The Regeneration of White Pine on Cutover Land in Central New England.

Not for publication.

In column A are the numbers of the lots as they are numbered in Table VII.
In column B are the ~~numbers of~~ corresponding numbers of the same lots as numbered on the Original Chart.

A.	B.	A	B	A	B
1	48	25	43	51	45
2	49	26	44	52	55
3-A	7	27	2	53	56
3-B	7	28	15	54	57
4-A	37	29	20		
4-B	37	30	31		
5	1	31	24		
6	4	32	32		
7	5	33	35		
8	9	34	42		
9	10	35	36		
10	11	36	38		
11	12	37	39		
12	14	38	40		
13	17	39	46		
14	22	40	53		
15	28	41	8		
16	29	42	26		
17	33	43	34		
18	51	44	52		
19	41	45	3		
20	54	46	6		
21	13	47	47		
22	16	48	50		
23	18	49	27		
24	19	50	31		

Over

On the original chart that I made at Petersham, the lots are numbered in the order in which I examined them. In Table III they are arranged chronologically in order of cutting. As the name and description is not given in Table III, and as again may wish to identify some of these lots I have on the other side of this sheet provided a table giving the corresponding number of the lots.

Table I.

The amount and character of the natural reproduction on "Area B" in the Harvard Forest. The area was thinned in 1911-12, cut clean in 1915-16 and examined in the fall of 1917. The figures denote the number of plants per acre.

	2 years old	3 years old	Over 3 years	Total
White Pine	410	2870	70	3350
	Seedlings	Seedling Sprouts	Stump Sprouts	Total
White Ash	390	1990	20	2400
Red Oak	20	540	10	570
Chestnut	10	510	40	560
Cherry	360	890		1250
Red Maple	9000	1000	40	10040
Hard Maple		10	10	20
Basswood	10	40	10	60
Beech			10	10
Birch	130	200		330
	9920	5180	140	15240

Table II.

Summary of White Pine reproduction on the four areas on the Harvard Forest that were first thinned and then cut clean.

Area	Date of Thinning	Date of Final Cutting.	Number of growing seasons between final cutting and date of examination	Number of pine seedlings per acre, all ages.	Number of seedlings per acre originating from different seed years.*
A	1908-9	1914-15	4	4100	All from crop of 1914. TS I SH5
B	1911-12	1915-16	2	3350	3280 from crop of 1914. 70 " " " 1911.
C	1910-11	1916-17	2	350	All from crop of 1914. TS I SH5
D	1911-12	1917-18	1	2600	20 from crop of 1911. 2430 " " " 1914 150 " " " 1917 TS IV SH5

* The seed years occurring during the period covered by these four cuttings are: 1908, 1911, 1914, and, for Area D, 1917. Practically no seed was produced during the intervening years. On none of these tracts was any pine reproduction found whose origin antedated the year in which the area was thinned.

Table III.

Amount and character of the reproduction on cleared Strip No. 1. Cut in 1911-12 and examined in the fall of 1917.

		From seed crop of 1914.	From seed crop of 1911.	Total
White Pine		2580	1210	3790
	Seedlings	Seedling Sprouts	Stump Sprouts	Total
White Ash	50	40	10	100
Birch	40	100		140
Black Cherry	140	720	20	880
Chestnut	10	330	50	390
Red Maple	320	270	40	630
Red Oak	40	870	10	920
White Oak	20	240	10	270
Poplar	10	70		80
	630	2640	140	3410

Table IV.

Summary of pine reproduction on the three clear-cut strips examined on the Harvard Forest.

Number of strip	Date of cutting.	Number of growing seasons between cutting and date of examination.	Number of pine seedlings per acre, all ages.	Number of seedlings per acre originating from different seed years.
1	1911-12	6	3790	1210 from crop of 1911. 2580 " " " 1914.
2	1912-13 1913-14	4 and 5	900	All from crop of 1914.
3	1917-18[1]	1	18740	18520 from crop of 1914[2] 220 " " " 1917

1. This area was thinned in 1911-12.
2. Number of live 4-year-old seedlings at the end of the first growing season after cutting. At the beginning of the season the number was 28100 per acre. The loss was due to the depredation of the Hylobius beetle during this season, when the seedlings were in their fourth year.

