, and the development of the Middle West, the small New England town began to dwindle. Farms began to be abandoned about 1850, and the movement reached its peak in the twenty years between 1860 and 1880. There followed a period of natural reforestation on cleared lands. At first, by reason of its adaptability to germination on the seed bed offered by old fields, and its abundant seed production, white pine outstripped all other species in the seeding up of farms. It is plain that those species which we now recognize as forest weeds, such as gray birch, poplar, and pin cherry, were then comparatively scarce, having been

kept out of the cleared lands while they were farmed and being in the forest of sporadic occurrence at best. Thus the earlier generations of old-field or second-growth pine were almost without admixture of other species. Because of the periodicity of seed years and the wide range of seed dissemination, the stands were of approximately even age and of high density and fair quality of timber. Large areas of abandoned land have continued to revert to forest, but in stands dating from subsequent to 1880 the amount and quality of white pine have steadily fallen off.

The cause and character of this deterioration are in part connected with the progressive effects of changing methods of lumbering. In the first half of the nineteenth century, logging in the region was mainly local, and lumber was manufactured by great numbers of small water mills. Little by little as the larger towns grew and lumbering became an organized business in the northern parts of New England, the stationary mills began to go out of use, lumber began to be shipped from longer distances, and various wood-working industries, with a wider range of purchase and operation, came into existence. With these changes the severity of cutting and closeness of utilization began also to increase, very considerable areas of culled original forest were cut over again, and the last of the older generation of pine was quickly used up. After 1890, and by imperceptible degrees, these wood-working industries, and to some extent also local lumber dealers, began to operate the oldest of the old-field stands. By this time in sum total the old-field forests of central New England had produced an enormous volume of timber, so great in fact that for nearly thirty years it has largely supported scores of towns and maintained a prosperity that has gone far to repair the loss of the old-time agriculture.

After two centuries of human occupation and use, the forest land began clearly to exhibit a number of significant changes in productiveness and condition. Historically we have reached a point where, broadly speaking, there are but

two sorts of forest land, that which has been one or several times cut or culled, but never cleared, and that which has reverted to woodland after a century or more of use as farms. Since 1900 both conditions of forest have been logged by clearcutting, frequently followed by fire, and always accompanied by the leaving of a heavy *débris* of slash. The immediate effect of this treatment has been a steady falling off in the composition of new crops following cuttings. The supply of seed-bearing forest of satisfactory age and species has become less and less. On the other hand, the prevalence of inferior light-seeded species more adapted to survival on exposed areas has constantly increased. Thus, even in cases where, as in older mixed stands, such as the culled remnants of virgin forests, a sufficient amount of desirable reproduction has been present, either the seeding in of weed species or the excessive development of hardwood stump sprouts has steadily eliminated the desirable elements in the forest. This result has been especially apparent after the cutting of pine woodlots. Trees which in respect either to form, age, or kind are merely weeds have multiplied a thousandfold. With sixty to seventy per cent of central New England now classifiable as woodland, almost the whole of our forest land is exactly in the condition of a garden that was never weeded.

But there are other tendencies at work which to the forest manager are no less significant. The greater part of the second-growth forests of to-day are standing upon land which originally bore either pure hardwoods or a mixture of hardwood and pine. In general it was only land under such types of forest which was considered rich enough for farms. In the older pine woodlots, those fifty years or more in age, there almost always develops an advance growth of hardwood, seedlings and small saplings, usually composed of the species whose seeds are transported by animals. For hardwoods the heavy duff layer and degree of shade which exclude the reproduction of pine seem particularly favorable, especially for such desirable species as white ash, red oak, and sugar maple.

Thus, potentially at least, there is going on a reversion to the composition of the first forest and the species which originally flourished on the land. Nevertheless, in practice even this prospect is thwarted, since, after cutting, the new generation of hardwoods is largely killed out by the combined effect of slash piles, weed species, and the over-development of stump sprouts. There are also cases and sites where there may be for a time a possibility of the replacement of pine. Although never found as advance growth in a dense old-field stand, when such a stand is cut in a seed year, and particularly on medium or light soils, there often occurs an abundant reproduction, sufficient in many cases to constitute a full stocking of the land. Here again, however, the effects of generations of neglectful treatment are too much for the slow-growing pine, and on all but the lighter soils, or in exceptional cases, the young crop is entirely shaded out. Beyond question, then — and this applies to all regions where hardwoods and softwoods occur together — cut-over forest land is reverting to hardwood progressively inferior both in kind and condition.

Undeniably the white pine woodlot is a transition type. Whether left standing beyond its usual cutting age or cleared off as in ordinary logging, it does not maintain its initial composition. Although the superficial evidence of this tendency is the reversion to hardwood, it begins to be obvious that other and more fundamental factors are also at work. It seems probable that under older stands of pure pine a definite deterioration of soil has taken place. In some cases this impoverishment may have carried over from the previous period of neglectful farming; more often the slowing of growth on the part of the pine and the susceptibility to disease, both characteristic of the type, are probably to be connected with a progressive exhaustion of the soil. The form of such pine stands, particularly the shallow and rising crown canopy, allows considerable drying out of moisture and does not conduce to the building up of a beneficial humus

layer. The exact nature of this alteration in the soil remains to be determined. That some unfavorable change occurs, the condition of the old stands seems plainly to indicate.

Commercially the pure white pine type is generally considered to be the best kind of second-growth timber now abundant in New England. It shows a high yield per acre on a comparatively short rotation. It is easy to log and transport, and it has commanded the widest market. But even these advantages should not suffice to justify the continuous and repeated production of the type unless it can be shown to promise as safe and as large a return as it has in the natural stands of the past. Sixteen years of continuous experience with the white pine type on the moderately heavy soils of the Harvard Forest have accumulated a strong case against it. The natural enemies of the species have reached a staggering number, and all of them are most acute where it occurs in pure stands. On all but the poorer soils the maintenance of the type involves a costly and sometimes fruitless fight with hardwoods. On the other hand, there are many advantages to be expected from mixtures of pine and hardwood. The superior quality of the pine so grown, quite generally assumed by timber operators, has been established (1). Mixed forests containing pine are obviously possible of establishment on a large percentage of ordinary cut-over land where the attempt to secure a crop of pure pine would be too costly. Most of the hardwood species in the region have now become marketable, many of them at prices better than can be got for pine. Finally, the mixed forest would certainly enjoy the greater security and vigor which are bywords in European silviculture.

For some years it has been the custom on the Harvard Forest to reproduce pure pine stands to mixtures of pine and the better hardwoods. As a general policy this decision seems increasingly sound, but, though the establishment of the young crop has been comparatively simple, its later handling will evidently present more complicated problems. In Euro-

pean practice, for example, mixtures of pine and hardwood are commonly two-storied or uneven-aged; here past treatment has left the wild stands that we must deal with largely even-aged. Can pine be economically grown with hardwood in that form? Then there is the matter of the expectable final yield and value. The advantages of the mixed forest are decisive only if the financial return can be definitely forecast and shown to be at least equal to that of alternative crops. In New England there are no mixed stands more than fifteen years old that have been under silvicultural treatment. For answers to such questions it is therefore necessary to supplement what has already been learned by resort to observations of unmanaged or natural forests. The present study has involved a careful analysis of the origin and silvical history of wild stands. The field work involved has consumed nearly a year and a half and extended over almost 2,000 square miles in north central Massachusetts and southwestern New Hampshire. Based upon the material thus gathered and upon the records of the Harvard Forest, there is here presented a discussion of the methods and possibilities of converting existing second-growth forests, especially white pine woodlots, into mixed pine and hardwood.

REFERENCES

1. Tarbox, E. E., and Reed, P. M. Quality and Growth of White Pine as Influenced by Density, Site, and Associated Species. *Harvard Forest*, Bulletin No. 7. 1924.

LIFE HISTORY OF PINE-HARDWOOD STANDS

ORIGIN

BROADLY speaking, the present mixed pine-hardwood stands have originated in one of two ways. That portion of the type which has or promises the greatest commercial value and which is by far the larger in area has come in on cut-over lands, usually on areas from which pine has been cut. The less extensive portion of the type, inferior in condition, has been brought about by the gradual seeding in of abandoned fields and pastures. In the former case the stand is substantially even-aged and the growing stock consists in part of advance growth, chiefly hardwood, which was present under the previous stand, and in part of seedling reproduction which took place at or about the time of cutting. Stands thus originated may be, therefore, in part of seedlings and in part of sprout elements. In the case of old-field mixtures the forest is wholly of seedling origin. All parent stands are what is loosely called second growth, and the varying influence of human agencies is always evident.

The most common forest type to be followed by a mixed reproduction of pine and hardwood is old-field white pine. This is even-aged in form and usually contains scattered hardwoods, principally red maple, black cherry, and paper birch. At about forty years hardwood advance growth begins to come in under the pine, and by the time the latter is ready to cut, at say sixty years, a very dense thicket of hardwood may be present. If the stand is clearcut in a pine seed year, an abundance of pine reproduction usually follows. This is never uniform over the entire cutting area, but tends to be in groups. The pine seedlings, together with the hardwood advance growth, constitute the bulk of the new generation.

Another old-field type, namely pine-hardwood, may be followed by a similar mixture. This type is made up chiefly of white pine, red maple, birches, black cherry, poplar, and other hardwoods having wind- or bird-disseminated seeds.