Table V

Amount and character of the reproduction on 11 cleared-group cuttings in the Harvard Forest. Six groups were cut in 1910-11 and 5 in 1911-12. All were examined in the fall of 1917. The figures denote the number of plants per acre for the eleven groups taken collectively.

	From seed crop of 1911.	From seed crop of 1914.	Total
White Pine	1145	5275	6420

	Seedlings	Seedling Sprouts	Stump Sprouts	Total
White Ash	279	74	3	356
Red Oak	38	254	7	299
White Oak	29	185	7	221
Chestnut	86	329	55	470
Birch	569	270	21	860
Black Cherry	282	314	7	603
Red Maple	615	142	62	819
Hard Maple	86	127		213
Beech	4	7	4	15
Poplar	54	12		66
	2042	1714	166	3922

Table VI.

Amount and character of the reproduction on an area in the Harvard Forest on which a Selection Cutting was made in 1909–10. The area was examined in the fall of 1917. The figures denote number of plants per acre.

	3 years old (from crop of 1914)	over 3 years old	Total
White Pine	660	580	1240
Hemlock		40	40

	Seedlings	Seedling Sprouts	Stump Sprouts	Total
White Ash	380	60		440
Red Oak		40		40
White Oak		80		80
Chestnut		240	80	320
Birch	140	200		340
Black Cherry	120	40		160
Red Maple		20	80	100
~~Totals~~	640	680	160	1480

Table VII.

Summary of Pine Reproduction on Cut-over Woodlots, examined in 1918. Figures in column for Pine Reproduction denote number of plants per acre. The summary for lots cut over in seed years is printed in red.

Number of Lot	Date of Cutting	Character of Former Stand.	Pine Reproduction
1	1905–6	Pine 40–50 years old. Nearly pure on lower slope; mixed with hardwoods on upper slope	500–1000, much thicker in places. Practically all from crop of 1905.
2	~~1905–6~~ "	Pure pine 50 years old, with mixture of pine and hardwoods in places.	500+ over most of all of lot. From crop of 1905 (13 years old)
3-A	~~1905–6~~ "	Mature pine and hardwoods	600–1000, crop of 1905
3-B	1906–7	Pure pine (mostly)	100–.
4-A	1907–8	Pure pine 50–60 years old.	100–.
4-B	1908–9	Pure, dense pine, 50–60 years old.	2000+ from crop of 1908.
5	~~1908–9~~ "	Large pine and chestnut 100 years or more old.	6000–8000 from crop of 1908.
6	~~1908–9~~ "	Pine and ~~hardwood, mostly~~ red maple. Pine rather widely spaced.	500–1000 from crop of 1908.
7	1909–10	Strips and groups of mature pine surrounded by immature pine or pine and hardwoods.	100– to 300 per acre on one or two cuttings.
8	1910–11	Dense, pure pine 50–60 years old.	100–.
9	"	Well stocked with rapid-growing pine 50 years old.	100–.
10	"	Small sized pure pine 40–50 years old.	100–.
11	"	Dense stand of small sized pine.	100–.

(Table VII continued)

12	"	Dense, pure pine 40-50 years old. Good-sized trees on Site I.	100—.
13	"	Pure pine in strips and patches among hardwoods.	100—.
14	"	~~Att~~ Small pine and hardwood mixed. 40-75 years old.	100—.
15	"	Fully-stocked pure pine, over 90 years old.	100—.
16	"	Fully-stocked stand of large pine and hardwood over 100 years old.	2000+ on strip 5 rods wide seeded from row of standing pines. 100— over remainder of lot.
17	"	North end mixed pine and hardwood. South end pure pine.	300 at north end 100— at south end.
18	"	Well stocked stand of pine 70-80 years old.	Sparse (200-300) over most of area, except around borders where seeded from standing trees (1000).
19	1911-12	Densely stocked, rapid growing 40 years old.	100— over most of area, 300 in spots.
20	"	Pine 50-60 years old and a few red maples.	100—. Mostly seeded from border trees, from cop of 1914.
21	1912-13	Dense stand pure pine, 40-50 years old.	100—.
22	"	Fully-stocked stand of pure pine 40-50 years old, rapid growth on Site I.	100—.
23	"	Dense pure pine 50 years old.	100—.
24	"	Pine and hardwood mixed 50 years old.	5000+ on upland bench 100— on slope
25	"	Fully stocked pure pine 40-50 years old.	100—.
26	"	Well-stocked pure pine and scattering hardwoods (chestnut) 40-50 years old.	100—.