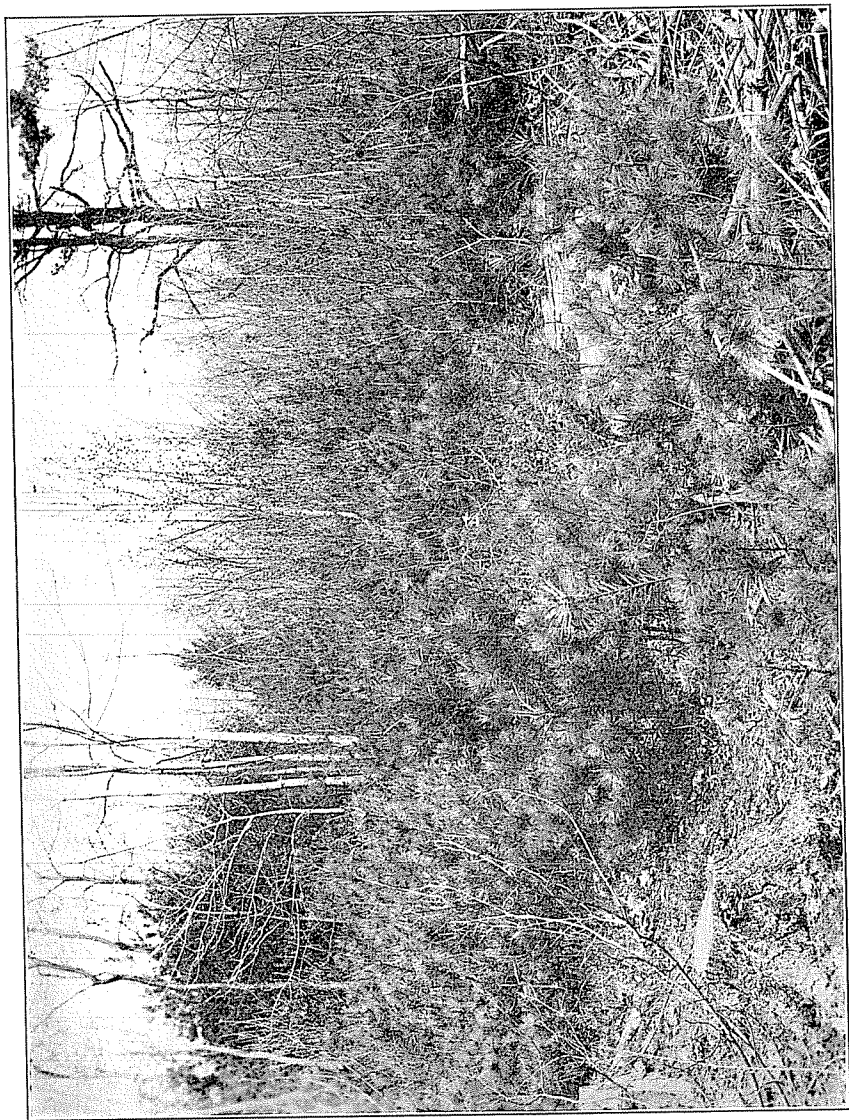


FIG. 2. YOUNG STAND OF PINE AND HARDWOOD
The result of cutting old-field pine in a seed year

Photographed by A. C. Cline

Advance growth of both pine and hardwood comes in before the old stand is merchantable, the hardwoods in the overstory evidently producing conditions favorable to pine reproduction. The pine seedlings, occurring sporadically in groups, are usually stunted in growth and are generally in the minority in the young mixture which claims the ground after the old stand is clearcut.

Under pure pine stands of low density, accidental shelterwood reproduction is sometimes present along with an advance growth of hardwood. The pine seedlings tend to be in groups wherever large enough holes exist in the canopy; and where the old crop has been carefully removed, a considerable amount of pine will be present in the ensuing mixture.

In addition to the old-field types, there is an even-aged, pine-hardwood type which results from the cutting of a previous mixed stand on land which has never been cleared, and which differs from old-field pine-hardwood in that it contains more of the better hardwood species, such as red oak, white ash, and black cherry. Generally it also has an advance growth of both pine and hardwood, and when clearcut may be followed by a pine-hardwood mixture of good composition.

Thus far the resulting mixtures have been even-aged. There is a type, however, which gives rise to an uneven-aged mixture. Advance growth pine often occurs under hardwood stands of low density. These pines are very much stunted in growth, seldom being more than ten feet high when twenty-five years old; but if allowed to stand when the hardwood is cut, they develop into a scattered overwood surrounded by the young growth of hardwoods, part of which consists of fast-growing sprouts from large stools.

Of these several ways in which a pine-hardwood mixture may originate, the clearcutting of old-field pure pine in a pine seed year is by far the most common and important. Since seed years occurred in this locality at three-year intervals for a period of about twelve years, lots cut over in the seed years of, for example, 1908, 1911, 1914 and 1917 have in many cases been found to come in to this mixture (1).

It is to stands thus originated, the most extensive in area, the most promising in yield, and the most nearly uniform in silvical conditions, that the following consideration of life history and management is confined.

COMPOSITION

Previous studies have already shown examples of the amount and character of the volunteer reproduction following the cutting of old-field pine stands (2). There is, however, a wide variation in its composition even over small areas. Composition varies with site, the character of the parent stand, as well as with the time and manner of its removal, and, perhaps most important of all, with accidental factors.

It is common practice in logging in this region to cut back all the hardwood advance growth which interferes with the chopping and skidding. Thus, one growing season after cutting there is a plentiful supply of sprouts from the stools of the advance growth, together with a much smaller number of sprouts from the stools of the larger hardwoods which formed part of the previous stand. These are supplemented by the seedlings of many light-seeded and bird-disseminated hardwoods, largely gray and paper birch, poplar, and black and pin cherry, species which are characteristically present under conditions of complete exposure following clearcutting. In addition to sprouts and seedlings, there are occasional root suckers of poplar and beech.

The species present as sprouts depend upon the composition of the advance growth, which in turn is largely influenced by site. On the best of the heavy soils, this consists of white ash, hard maple, beech, yellow and black birch, basswood, and elm, together with others which are more common on the medium soils, red oak, paper birch, black cherry, and red maple, and small amounts of those which are able to grow on the very light soils, white oak, poplar, gray birch, and pin cherry. The three latter owe their presence to large holes in the pine canopy, being too light-demanding to grow

under a heavy shade. On site I, white ash is generally most abundant, with the maples and shade-tolerant birches (black and yellow) in second place. On the medium soils (site II) comparatively little ash is found as advance growth, red maple, red oak, and black cherry holding first place. It cannot be said that the most shade-tolerant species are most abundant, or that they attain the largest size under the average old-field pine canopy. Black cherry is often very abundant, though it tends to come in late; also chestnut, before its elimination by the blight, sometimes ranked near the top in point of abundance. Yet neither of these is as shade-tolerant as many of the others which are less numerous. The light-seeded species in the advance growth are readily accounted for either by seed trees present in the stand itself, or around its margin. The heavy-seeded species, such as red and white oak, come in comparatively late, owing to the fact that the various animals which do most of the planting frequent chiefly the older pine stands. Under the pine canopy the hardwood grows slowly, attaining an average height of about ten feet when the pine is sixty years old and ready to cut.

As to the pine element, its presence in the young stand is less influenced by site than by the supply of seed, for when old-field pine is clearcut in a seed year, pine reproduction usually follows, regardless of other factors. Pine is less exacting in its soil requirements than most of the better hardwoods, and may be found reproducing itself on light, sandy soils, as well as on the heaviest.

Both the greatest variety in composition and the highest density of stocking are found on the most recently cut areas of site I. In other words, both the number of individuals and species of hardwood vary inversely with the time since cutting, and directly with soil quality. On the lightest soils, only a scattering of such species as gray birch, white oak, and poplar will be present after cutting; whereas on the heavy soils there may be as many as 30,000 stems per acre and twenty different species.

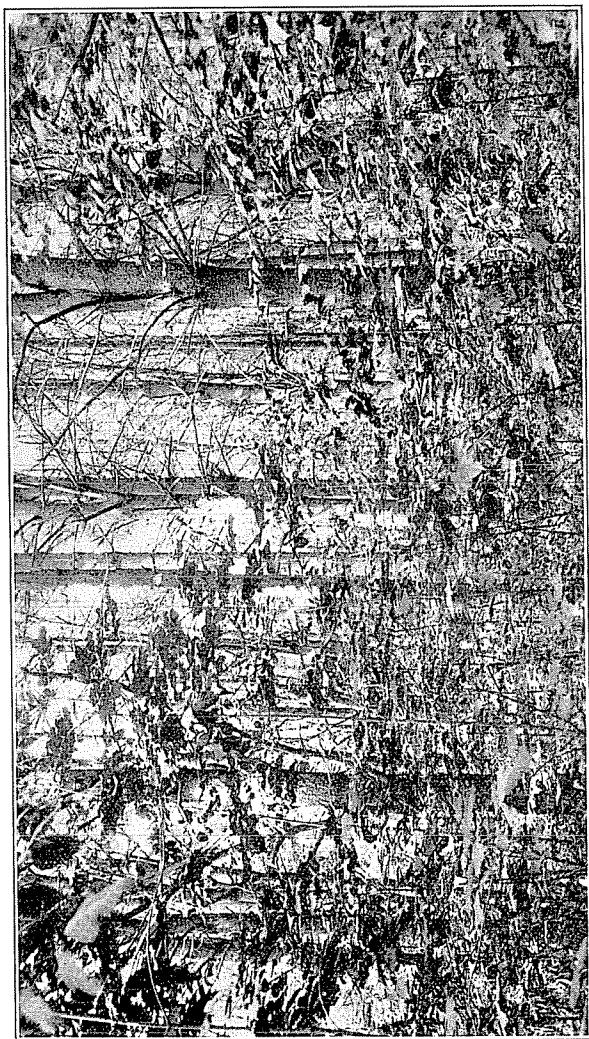


FIG. 3. ADVANCE GROWTH HARDWOOD UNDER OLD-FIELD PINE

On rich soils a very dense thicket of valuable hardwoods is often present by the time the pine is ready to cut

Photographed by A. C. Cline

HEIGHT GROWTH IN YOUNG STANDS

Although the young mixture is even-aged, at any time after the first growing season it is extremely uneven both in the vertical and horizontal distribution of stems, and in the rate of growth of its elements. A two-year-old ash sprout eight feet high may be standing beside a pine two-tenths of a foot high of the same age. Such striking differences in height are due to the exceedingly rapid growth of sprout hardwoods as compared with that of both pine and seed hardwoods. While sprouting stools of all sizes are represented, the great majority are under two inches in diameter (seedling and small sapling stools), and of these, the seedling stools, less than half an inch in diameter, are most numerous. In other words, during the twenty-odd years of their existence under the pine canopy, the hardwoods seldom grow to have a basal diameter of more than two inches, and most commonly, of more than half an inch. Far less abundant numerically, but most vigorous of all in height growth, are the sprout groups from stumps of the large hardwoods which occurred in the previous stand.

Measurements of sprouts establish the fact that for a given age, and size of stool, many species of the better hardwoods have practically the same height. Height growth does not appear to be influenced by the number of sprouts per stool. Figure 4 is a composite of graphs for sprouts of red oak, white ash, paper birch, yellow birch, black birch, black cherry, red maple, and hard maple, all growing upon the better grades of soils (sites I and II). Growth rates of these species were so nearly alike that one graph served for all the species considered. Though more intensive study might disclose slight differences in height growth, these are unimportant from the standpoint of practical silviculture.