ble VII continued)

27	1913–14	Mature pure pine, and large pine and chestnut	100—.
28	"	Pine and some hardwoods.	100—.
29	"	Pine and chestnut, 50–60 years old.	100—.
30	"	Well stocked with 50-year old pine.	300–400 from seed trees, irregularly distributed.
31	"	Small to medium-sized pine 40 years old and some chestnut	100—.
32	"	a strip (3.5 x 10 rods) of pure pine 40–45 years old.	2000, from crop of 1914.
33	"	Pine and hardwoods, pine 40–50 years old.	100—.
34	"	Dense stand of small, 40-year-old pine.	100—.
35	1914–15	Fully stocked pure pine 70–80 years old with admixture of hardwoods	2000+ from crop of 1914
36	"	Well-stocked pure pine, 60–70 years old, with admixture of hardwoods in one corner of lot	3000+ from crop of 1914
37	"	Pure pine 40 years old with a scattering of larger, older pines on lower slope	100— over upper slope 500–1000 on lower slope, from crop of 1914
38	"	Well-stocked with pine and hardwoods (pine predominating), irregular in age and age, 40–60 years	5000+ from crop of 1914.
39	"	Fully stocked pure pine, 50–60 years old.	500–1000, better in places, well distributed, from crop of 1914.
40	"	Densely stocked, medium age pure pine, 50–60 years old.	2000, from crop of 1914.

(Plot VII continued)

41	1915–16	Fully-stocked pure pine 50–60 years old.	100–.
42	"	Pine and chestnut 60–70 years old.	500–1000 over portions of tract 100– over remainder
43	"	Pine 50–60 years old and large scattering hardwoods.	1000 over ¼ of area. 100– over remainder.
44	"	~~Fully stocked pine~~ pines 60 years old, large size for age on Quality I site.	100–.
45	1916–17	Dense stand of pure pine 50–60 years old; large trees on Quality I site.	100–.
46	"	Fully-stocked pure pine 40–50 years old.	100–.
47	"	Well-stocked pure pine, 50–60 years old.	100–.
48	"	Densely stocked pure pine 40–50 years old.	100–.
49	1917–18	Dense stand of rapid-growing pure pine, 40–50 years old.	100–.
50	"	Fully stocked with 60-year-old pine and an admixture of hardwoods.	500+ in small patches 100– over most of area.
51	"	Densely stocked pure pine 50 years old.	100–.
52	"	Fully stocked pine 50–60 years old with patches of hardwoods and pine mixed.	1000 over mixed-stand areas. 100– over pure pine area.
53	"	Fully stocked stand of mixed pine and hardwoods 60 years old.	100–. a few small patches of 1914 seedlings.
54	"	Fully stocked pure pine 60 years old	100–.

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Introduction.

The Purpose of this Investigation.

The investigation whose results are recorded in this bulletin was begun in the autumn of 1917 and continued thru the spring, summer and fall of 1918. The Harvard Forest, whose cutover areas were first examined, is in the town of Petersham in northern Worcester County, Massachusetts. The cutover woodlots that were examined lie in Petersham and neighboring towns in Worcester County and in the southern part of Cheshire County, New Hampshire, which adjoins Worcester County on the north.

The purpose of the investigation was:

(1). To determine the degree to which natural restocking is taking place on the cutover pine lands in this region.

(2). To determine the chief factors involved and the effect of each factor upon the regeneration of the species.

(3) To deduce from the foregoing study the most effective and practical methods of restocking cutover pine land by natural seeding.