In the case of hardwoods originating from seed, measurements show that they too have a practically uniform rate of

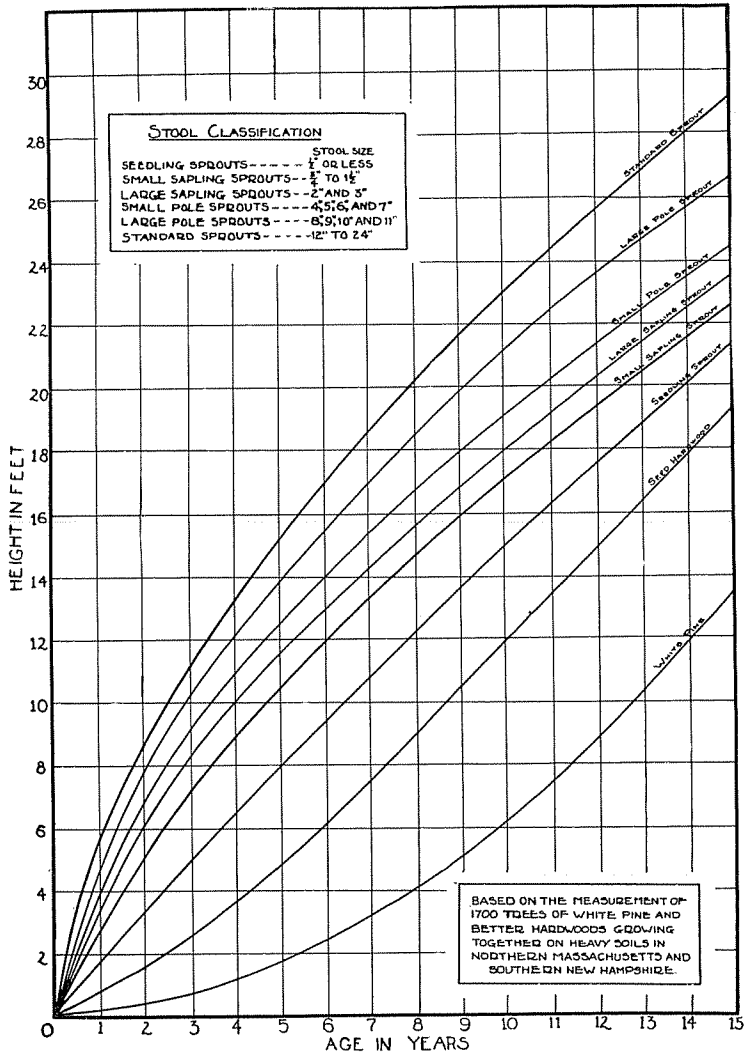


FIG. 4. HEIGHT GROWTH OF SPROUTS AS INFLUENCED BY THEIR AGE AND THE SIZE OF THE PARENT STOOL

(Average height-age curves of better hardwoods of seed origin, and of dominant White Pine from mixed pine-hardwood stands added for comparison.) Stool ages Range from 1 to 60.

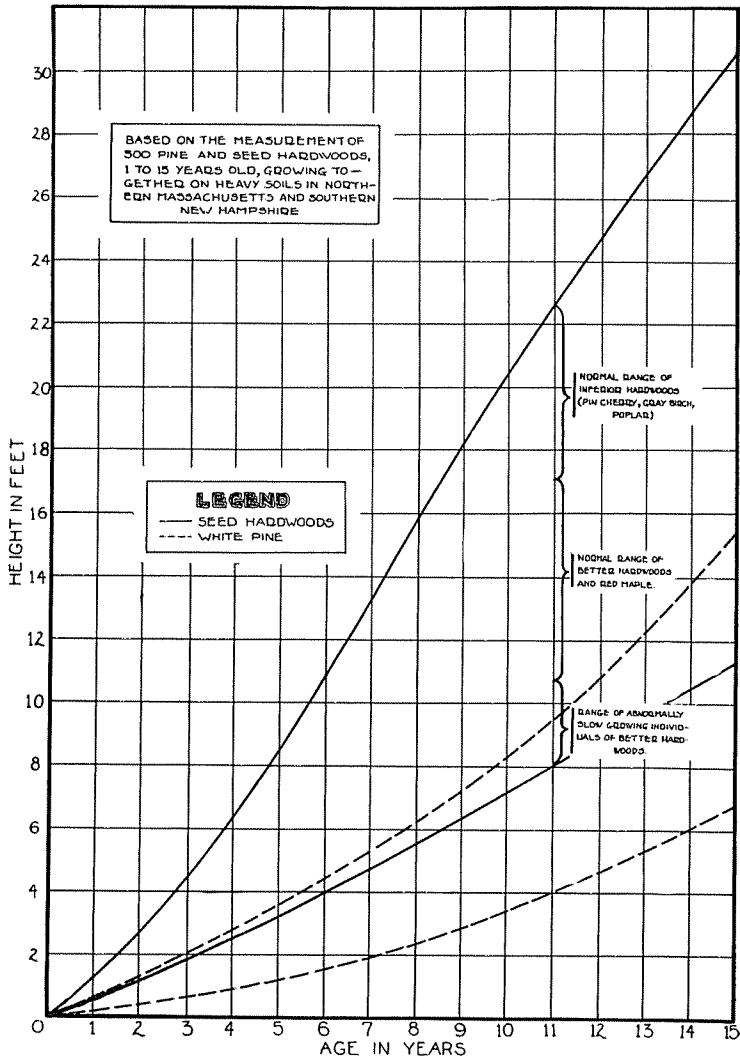


Fig. 5. THE RANGES IN TOTAL HEIGHT ON AGE OF HARDWOODS ORIGINATING FROM SEED, AND OF WHITE PINE

growth, though slower than that of the sprouts. Figure 5 shows the ranges in height growth of seed hardwoods, both better and inferior species, and of pine. It will be noted that poplar, pin cherry, and gray birch outstrip all others. These inferior species are relatively short-lived, but on the other hand, on account of their early vigor, they are able to crowd out many of the better hardwood seedlings. The inferior hardwoods, with the exception of red maple, originate mostly as seedlings after cutting, and thus play a negligible part in the sprout element.

It is plain from Figures 4 and 5 that pine is outgrown in height, at least during early life, by every species of hardwood, both sprouts and seedlings, with the exception of the very fastest-growing pine as compared with the slowest-growing hardwoods. The latter include ashes which have been cropped by deer, red oaks attacked by a twig disease, black cherries attacked by black knot, and other individuals whose slow growth cannot be readily accounted for. The pine is still further handicapped by numerous pests. During the first three or four years, large numbers are killed outright by the Pales weevil, and the growth of many others is seriously retarded (3). When a little older, it is attacked by the white pine weevil (4), and this pest may continue to attack it for twenty years or more, greatly retarding its height growth. Furthermore, the tips of the leaders of pines between three and fifteen feet high, sometimes the tips of the side branches as well, are occasionally nipped off by squirrels and possibly other animals.

RELATION OF SIZE OF STOOL TO NUMBER OF SPROUTS

Hardwood sprouts owe their dominance not only to rapid height growth but also to the space demanded by the wide-spreading stems. Figure 6 is based on stem counts made for stools of red oak, white ash, red maple, and paper birch. Up to a certain point the number of sprouts varies directly with the size of the stool; the maximum occurs with stools about

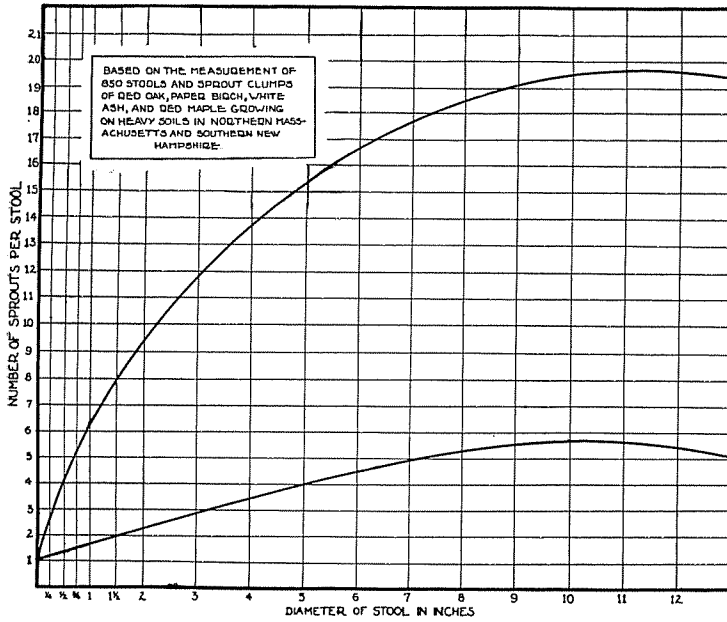


FIG. 6. THE RELATION OF THE DIAMETER OF HARDWOOD STOOLS TO THE NUMBER OF SPROUTS

Sprout Ages Range from 3 to 15; Stool Ages from 1 to 60. (Upper and lower curves are the average maximum and minimum, respectively)

one foot in diameter. Thereafter, increased size and age result in a reduction of sprouting capacity, until finally no sprouts are produced. The wide range in numbers of sprouts per stool is due to differences in individual vigor as well as to specific habit. Within the range of advance-growth hardwood stool sizes, there is little or no noticeable variation in number of sprouts per stool attributable to species; but with the older, larger stools, specific tendencies become more pronounced. For example, old ash stools send out a few bunches of stout sprouts from points mostly above the root collar, while paper birch produces a great number of weak, limber sprouts uniformly encircling the root collar. Of the principal hardwoods in this region, red oak and white ash produce fewer sprouts, considering only the old stools, than paper birch and red maple. However, regardless of the number of sprouts per stool at the start, the number decreases with age until at the end of a sixty- to seventy-year rotation the sprout clumps of all species will in general be composed of from two to five stems.

HORIZONTAL DISTRIBUTION IN YOUNG STANDS

As to general areal distribution of the elements in the young stand, two important conditions have been observed: one, a result of natural causes, the other, of artificial. Chiefly because of ground cover, soil factors, and large holes in the canopy of the parent stand, both the pine and the hardwoods are more or less concentrated in groups. The other condition is brought about by piling the slash in windrows, a common practice in logging. Necessarily, the restocking is largely confined to the lanes between the windrows, and a stripwise stand is started, although within the strip it tends to be groupwise. Whatever the distribution may be, at the end of the first ten years the hardwood element has already strongly overtopped the pine.

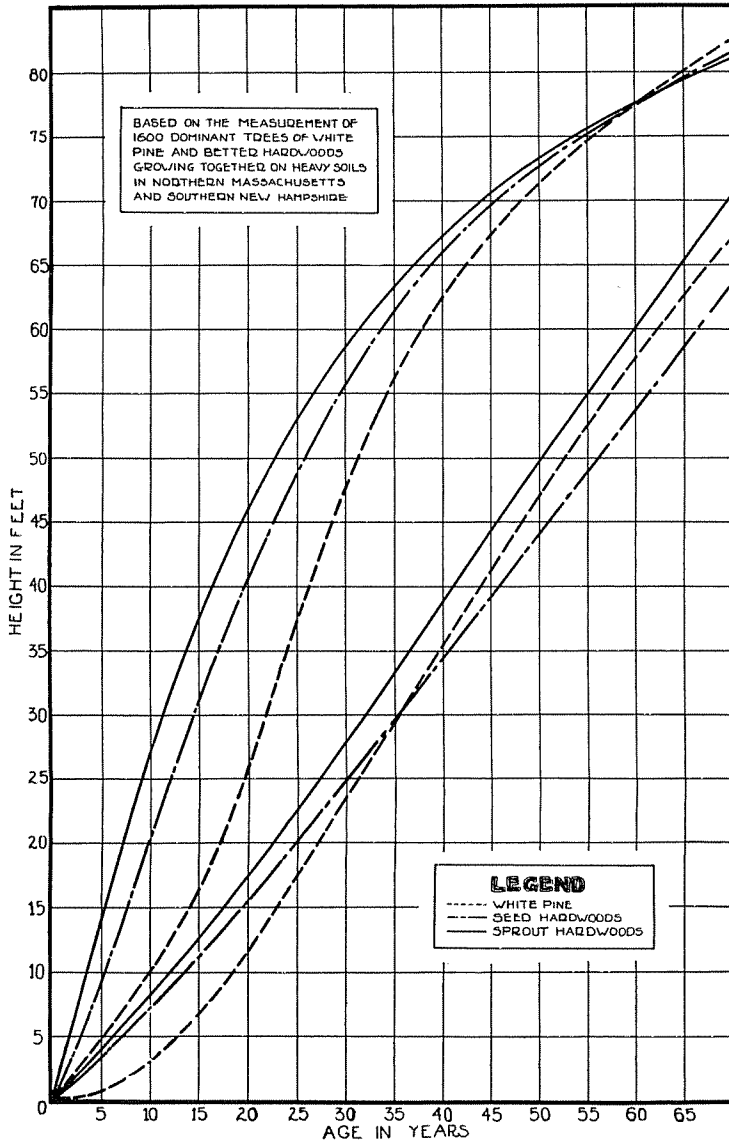


FIG. 7. THE RELATION OF TOTAL HEIGHT TO AGE OF WHITE PINE AND BETTER HARDWOODS OF BOTH SPROUT AND SEED ORIGIN

(The average range in heights is included within each pair of lines of like kind)

HEIGHT GROWTH IN OLDER STANDS

Figure 7 shows the ranges in the relative height growths of the constituents of a mixed stand for a period of seventy years, only trees which have been free to grow being considered. Measurements of hardwoods of sprout origin were confined to those from stools either observed to be, or estimated to have been, less than $2\frac{1}{2}$ inches in diameter, since it was desirable to concentrate on such stool sizes as would commonly have to be dealt with in managed stands, namely, sizes common to advance growth. Height growth in the older age classes was also found to be practically uniform for the most common better hardwood species, the ranges in heights being influenced by site rather than species.

While the pine at first grows much more slowly than the hardwoods, its growth gradually accelerates until it equals that of the hardwoods, and finally exceeds it. The graph (Figure 7) shows that the poorest of the pine, if free to grow, equals in height the poorest of the hardwoods at about thirty-seven years; while the best of the pine does not catch up with the best of the hardwoods until sixty years of age. The best hardwood sprouts grow more rapidly than the best hardwoods from seed, up to an age of about sixty-two years; while the poorest, stunted seed hardwoods never equal in height the poorest sprouts. But these observations apply only to individuals which have been free to grow. In the wild stand, for every pine and every seed hardwood that is free to grow, there are ten or perhaps a hundred which are obliged to struggle along under the shade of their more rapidly growing neighbors. A great many of the most desirable individuals of both pine and hardwood are eliminated by faster-growing hardwood sprouts and weed trees.

SHADING AND ABRASION

During the first several years, root competition may account to some extent for the slow growth or death of pine



FIG. 8. A YOUNG STAND OF PINE OF HIGH PROSPECTIVE VALUE SHADED OUT
BY WEED HARDWOODS

One result of "letting nature take her course." There is almost an impenetrable barricade of dead
pine saplings

Photographed by H. H. Tryon

seedlings; but until the pines have grown to such a height that the hardwoods can damage them mechanically, the high rate of mortality is due to shading. The shade cast by the overtopping hardwoods so cuts down the light that, in spite of the fact that pine is of medium shade tolerance, it is killed. This process occurs chiefly during the first fifteen to twenty years. The period of death through shading grades off into a period of death through abrasion, although for a time the two forces work simultaneously. As the pine struggles higher among the hardwood crowns, the value of shading as an eliminating factor decreases, while that of abrasion increases.

For a given density and site, the abrasive effect of the hardwoods upon the pine varies with the species of hardwood. From measurements of hardwood crowns, Patton was able to separate the important hardwood species into two classes which he called "space-demanding" and "crowd-enduring" (5). The former is typified by red oak; the latter, by white ash. Under space-demanding he listed oak, beech, and basswood; under crowd-enduring, ash, sugar maple, black cherry, red maple, black, yellow, and paper birch. In general, the space-demanding species cause the greater damage to pine through abrasion, though stiffness of the stem is also a factor.

Furthermore, sprout hardwoods do greater damage to pine than do seed hardwoods, owing to the relatively greater crown spread of the former, which in turn is probably due to greater freedom of growth throughout life. Crown measurements made in this study appear to show that, for a given height and diameter, sprout hardwoods have a greater crown spread than seed hardwoods. Sprout clumps from large stools do greatest damage; and if the species happens to be a space-demanding one, the abrasive action reaches the maximum. Red oak is perhaps the worst offender in this respect, its wide-spreading sprouts inclining at angles of from ten to fifteen degrees from the vertical.

There is also a seasonal variation in the abrasive action. Undoubtedly the most damage to pine by hardwoods is done

in winter, when the limbs and twigs are coated with ice, and when the winds have full sweep. Here enters the question of species again, for the relative amount of damage depends much upon the rigidity of the stem. Red maple and paper birch, for example, with their suppleness, will do much more damage than will the relatively rigid ash and poplar.

Density of stocking also has its effect on the severity of the mechanical action. High densities produce small crowns, which in turn produce smaller diameters. "The smaller the diameter for any given height, the less the rigidity of the stem. The thin-stemmed, small-crowned trees sway in the wind and their crowns rub off all the lateral buds from their own and the neighboring crowns" (5)

Site must also be considered, for good sites tend to produce tall, spindling trees; while on poorer sites the individuals are stockier, and hence sway less. Therefore the rate of pine mortality is less on poorer sites. Fisher (2) says, in considering the rate of death on several sample plots: "This plot represents soil of a quality I, a site distinctly more favorable for hardwood than for pines. The figures show that suppression proceeded here much more rapidly than on the lighter, sandier soil of plot 2." And then again later he states that the pines, "Though completely overtopped, would have survived from five to ten years longer on poorer soil."

SURVIVING PINES AS REMNANTS OF GROUPS

Although the pine and hardwood elements tend to be groupwise in the beginning, groups of pine are rarely found in the older stands, particularly in high densities on site I. In understocked stands on the medium soils, many of the pines do survive, and in this case the groupwise form may be maintained until maturity. With high density and good soil, however, single pines are found growing on even terms with the hardwoods in old stands. In fact, the pine may be dominant in old stands. But this position of co-dominance, or dominance, was not achieved through the ability of the indi-

vidual tree to withstand shading and abrasion by hardwoods throughout life. Rather it is due to the fact that the individual is a remnant of a group. Given at the start a group of pines, the hardwoods encroach farther and farther as the stand develops. Figure 9 illustrates how, starting at the outer edge, one rank after another of the pines is eliminated by the hardwoods until only a single pine remains. In the middle-age classes many of the pines eliminated are still standing, while in the old-age classes oftentimes only the prostrate stems, and stumps are found.

The rate of group reduction under any given set of conditions decreases as the stand develops. While the first, or outer, rank of a group of pines is being eliminated, the inner members are developing. When the first rank has been killed out, the hardwoods can immediately reach the next, but the gradually increasing size of the individuals in the succeeding rows slows up the process of elimination. The dead trees stand as physical barriers guarding the few remaining interior trees from the ever-expanding hardwoods.

The size of the pine group necessary in order that there be a survivor is influenced by site and by the species of the surrounding hardwoods. On poorer soils, a smaller group will suffice to pull a single pine through than is necessary on better soils; while with the space-demanding oak, the rate of reduction is much higher than with the crowd-enduring ash.

Owing to the reduction of the pine's crown by abrasion, diameter growth is retarded until the pine reaches a dominant position. This probably is an explanation of the central core of narrow rings so frequently found in old-growth pines in mixture with hardwoods. Once the pine has passed the hardwoods, however, its crown expands to normal size and its diameter growth increases. In cross-sections of such trees the core of narrow rings is found to be surrounded by an outer rim of wider rings. The number of annual growth rings in the inner core becomes a measure of the length of the period of sub-dominance. This is quite in contrast to the

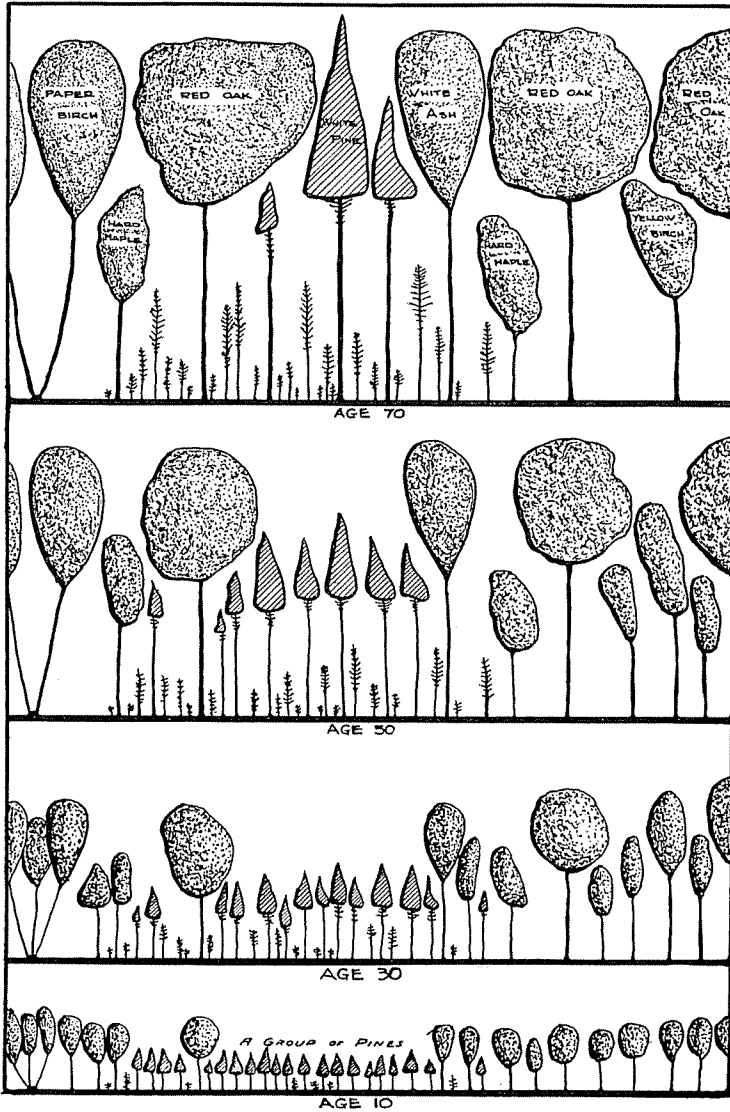


FIG. 9. THE DEVELOPMENT OF A WILD STAND OF PINE AND HARDWOOD

Showing the reduction of a group of pines through shading and abrasion by hardwoods until only a single thrifty pine remains. The Red Oak, a space-demanding species, does more damage to the pine than the White Ash, a crowd-enduring species

Drawn by C. R. Lockard

diameter growth of pine grown in pure stands. Here the widest growth rings are found near the centre, while the outer rim is made up of narrower rings.