The scope of this investigation does not include weedings or liberation cuttings and thinnings in young stands, but is confined to the seeding of the area, the germination of the seed and the establishment of the young seedlings.

Physiography and Climate.

The district covered in this investigation is fairly typical of central New England. As usually defined this region comprises the plateau-like highland stretching southward from the White Mountains between the Connecticut and Merrimac rivers in New Hampshire and extending on thru central Massachusetts into northern Connecticut. Along the Massachusetts - New Hampshire line the average elevation is 1000 to 1200 feet above sea-level, declining to about 700 or 800 feet near the Connecticut line. In Massachusetts the western front of this central upland rises sharply 700 to 900 feet above the valley of the Connecticut River and its eastern margin rises almost as abruptly to about 600 feet above the eastern

lowlands. At the New Hampshire line it is about (36) miles wide and 20 at the Connecticut State line. Rising far above the general level of this highland are a number of prominent, isolated peaks, notably Kearsarge and Monadnock in New Hampshire and Mount Grace and Wachusett in Massachusetts.

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The geological history of this region is briefly as follows. In ancient geological times this territory was occupied by a lofty mountain range, which, in the course of geologic ages was eroded down almost to a sea-level plain — termed by geologists a peneplain. This peneplain was then, thru another long geologic period, gradually uplifted to about its present elevation, while the process of erosion carved out the rounded or broad-topped hills and ridges separated by shallow valleys that now form the more detailed topographic features of the central highland. The ridges generally have a north and south trend, and the small streams in the valleys between them flow either north or south into larger streams

that cut across the highland in rather narrow, steep-walled valleys, such as that of the Millers river.

Then came the glacial period when the whole of central ~~New England~~ and southern New England was covered by a thick mantle of ice that crept down from the north, and which left, upon receding, a thin layer of glacial till or "boulder clay;" thus furnishing the material that the New England pioneers so laboriously removed from their fields and erected into the innumerable stone walls that now form such a conspicuous feature of the landscape. In most of the shallow valleys, however, temporary lakes were formed as the walls of the glacier melted or retreated northward, and on the beds of these glacial lakes deposits of sand and gravel, often of considerable depth, were laid down. In this manner were formed the small but numerous "sand plains" that are now one of the most conspicuous physiographic features of the region.

The isolated "monadnocks" or mountains that rise above the general level of the central highland are the residuals of much higher peaks that formed part of the ancient mountain range. Because of their position on the divides of the larger streams that then drained the region and also, perhaps, because of the greater resistance of the rocks composing them, they were not weathered down to the level of the old peneplain.

Over the greater part of this central New England plateau, the soil covering the slopes and summits of the lower hills and ridges is ~~usually~~ generally a sandy loam in which are many stones and boulders, while in the valleys it is usually very gravelly or sandy — often pure sand as on the typical sand plains. The heavier loamy soils of the upland slopes and flattened hilltops are, as a rule, fairly deep and fertile, and would make good agricultural land if it were not for the excessive amount of boulders. These, however, render agricultural development an economic impossibility over extensive areas,

which must always remain absolute forest soil.

As over all of New England, the rainfall is abundant and well distributed thruout the year. The average annual precipitation over central New England is about 40 inches. For the six months from April to September inclusive the average monthly rainfall is 3.5 inches, the month showing the lowest average being June with 3.06 inches, and the highest being August with 3.85 inches. May and July both show the same average, 3.39 inches. Considerable variation from the normal, however, is not uncommon, excessively dry or very wet summers coming at not infrequent intervals.

The average of the monthly mean temperatures for the five months of the growing season, May to September inclusive, is 64 degrees, May having the lowest monthly mean, 56.7 degrees, and July the highest, 70 degrees. The cool, moist climate is ideal for White Pine and central New England

is one of the optimum regions for this species.

Character of the Original Forest.

The original forests on the loamy soils of the uplands were undoubtedly mixed forests of White Pine, Hemlock and various hardwoods. North of the New Hampshire—Massachusetts line the principal hardwoods were White and Yellow Birch, Hard Maple, Beech and Red Oak; south of that line, in addition to the foregoing there was probably a large percentage of Chestnut and White Ash in the mixture, with an occasional Hickory, White Oak, Black Cherry and Basswood. The sand plains were likely covered by a comparatively open forest of White, Pitch and Red ~~Pine~~ pines.