Thus, a mature, even-aged stand in which single dominant pines occur mixed with hardwoods can have originated only from a groupwise distribution. One or a few pines from each group survive as individuals in the final stand.

QUALITY IN THE SURVIVING PINES

But if there is a loss in diameter growth in the surviving pines, there is a compensating gain in the quality of wood produced. Quality in second-growth pine is determined largely by length of internode, knot size, and rate of pruning. In pure pine stands, length of internode is a function of site, while knot size is a function of early density (6). These two factors of quality are likewise influenced in the mixed stand, but as regards rate of pruning there is a decided difference. Pure stands of pine are very poorly pruned. In most cases the branches, though dead, persist for as long as seventy years, because the action of natural forces tending to remove them is relatively slow in this form of stand. The dense year-around canopy keeps out much of the precipitation and sunlight, the combined effects of which hasten decay. Furthermore, the mechanical action of snow and ice is comparatively little, and that of hardwoods is absent. Pure pine stands are too dry and well ventilated to permit the rapid decay of dead wood.

But with a group of pines in a hardwood stand which is partly open in winter, and thus allows easy access to the elements, pruning proceeds at a much more rapid rate. Furthermore, as the pine group diminishes in size, the crowns of the nearby hardwoods, particularly the sub-dominant ones, help clean the pine boles, so that when the stand is about fifty years old the surviving pines are in a position to begin to lay on clear wood, and to develop into high-quality, veteran trees.

PINE IN UNEVEN-AGED MIXED STANDS

In uneven-aged pine-hardwood stands, single pines are sometimes found which do not owe their presence to the sacrifice of a large portion of a group. These pines were advance growth, but of unmerchantable size, at the time the previous stand was cut. In spite of the rapid growth of the surrounding hardwoods in the stand following cutting, the pines had such a start that they were able to maintain their lead. Their side branches, abnormally small anyway for want of light under the parent stand, were soon pruned off by the hardwoods so that a clean bole was developed at an early age. The bark of such trees furnishes an unmistakable sign of their origin. Whereas the bark on a pine grown in an even-aged group is often smooth until middle age, that on the lower part of the bole of an advance growth pine is rough and cracked.

SUMMARY

It appears then that, in the young volunteer stands following the clear-cutting of the pine type, the most valuable elements in the mixture are largely eliminated by unregulated competition. The better the soil, the more rapid the elimination. The pine element suffers severe losses in numbers due to suppression by hardwoods. It is only where it originates in groups that a few trees ultimately survive. The seed hardwoods also experience many casualties, as they grow more slowly than the sprouts and are soon overtopped. While at the start the combatants are exceedingly numerous, the fight is always won by the sprouts of such hardwoods as red oak and red maple, together with relatively few pines, remnants of groups, and seed hardwoods. The inferior hardwoods, such as gray birch and pin cherry, start rapidly, do much early damage, but eventually fall out because they are short-lived. The few pines which do come to maturity in mixed stands are of notably good quality. Such being the

case, one may confidently expect that proper management will result in a pine-hardwood mixture far superior to even the very best of the wild stands.

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THE MANAGEMENT OF PINE-HARDWOOD STANDS

WHATEVER may prove to be the most efficient methods of maintaining an ultimate managed forest, the forester to-day must, in a literal sense, make the best out of the growing stock as he finds it. Thus, the creation of mixed pine and hardwood crops can be effectively accomplished in one of two ways: either by the timely weeding of such volunteer mixed sapling stands as were described above, or by handling the cutting of mature pine in such a way as to secure a sufficient and satisfactory amount of pine in the new growth which follows. In fact, these two operations are both necessary in any proper scheme of management. It is the latter, however, the control of reproduction, which is first, both in importance and in time. The fundamental factor is soil. On the lighter, sandier soils the softwoods tend to predominate. Conversely, on the richer, heavier soils the hardwoods have all the advantage, so that in such cases there is no question of pine, either actually or potentially. Generally speaking, it is on the medium soils, that is, site II, where the formation and maintenance of mixed pine and hardwood stands may be expected to succeed.

STARTING THE CROP

Up to the present time experience in starting crops of pine-hardwood has been confined largely to the cutting of old-field white pine by either the clearcutting or shelterwood method. In addition to the results obtained from carefully planned and executed reproduction cuttings on the Harvard Forest, numerous cases have been studied where more or less satisfactory reproduction has resulted unintentionally. At least three methods have been practiced, namely: (1) clear-cutting in a pine seed year; (2) shelterwood; and (3) clear-cutting followed by planting. In each case the aim is to obtain pine, since the hardwood is abundantly available as

advance growth, supplemented by seedlings which come in subsequent to cutting.

CLEARCUTTING IN A SEED YEAR

In clearcutting pine in a seed year, logging should be delayed until the seeds have fallen, as otherwise they will be destroyed in the slash piles. At the time of logging, all advance growth hardwood should be cut back close to the ground, the purpose being "to secure an even, uniform start of seedling sprouts on the cleared area, to relieve the pine of competition for at least two years, and to preclude the development of irregular and bushy trees in the new stand" (1).

Even though an abundant supply of pine seed is assured, the prospects of a satisfactorily stocked new stand are very poor unless the slash is disposed of. If circumstances permit, live burning as the logging progresses may be preferable to delaying until some later time, chiefly because of the decreased cost of removing logs from an area free of slash. However, a more wholesale burning after logging when the slash has dried out is oftentimes the more feasible, and at present is the method in common use on the Harvard Forest. At the termination of the first growing season following logging, the reproduction is composed of one-year-old hardwood sprouts and seedlings, and one-year-old pine seedlings. The young stand is exactly even-aged.

While the clearcutting of pure pine in seed years has some advantages, notably the comparatively low cost of removing the crop in a single operation, yet it cannot be considered a satisfactory method for general use. Seed years do not always occur as expected, nor can one depend upon an abundant crop of seed even at three-year intervals. Furthermore, cutting cannot always be made to coincide with seed years. Another drawback is that the pine enters into competition with hardwoods as one-year seedlings, and is consequently quickly overtopped.

SHELTERWOOD

Where annual cuts are to be made, a shelterwood system is preferable to the seed-year method. The reproduction is more certain, and by the time the old stand is removed and competition with the hardwoods sets in, the young pine will be already from four to ten years old. Under this system as practised on the Harvard Forest (1), the old wild stand is removed in two cuts. The first, or reproduction cutting, may be made whenever convenient, but preferably on bare ground, so that the litter and humus will be torn up as much as possible by the logging. Much of the advance growth hardwood will unavoidably be cut back, but no special effort should be made to do a thorough job, since it must be done again at the time of the final cutting. When sprouts are cut back, the number of stems is approximately doubled, and their height growth is fully as great as before, at least for a few years. The canopy should be sufficiently opened up to start pine reproduction and to permit it to grow vigorously. Ordinarily this means reducing it to about fifty to sixty per cent of full. The reproduction cutting should remove dead, overtopped, intermediate, and some co-dominant and dominant trees, especially the large-crowned scrubs, and should leave well-formed dominants and co-dominants which will be capable of abundant seed production. The large-crowned scrubs would do great damage to the reproduction if left to be felled in the final cut.

In addition to allowing sufficient light on the forest floor, a further reason for making the reproduction cutting rather severe is that the disposal of slash for this operation may be carried on without any loss of pine reproduction. Owing to the character of the cutting, slash must be burned in small piles, preferably as the logging progresses. After reproduction comes in, it should not be less than four nor more than ten years before the final cutting is made. If made too soon, the reproduction is so small that much more of it is killed by

the Pales weevil (2), and so shallow-rooted that it dries up when the canopy is completely removed. At the time of the final cut, all of the advance growth hardwood should be cut back to the ground, except in cases where the groups are especially dense and so located as not to be seriously damaged in logging. In burning the slash, care must be taken to do as little damage to the pine reproduction as possible. It is entirely unnecessary to make a clean burn; only material which will prevent the growth of the seedlings need be considered. If the operation is carried on when deep snow is on the ground, damage to reproduction is reduced to the minimum.

CLEARCUTTING AND PLANTING

Clearcutting with supplementary planting, in which the old stand may be cut at any time, and the slash burned when most convenient, is a system well adapted to small scattered operations which have to be carried on at all seasons. It allows the old stand to be removed in one cut; the establishment of the new crop is certain; and the pine can be given a start of two years over the hardwood. However, natural reproduction methods have the advantage of bringing about denser stocking than would ordinarily be obtained by planting. According to Tarbox's table showing the relation of the number of trees per acre to knot size (3), a knot as small as a pin knot (not over $\frac{3}{8}$ of an inch in diameter) can be produced in the butt log only by a density of at least 2,000 to 3,000 trees per acre at twenty to thirty years. His table is for site II, but for site I the density would have to be fully as high. Thus, in order to produce a butt log of as good quality, a plantation spacing of 4 feet by 4 is necessary. On account of the Pales weevil (2), planting must be delayed until the third growing season after cutting; and large, thrifty stock should be used in order that the pine may compete more successfully with the hardwoods. Confusion and loss of time in planting may be avoided by first going over the cutting area to locate and mark in some suitable manner the areas to be planted. These

would naturally be places where the hardwood was thinnest. On the Harvard Forest the hardwood groups are encircled by strings just before planting commences.

PINE HEIGHT GROWTH AS RELATED TO THE REPRODUCTION SYSTEM

The behavior and, more specifically, the height growth of the pine varies with the reproduction method used. As shown by Gast (4), pine seedlings originated under shelterwood often have crooked tap roots which extend horizontally along the top of the mineral soil and bottom of the humus. This condition of the root system is associated with a stunted growth of the seedling, and too dense a canopy in the overstory. While a sufficiently heavy reproduction cutting will largely overcome the slow growth of shelterwood seedlings, and, presumably, the tendency of the tap root to continue in the upper layers, still it is undoubtedly true that reproduction under shelterwood is apt to make slower height growth than that initiated by clearcutting. The latter produces a straight tap root and grows rapidly. It would appear that the relatively rapid growth was due to increased light. In actual practice, shelterwood reproduction has the advantage in height over clearcutting reproduction since it is several years old and a foot or more in height at the time the final cutting is made. The height growth of large planted stock during the first season in the field is about two-thirds normal. This is due to the reaction which unavoidably accompanies transplanting. Owing to the delay in planting occasioned by the Pales weevil and to the relatively small size of the planting stock, planted pine also fails to equal shelterwood pine in getting a start on the hardwoods.

TREATMENT OF IMMATURE STANDS

WEEDING

The study of wild stands has shown that the pines and hardwoods tend to occur in separate groups. Even were it

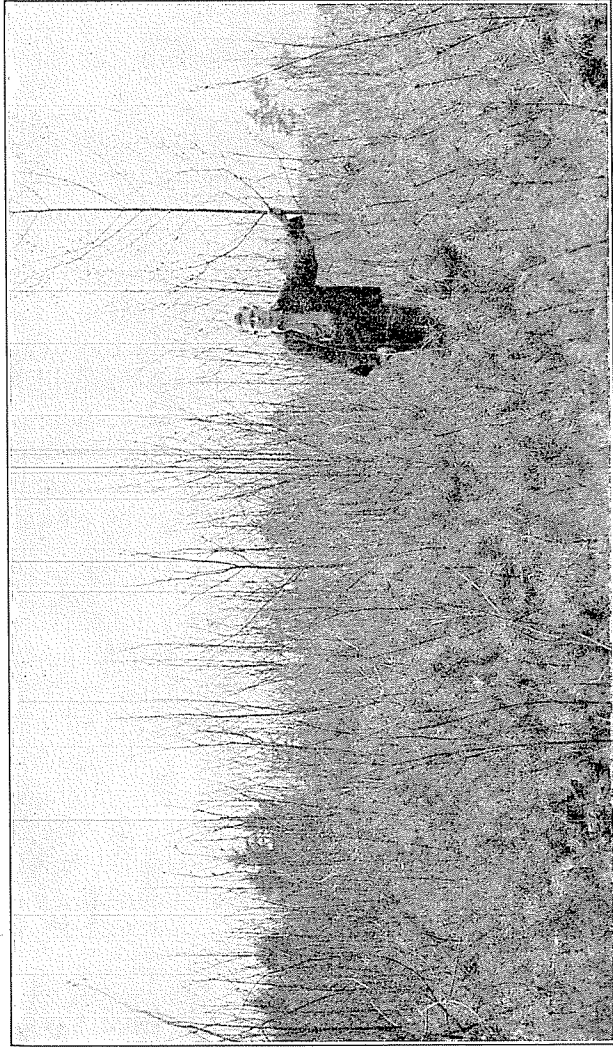


FIG. 10. PINE AND HARDWOOD SEGREGATED INTO GROUPS BY WEEDINGS

The pine is natural reproduction obtained by the shelterwood method

Photographed by A. C. Cline

practically possible to secure a stemwise mixture, it would be far too costly to maintain. Furthermore, the weeding and releasings necessary to keep free a single pine surrounded by hardwoods would result in spoiling the hardwoods. A group-wise arrangement of the young stand is not only the most practicable to handle, but is indispensable to the survival of any worth-while amount of pine.

Thus, the first object of weeding is to segregate and bring along suitable groups of pine and hardwood. Ordinarily the first weeding should be made when the hardwoods are three to four years old (1) in a season when the leaves are off so that the pines are plainly visible. Spring is preferable to fall because the pines, which hitherto have been growing in the shade, are given a chance to "toughen up" under more complete exposure before winter sets in. Just how long weeding can be delayed depends partly upon how the stand was started. When the hardwood is three years old and has an average height of 5.0 feet, shelterwood pine will be at least eight years old and 3.0 feet high; planted pine, five years old and 1.3 feet high; clearcutting pine, three years old and about .8 feet high. Thus weeding may be delayed longest with the shelterwood method.

Before weeding is done in stands reproduced naturally, the entire cutting area should be gone over for the purpose of deciding upon and marking the locations of the pine groups. Areas not covered by pine will usually contain hardwoods from which the hardwood groups will be recruited. The size of the pine group may vary from one fiftieth to one tenth of an acre, or be even larger; though if too large, some of the benefits of mixing will be lost. All the overtopping hardwoods in the pine groups should be lopped back so that the tip of each pine has room to grow. From the hardwood groups undesirable sprouts and weed species, gray birch, poplar, pin cherry, and red maple, should be cut back, except where these are subdominant and give promise of remaining so. Weed species which are subdominant may be used to

advantage in maintaining the early high density which is needed to insure quality in the final crop. Of the hardwood species to favor, white ash, red oak, and paper birch are of first importance in this locality, not only because they are valuable, but because they are most abundant. Other desirable hardwoods are basswood, beech, yellow and black birch, hard maple, and black cherry. Sprouts from stools much larger than two inches will usually be found too rank-growing and too many per stool to justify their use as prospective crop trees. The hardwood group after weeding should be composed of well-formed seedlings, seedling sprouts, and small sapling sprouts of the better hardwood species. Great care should be taken not to cut too much; early density is one of the keynotes to high quality.

In weeding, it has been found on the Harvard Forest that partial severance of the stem, followed by bending down to the ground that part above the cut, results in a very much lessened growth of sprouts starting from below the cut, and oftentimes in the death of the tree. This method of lopping is particularly well adapted for use with the larger, more rapidly growing sprouts. Patches of small seedling inferior hardwoods can best be cut clean off. For the first weeding, experience has shown the machete with a 19-inch blade to be the most efficient tool. Within a few years after the first weeding, a second will be needed in order more definitely to set the composition, to favor the best-formed and most uniformly growing hardwoods, and to keep the pine groups free to grow. In some cases as many as three weedings may prove worth while. The tendency should be to go over the area lightly and often, rather than heavily and seldom. In the second and any additional weedings, light hand axes may be found more useful than the machete. The final weeding, and any improvement cuttings made subsequently, should be done not only with a view toward improving the composition and form of the groups themselves, but also toward developing such a marginal belt of hardwood species as will cause the

least interference with the development of the pine groups. It is in this zone of contact that the struggle is keenest between the two elements of the stand. Space-demanding species such as red oak do the most damage to pine by abrasion, and should be cut out in favor of crowd-enduring species such as white ash. The form and composition of this outer rank of hardwoods will greatly influence the cost of keeping the pine groups free to grow until the pine has passed the period of subdominance.

THINNING

Owing to fundamental differences in the growth of pine and hardwood, it is necessary to consider pine thinnings separately from those in hardwoods.

In contrast to that in pine, differentiation in height commences in hardwoods the very first year, the sprouts forging ahead of the seedlings in a very decisive manner. No thinnings are effective or needed until the crown canopy is established, which happens earlier with hardwood than with pine. From the behavior of young hardwood stands on the Harvard Forest, it is thought that a method of thinning approaching the French will be found adaptable. With this method the most desirable dominant trees, but not necessarily the final crop trees, are selected as soon as the need for thinning becomes apparent. These trees are given sufficient room to grow by cutting those of the contiguous trees which interfere with the normal development of those selected. Red oak, on account of its tendency to spread, should be allowed less room for crown expansion than the crowd-enduring white ash, which, if hemmed in too closely, becomes tall and spindling — too small in diameter to lend itself to economical utilization for lumber.

Pine thinnings in this region either have been confined largely to middle-age stands, or have been experimental in nature. However, a close study of fully stocked young stands has uncovered certain tendencies which indicate the kind of

thinning to be used. A combination of medium soil and trees of exactly the same age permits of but little differentiation into height classes. In such a stand it would be difficult to select the most desirable crop trees. Probably a modified German thinning would be chosen. Overcrowding should be corrected by removing a sufficient number of relatively small and inferior trees, and even some of the better trees if necessary. A combination of very rich soil and trees varying in age by the span of two or more seed years causes a decided differentiation in heights. Under these conditions a sufficiently large number of free-to-grow trees are present to warrant nothing more than a light thinning on the French plan, which will remove only those trees interfering with the normal growth of those to be left. Since planted pine is strictly even-aged, while naturally reproduced pine is often the result of two seed years, the German method would perhaps be most often used for the first thinning in pine groups originated by planting, particularly on the medium soils, while the French method would be better applicable with groups originated by natural means, especially on the richer soils.

There are several reasons why thinnings in the pine groups should be conservative, especially if high quality is desired. Among them are the following:

1. Since in pure, even-aged pine stands knot size is largely a function of density, high quality can be obtained only through high density.
2. Since the crookedness of the stem caused by the white pine weevil varies inversely with density, the straightest trees are grown in the highest densities.
3. Since the hardwoods have a tendency to overcome the pines where the groups of the two elements come in contact, very conservative thinnings should be made on the margins of the pine groups.
4. Since within the limits of a 60-70 year rotation width of board has very little effect on market value, it is not necessary to stress rapid growth in diameter.

As the pine and hardwood groups advance in age, there will be losses along the margins of the pine groups, unless the hardwoods responsible for such loss are removed in thinnings. At worst, the loss will be practically negligible when com-



FIG. 11. MIXED PINE-HARDWOOD IN GROUPS SIXTY-FIVE
YEARS OLD

The pines are tall and straight, and relatively clear of branches

Photographed by A. C. Cline

pared with that in a stemwise mixture, where, in order to keep the pine free, numerous liberation cuttings would be necessary. With the exception of the marginal zone, the pine and hardwood groups can each take their own pace, and develop unhampered by competition.

ROTATION, AND CHARACTER OF THE MATURE CROP

Although the groupwise pine-hardwood mixture is eminently adapted to long rotations, the treatments recommended in this section apply particularly to rotations of sixty to eighty years. While in rotations of this length the numerous advantages of the mixture over pure stands of pine are not realized in the fullest measure, yet there is an appreciable improvement in the quality of the pine. Since under present market conditions the value of short rotation pine is not influenced by width of board, the factor of diameter may be left out of consideration for the time being. There remain two other factors of quality, namely, texture of wood and freedom from knots (clearness). Regarding the first of these, nothing new has been shown by this study. It is quite generally held, however, that the highly desirable "cork" pine of soft texture is associated with the mixed forest; and there is every reason for believing that pines grown in the groupwise mixture on longer rotations will exhibit this characteristic. In the matter of freedom from knots, more definite statements can be made. It has been shown that, in wild stands approaching the groupwise form, natural pruning proceeds more rapidly than it does in the pure stand. At the end of fifty years the boles will be fairly clean of branches and in a position to form clear wood thereafter. Obviously, this factor of quality increment becomes of ever-increasing moment with the lengthening of the rotation.

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EXPECTABLE RETURNS FROM PINE-HARDWOOD STANDS

YIELDS

IN estimating the yields from pine-hardwood mixtures under management, it is necessary at present to resort to the use of yield tables constructed for wild stands. For the hardwoods, Patton's tables (1) have been chosen. These were made for red oak and white ash growing under the most favorable conditions to be found in wild stands. Though they show volumes somewhat lower than those in European tables for cultivated hardwoods, the diameters and heights of Patton's average trees correspond closely at the different ages with those shown in the European tables. This would seem to indicate that differences in volumes (yields) were due to differences in degree of stocking rather than to fundamental differences in growth rates; and that Patton's statements of yields will be conservative when applied to managed oak and ash mixtures. But are they applicable to stands containing other hardwoods — paper birch, hard maple, black cherry, and so forth? Since all hardwoods tend to approach either oak or ash in form, and differences in composition in even-aged mixed hardwood stands have been found to cause no variation in yield (2), the use of Patton's tables seems entirely justified. By averaging the oak and ash yield tables, values are obtained which are higher than those given by Spaeth (2) for wild mixed hardwood stands, and lower than those given in European tables for intensively cultivated stands.