Origin of the Present Woodlands.

Only a few small and scattered remnants of the virgin forest are found in this region today. Yet more than half the area of Worcester County—the largest and one of the most populous

counties of Massachusetts — is today covered by some kind of forest growth[1], and undoubtedly a larger proportion of the other counties in Massachusetts and New Hampshire ^ embraced within the territory under consideration. It is estimated that the "pine woodlots" — 50 to 100 percent pine — cover in the aggregate about one-third of the wooded area, but in the last fifteen years have furnished 80 percent of the cut from this region.[2]

[1] Foot note on page 8a.

[2] Foot note on page 8a.

The origin of these pine lots is of special interest in the study of pine reproduction. It is safe to say that 90 percent of them originated on land that was formerly cultivated or pastured.[2] These even-aged stands are usually cut when from 50 to 70 years old, and during the last thirty years or more have furnished an enormous quantity of second-growth timber to the numerous wood-using industries ^ of this part of the country. But when cut off these lots very seldom reproduce a stand of pine. It is a matter of common observation among the lumbermen and farmers

[2] Foot note same as above.

that are / located in

Foot notes to page 6 of manuscript

(Footnotes to page 8 of manuscript)

[1] Fifty-seven percent, according to "The Forests of Worcester County", published by the Massachusetts State Forester, 1916.

[2] Journal of Forestry, Vol. XVI, No. 2, February, 1918, page 253. Note on Second-Growth White Pine as Related to the Former Uses of the Land.

[2] (Same as above)

that when a pine lot is cut over it "grows up" to hardwood, and usually the most worthless species of hardwoods, such as Gray Birch, Poplar, Pin Cherry and Red Maple. That undeniable fact, however, does not in itself furnish evidence as to whether the area was well-stocked with an advance growth of young pine at the time of cutting, or well seeded either just before cutting or within the next few years. Such may have been the conditions but the pine seedlings would almost certainly have been suppressed and soon killed out by the rank and fast-growing hardwood sprouts. The only general exception to the foregoing is to be found on very sandy or gravelly soils,- as on the limited areas covered by the sand plains. Here the soil is not favorable to the growth of hardwoods and the White Pine is not suppressed by the Pitch Pine that grows abundantly on these sites. Very often an excellent reproduction of White Pine will come in beneath the light

shade of a mature stand of Pitch Pine, and will eventually grow up thru and overtop the latter. But on the heavier soils of the uplands it is very seldom that a cutover pine lot will ~~immediately~~ reproduce ~~and grow~~ a second well-stocked stand of pine.

The Importance of Restocking Cut-over Pine Land.

But the sound economic development and permanent prosperity of this region demand that all timber land be restocked at once after cutting and so managed that it will continually produce crops of good timber. The very fact that these lots were once tilled or pastured but finally abandoned and allowed to grow up to timber is in itself a strong argument that they are unsuitable for profitable farming, and the excessive stoniness of the soil generally corroborates this presumption. The better agricultural land is still being farmed. During more than two generations a process of natural

land classification has been going on, the result of which plainly shows that over 50 percent of the area of this region is better adapted for the growing of timber than for agricultural purposes.

Moreover, the great and continuous demand for second-growth pine lumber in this part of the country indicates that the growing of pine on these lands is the most profitable use to which they can be put. "The closest utilization of saw timber so far developed in the United States is practiced in the woodlot region of central New England."[1] The stumpage value of White Pine now ranges from 10 to 15 dollars a thousand board feet with every indication of a steadily upward trend. Once established and the young growth freed from suppression by hardwoods, it grows rapidly and fully stocked stands on average soils will produce from 40,000 to 50,000 board feet of timber in 50 to 60 years. From the purely economic viewpoint, therefore, it is imperative that cutover

[1] Foot note on page 11a.