For predicting the yields of pine, Margolin's table (3) has been used. The yields for site I and site II have been averaged in order to obtain a mean for the range of the better soils. Margolin's table was considered preferable to Tarbox's (4) because the latter, though made for the region covered by this study, gives relatively low yields in the older-age classes on site I on account of crown friction.

The following synthetic yield tables, upon which Figures¹² and 13 are based, are considered applicable to fully stocked stands growing on the better soils in this region.

TABLE I
YIELD TABLES FOR MIXED PINE AND HARDWOOD
ROUND EDGE SAWING

Age	PINE (Margolin's Table — Average of Sites I and II)	Bd. Ft.	HARDWOODS (Patton's Table — Average of Red Oak and White Ash Tables)	
	Cu. Ft.		Site I Cu. Ft.	Bd. Ft.
25	2,710	6,900		
30	3,625	11,750	2,245	
40	5,815	28,150	3,382	
50	7,900	42,850	4,258	
60	9,500	53,550	4,922	23,800
70	10,870	63,000	5,280	27,700

The expectable yields of mixed pine-hardwood stands may be calculated with the aid of Figure 12, which gives the yield in cubic feet by decades for all possible combinations in percentage composition by area, from a pure pine stand to a pure hardwood stand. For example, given a stand which contains 60 per cent pine and 40 per cent hardwood by area, at sixty years the pine yield will be 5,700 cubic feet, and the hardwood, 1,968 cubic feet. Similarly, Figure 13 shows the yields in board feet for the sixth and seventh decades.

STUMPAGE VALUES

In predicting stumpage values for sixty years hence, one must take into account the fact that present prices are based upon wild stands of poor quality, and that the general tendency is for stumpage to appreciate as time goes on. Pine when grown in mixture with hardwoods, particularly on rotations of over sixty years, is of better quality than when grown in a pure stand, and should command a correspondingly higher price. Hardwood stumpage will show, in all probability, a proportionally higher increase in value than pine during the rotation.

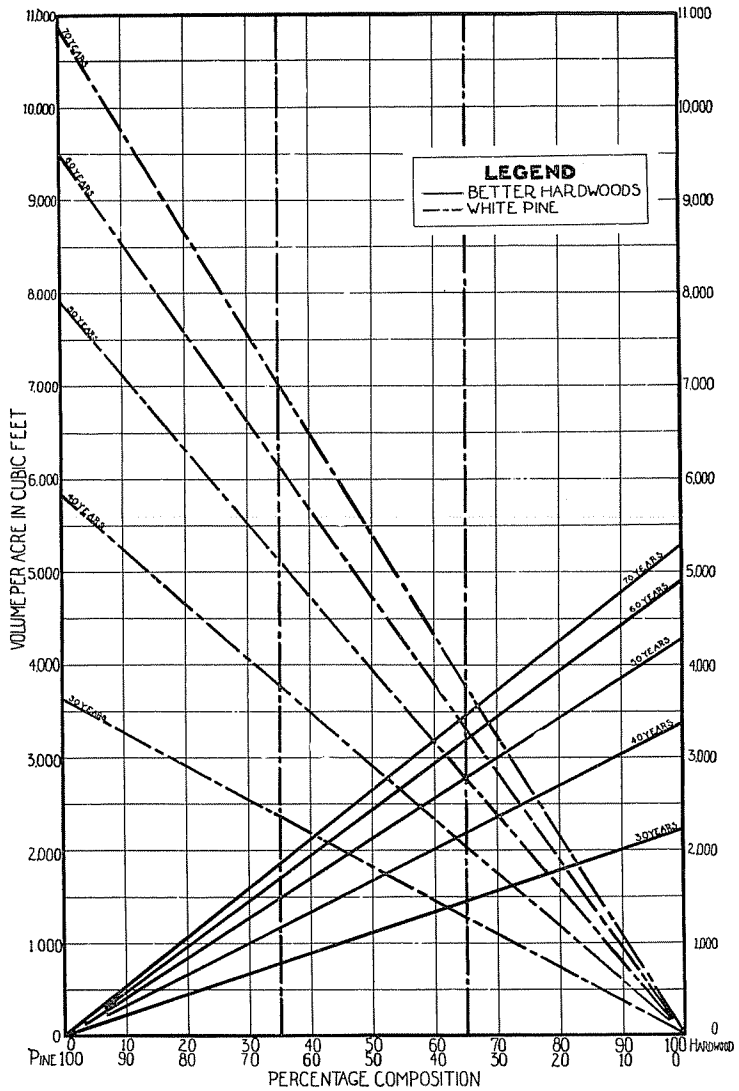


FIG. 12. THE YIELD PER ACRE IN CUBIC FEET FOR ALL COMBINATIONS IN PERCENTAGE COMPOSITION BY AREA OF PINE-HARDWOOD MIXTURES

The two dash-dot lines indicate the range in composition within which all the advantages of the mixture obtain

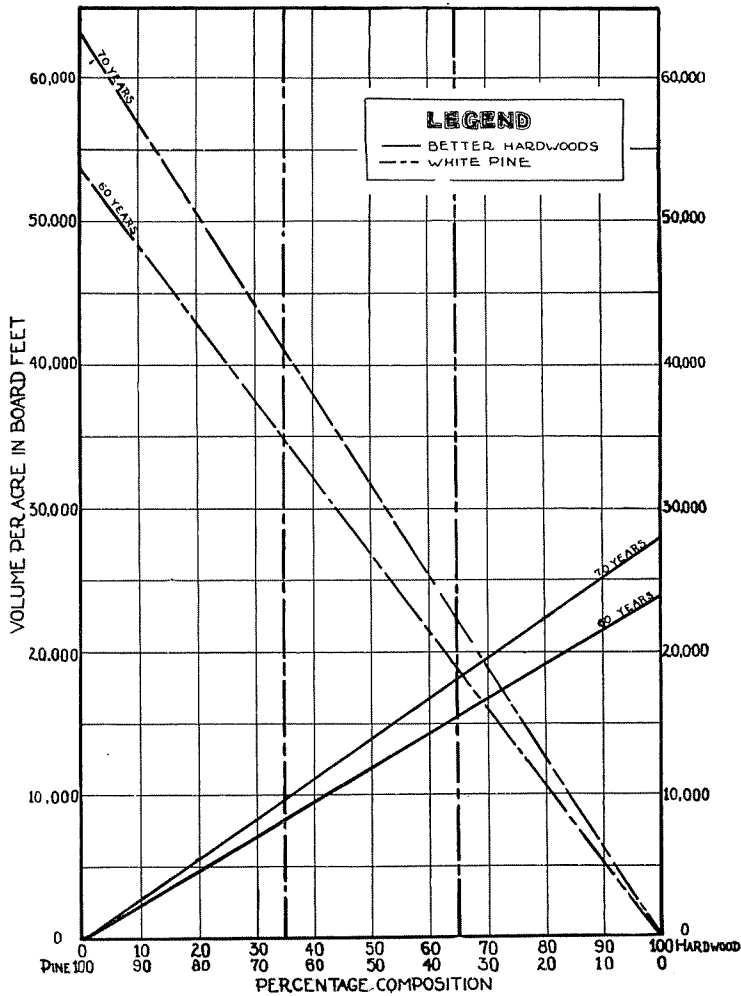


FIG. 13. THE YIELD PER ACRE IN BOARD FEET FOR THE SIXTH AND SEVENTH DECADES FOR ALL COMBINATIONS IN PERCENTAGE COMPOSITION BY AREA OF PINE-HARDWOOD MIXTURES

The two dash-dot lines indicate the range in composition within which all the advantages of the mixture obtain

In the following table the expectable stumpage prices of pine and hardwood grown in pure stands have been included for the sake of comparison with those of pine and hardwood in mixture.

TABLE II
EXPECTABLE STUMPAGE VALUES OF PINE, PINE-HARDWOOD,
AND HARDWOOD IN 1985

ROTATION OF 60 YEARS		
Type of Stand	Species	Stumpage Value per M*
Pure Pine	White Pine	\$18.00
Mixed Pine-Hardwood	White pine	22.00
	Hardwood	30.00
Pure Hardwood	Red Oak, White Ash, Paper Birch, etc.	30.00
Fuel Wood	\$2.00 per cord	

* Operating profit not included

GROSS INCOME FROM PINE, PINE-HARDWOOD AND HARDWOOD

Applying the above stumpage values to the yields obtained at the age of sixty, the expectable gross returns are as follows:

Type of Stand	Expectable Gross Returns per Acre at the Age of 60		
Pure Pine			\$963.90
Mixed Pine-Hardwood	Pine	589.05	
	Hardwood	357.00	
	(50-50 mixture)	Cordwood* 10.00	\$956.05
Pure Hardwood	Sawtimber	714.00	
	Cordwood	20.00	\$734.00

* 5 cords per one-half acre

COMPARISON OF COSTS AND RETURNS

While the gross returns show a difference in favor of pure pine, the net returns are in nowise proportionate. To calculate and compare the net returns from these several types of stand when under management necessitates so many

assumptions and allowances that it has been considered impracticable to present more than a discussion of some of the most important profit-influencing factors, together with an estimate of the net returns from a pine-hardwood mixture. Whether or not the growing of any one type of timber is more profitable than that of any other depends very largely upon the cost of crop establishment. The various methods of establishment may be listed as follows:

- I. Crop Establishment by Natural Means.
 - A. Clearcutting in a pine seed year to obtain:
 - (a) A pure pine stand.
 - (b) A mixed pine-hardwood stand.
 - B. Shelterwood cutting to obtain:
 - (a) A pure pine stand.
 - (b) A pine-hardwood stand.
 - C. Clearcutting to obtain a pure hardwood stand.
- II. Crop Establishment by Artificial Means.
 - A. Clearcutting followed by planting to obtain:
 - (a) A pure pine stand.
 - (b) A mixed pine-hardwood stand.

Regardless of the reproduction method employed, the disposal of the slash resulting from cutting the old stand is essential. Burning slash is at present a costly operation, but as soon as limbwood commands a higher price this expense will be greatly reduced.

With the shelterwood method, slash disposal now costs from 50 to 100 per cent more per acre than with the clear-cutting methods. This is due principally to the necessity of burning the slash in small piles in both the first and final cuts. With clearcutting methods, the slash is usually windrowed, and requires the minimum amount of handling. However, this cost differential will be lessened materially with more experience in handling partial cuttings. In fact, if it proves satisfactory to make the first cutting a very heavy one, slash burning after the final cut may be dispensed with entirely, thus bringing the cost of slash disposal with the shelterwood method down to a figure not exceeding that with the clear-cutting methods.

Owing to the impossibility of laying out the logs in wind-rows, at least in the first cut, and to the necessity of dodging around the trees left for the final cut, logging costs with the shelterwood method are about 20 per cent per acre higher than with the clearcutting methods. In a shelterwood cut recently made by the Harvard Forest, the logging (hauling) costs were reduced about 15 per cent in the first cut by burning the slash before the logs were removed. But as far as can be foreseen, it is unlikely that logging in a shelterwood cutting can ever be done as cheaply as in a clearcutting.

Weeding is another cost item common to all methods of crop establishment. With the pine-hardwood mixture this amounts to about 30 per cent more than with pure pine, and very little, if any, more than with pure hardwood.

Planting will cost about 75 per cent more with a pure pine stand than with a pine-hardwood mixture, assuming a 50-50 groupwise mixture.

Supervision costs most in the case of the shelterwood system, but this is a cost item of relatively minor importance.

Taxes, protection, and other annual charges vary but little with the reproduction method used, and may be considered constant. The amount of interest depends largely upon the initial investment, and hence is highest with the shelterwood method.

All things considered and with successful reproduction assumed in each case, the shelterwood method shows the least net profit. Clearcutting with planting comes next in order, and most profitable of all, but least dependable, is clearcutting with natural reproduction. At present, clearcutting followed by planting seems the most practicable method of establishing a mixed pine-hardwood stand, though it is likely that, once stands of desirable composition are established over sufficiently large areas, it will be found much more desirable to reproduce them by natural means.

NET RETURN FROM PINE-HARDWOOD MIXTURES

The following table gives the costs of establishing pine-hardwood stands forming part of an organized forest. It compares the net annual income from such a forest at present in its abnormal condition with that sixty years hence, when it is assumed that the forest is approaching normal.

Given: a forest of 5000 acres made up of forest types common to the region, many of which may be followed after clearcutting by a pine-hardwood mixture; pine planted in groups with a spacing of $6' \times 6'$; an initial investment in land and timber of \$300,000.00; approximately normal distribution by area of age classes, but only two thirds normal growing stock in each age class; a rotation of sixty years; regulation by the area method (clearcutting one sixtieth of the total area each year, or 83.3 acres); an average volume per acre at present of 20,000 board feet for the area of the annual cut; interest, 6 per cent, simple.

The sum of all expenses incurred and incomes received through the treatment or exploitation of a part of the forest is distributed over the entire forest. The per-acre figures listed in Table IV, therefore, apply to each and every acre of the entire forest of 5000 acres.

As the full property tax rate is used in this computation, the final net return is conservative, even though full yield table volume may be somewhat high. Furthermore it is probable that during the next ten to twenty years it may become generally profitable to make thinnings, which would still further increase the net income.

The net loss of six cents per acre may be taken as a capital investment, the cost of making the forest permanently and highly productive. As maximum carrying charges have been used, it is a loss which under many conditions might be turned into a gain, even at the start.

TABLE IV

COSTS AND RETURNS OF MIXED STANDS FORMING UNITS IN
AN ORGANIZED FOREST NOW AND SIXTY YEARS HENCE

A. 1925		COSTS	Per acre
1.	Crop Formation (50-50 Pine-Hardwood Mixture)		
A.	Slash Disposal	\$.17	
	\$.50 per M		
	20 M per acre		
B.	Planting (in groups totaling 50% of 83.3 acres)17	
	Stock, \$4.50 per acre of cutting area		
	Labor, \$5.50 per acre " " "		
C.	Weedings and Improvement Cuttings	<u>.17</u>	.51
	Two weedings at \$4.00 each per acre		
	Improvement cutting at \$2.50 per acre		
2.	Carrying Charges		
A.	Protection		
	Provided by Town		
B.	Taxes80	
	2% on two thirds cost value		
C.	Interest	3.60	
	6% on \$300,000.00		
D.	Supervision and Overhead	<u>.60</u>	5.00
	Total cost		<u>\$5.51</u>
RETURNS			
1.	Net Income from Annual Cut		Per acre
A.	Sawtimber	\$5.33	
	20 M of all kinds per acre at \$16.00 per M		
B.	Cordwood	<u>.12</u>	\$5.45
	5 cords hardwood per acre at \$1.50 per cord		
	NET LOSS AT PRESENT, \$.06 PER ACRE		
B. 1985		COSTS	
Same as for 1925 with exception of taxes, which are assumed			
to be \$.50 per acre; and slash burning, which, owing to			
the salability of limbwood, is assumed to be reduced to			
\$.10 per acre			
	Total Cost		\$9.64
RETURNS			
1.	Net Income from Cut of 1985 (based on an annual cut		
	of pine-hardwood stands, 50-50 mixture by area)		
A.	Sawtimber and Cordwood		\$15.93
	83.3 acres at \$956.05 per acre		
	(Operating profit not included)		
	NET PROFIT, 1985, \$6.29 PER ACRE		

PINE-HARDWOOD MIXTURE COMPARED WITH PURE PINE

Pure white pine, now so prevalent throughout New England, has oftentimes been used as a standard by which to judge the profitableness of other types of stands. To arrive at a fair comparison of pure pine with mixed pine-hardwood, it is essential to consider only two factors: the cost of crop establishment, and the value of the crop when ready to cut. In regard to the former, the cost of planting an entire acre to pine is obviously more than planting part of an acre, perhaps twice as great. With due allowance for the added cost of weedings in the mixture, the pure pine is certainly the more costly to establish. For final stumpage values one must perforce look a long way ahead. But judging from the general trend of values of both pine and hardwood, particularly as noted in the increased demand for hardwood, and the prospective high value of "quality" pine grown in mixtures, a prediction of greater worth for the pine-hardwood crop is unavoidable. Furthermore, it should be pointed out that estimates of final yields and values are usually based upon an assumption of normal growth throughout life. Such an assumption is unwarranted when dealing with a crop so subject to ailments as pure pine. Temporary types of timber, owing their existence to a sudden change in Man's treatment of the land, and therefore unadapted to the environment, are generally so acted upon by insects, fungi, and other destructive agents that a reduced final yield and inferior quality will result.

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pure forests were formed over large areas. To-day, however, German forestry is tending away from these pure stands of one species, and towards the formation of mixed stands of conifers and broadleaved species. In France for years the natural methods have been those more closely followed, and from that country little is heard about soil depletion, growth stagnation, and so on.

The first reason for the formation of mixed woods is that mixtures tend to conserve the fertility of the soil, while pure stands tend to dissipate it. Agriculture has shown that repeated crops of the same sort cannot be raised on the same area year after year without the soil's suffering as a consequence. Two generations of spruce in Bavaria have caused a site originally classed as III to degenerate to a IV or even V. In Saxony the same thing is true. The soil turns blue-gray in color and is covered with a sort of peat which excludes both air and moisture. About the third generation, growth stagnates, and the foresters are forced to introduce an underwood of beech or oak, or to allow birch to come up with the spruce.

Pure forests, especially of conifers, tend to reduce the water content of the soil. The thick canopy intercepts the precipitation which in mixed woods is more equitably precipitated over the soil itself. In mixed stands a highly hygroscopic humic layer is formed, which tends, as European experiments have shown, to make soil moisture conditions in mixed woods more favorable for tree growth than in pure woods, where, as has been proved in France, pure stands of conifers cause the gradual sinking of the water table (4). Another advantage of the mixed stand in this connection is that where there are several species differing in their individual requirements, the soil can be most thoroughly utilized. Different depths and extents of root systems allow each class to draw its food materials from different layers of the soil.

Another advantage of the mixed stand over the pure stand lies in the fact that the mixed stand suffers less from injuries from external causes. Trees sensitive to frost are apt to be

less damaged when grown in with more hardy species. Shallow-rooted species mixed with those possessing deeper root systems are less liable to windfall. Insect attack is lessened. Hess (5) in 1887 recommended as the first measure of protection against insect attack the "avoidance of the formation of pure forests of spruce or Scot's pine; formation of mixed crops of suitable species." Experience has shown time and time again in Europe that mixed stands suffer nowise the same damage from insects as do pure stands. This is because for one reason there is a smaller amount of food for any given insect. It is an entomological axiom that insects increase in proportion to their food supply. Obviously, then, an insect which gets its nourishment from some one particular species is increased indefinitely through planting in pure stands. An example of this state of affairs is shown in the case of the white pine in New England and the white-pine weevil. Peirson (6) says that "the wide extension of white pine both by artificial means in planting and by natural seeding in abandoned pastures has made available large quantities of tender shoots which are extremely favorable to the rapid development and increase of the weevil."

Injuries to pure forests due to external agencies are brought out by the following quotation from Professor Hartig's work published in 1882 (7):

"The transformation in the natural woods of Germany, the formation of pure equal-aged crops of the same species of trees, instead of the composite mixed forests and copses made up of all sorts of trees of all ages, and especially the restriction of the broad-leaved species by the formation of pure crops of conifers, have, during the present century, and most particularly in the last few decades, threatened the well-being of our woods to an extent which was formerly unknown. And it is chiefly the enemies belonging to the animal and vegetable kingdoms which find in the recent developments of our woodland economy the conditions favorable to their increase in enormous strength so that the complaints made

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APPENDIX

CLASSIFICATION OF SITE

In the region dealt with in this study, really fertile, deep soils are confined to comparatively small areas along streams in the wider valleys, or on small benches or plateaux on the slopes or ridges. Sands and gravels are also of limited occurrence and usually represented by glacial sand plains or gravel deposits along the margins of valleys. The great bulk of the land surface is covered with soil of medium fertility in which a considerable percentage of clay occurs mixed with granitic sands. In silvical studies hitherto made, three qualities have been found sufficient, and of the three, site II probably occupies 75 per cent of the forest area.

LIST OF SPECIES

- Pinus strobus*. White Pine.
- Pinus rigida*. Pitch Pine.
- Pinus resinosa*. Red Pine, Norway Pine.
- Picea rubens*. Red Spruce.
- Tsuga canadensis*. Hemlock.
- Abies balsamea*. Fir.
- Populus tremuloides*. Poplar, Popple.
- Populus grandidentata*. Poplar, Popple.
- Betula populifolia*. Gray Birch.
- Betula papyrifera*. White or Paper Birch.
- Betula lenta*. Black Birch.
- Betula lutea*. Yellow Birch.
- Fagus grandifolia*. Beech.
- Castanea dentata*. American Chestnut.
- Quercus alba*. White Oak.
- Quercus rubra*. Red Oak.
- Tilia americana*. Basswood.
- Fraxinus americana*. White Ash.
- Acer saccharum*. Sugar Maple, Hard Maple.
- Acer rubrum*. Red or Swamp Maple.
- Prunus serotina*. Black Cherry.
- Prunus pennsylvanica*. Pin Cherry.
- Ulmus americana*. American Elm.