(Footnote to page 11 of manuscript)

[1] R. T. Fisher. Utilization and Round-Edge Lumber. Proceedings of the Society of American Foresters, Vol. XI, No. 4. October 1916.

pine lands be promptly restocked and kept productive. This can, ofcourse, be accomplished by setting out seedling trees raised in a forest nursery, and a number of wood-using establishments in the region have already done some planting. But until we have a fairly complete knowledge of the factors affecting natural reproduction and of the conditions which must be observed in order to insure a prompt and full re-seeding of the cut-over tract, we are not justfied in assuming that planting is the cheapest or most satisfactory method of restocking these areas.

Methods Used in Making the Investigation.

The specific methods adopted in examining the different areas are fully described in Part II under Records of Investigation, but an explanation of the general methods employed and the important factors involved in conducting the ~~Examination~~ investigation may properly be made in these introductory statements.

When this investigation was begun the Harvard Forest had been under management for ten years, during which period annual cuttings had been made in accordance with one or another of the various silvicultural systems. The object of securing a good reproduction was kept foremost in planning and conducting the operations. It was pioneer work in applying forest management to white pine forests in this country, and therefore largely experimental. The results obtained in regenerating the areas, especially when compared with the results on pine woodlots in the same region that have been cut off during the same period, cannot help but shed a great deal of light upon the problem.

These regenerated areas on the Harvard Forest were first carefully examined, by methods explained in detail in Part II, to ascertain the amount and character of the reproduction on them. Then 54

pine lots, whose date of cutting was known or ascertained, were examined for the same purpose. The result of these examinations is also recorded in Part II.

It was important to know the date of cutting of each area or woodlot in order to ascertain the relation of the reproduction — or lack of reproduction — to seed years. Records have been kept since 1905 which show that in this locality that year and every third year since (namely, 1905, 1908, 1911, 1914 and 1917) have been seed years, and that little or no seed has been produced in the intervening years. Nor have the successive seed years produced equally heavy crops. The crop of 1908 was the heaviest on record and that of 1914 was also very heavy. That of 1911 was considerably lighter than either of these but was considered a fairly good crop, while that of 1917 was very light. There is no definite record of the amount of the 1905 crop but it is believed to have been

fairly heavy. It will be seen from the results arrived at that this record of seed years furnishes the basis for the whole investigation, for without that information this research, if undertaken at all, would have had to have been conducted largely "in the dark" and no positive conclusions of much value could have been drawn.

It will also be observed that in discussing and tabulating the amount of reproduction found on the areas and woodlots, the numbers counted have been reduced to a common standard,—the number of plants per acre. This is the most familiar and useful standard of comparison. In deciding whether an area is fully or "normally" stocked with young trees, it is helpful to have in mind a few figures denoting the number of trees per acre which, if regularly spaced at certain distances apart, it will take to cover an acre. It is, of course, generally understood that in order to produce

a good, fully-stocked stand of timber, a much larger number of seedlings must be planted or obtained by natural seeding than can live to grow to maturity. The planting distance that has usually been adopted for ~~the~~ pine plantations ~~that have been set out~~ in central New England is 6 by 6 feet, which will require about 1200 (exactly 1210) plants per acre. If spaced 12 by 12 feet apart the number required would be one-fourth, or 300 per acre. A spacing of 8 by 8 feet requires 680 per acre. If the young trees were set out exactly one foot apart each way, there would be, of course, as many trees as there are square feet in an acre, — 43,560. On areas that have been thickly seeded by natural means one sometimes finds 3- or 4-year-old seedlings present at the rate of 40,000 to 60,000 per acre, or even more. Needless to say, the vast majority of these will be killed out by the struggle for light and growing space before reaching the size of large saplings. It is also true that

where the young growth occurs in dense stands, none of the trees grow so rapidly as they would if less crowded.

On naturally seeded land no such regularity can be expected as in plantations, but in order to produce a fully-stocked stand of timber the seedlings should be distributed with a fair degree of regularity over the entire area. There may be present on a certain tract a vast number of seedlings per acre, but if they are massed in scattered patches of dense growth with blank spaces between, the tract is not well stocked. Two conditions therefore must be met in order to produce a fully-stocked stand; (1) a sufficient number of seedlings per acre and (2) a fairly even distribution of the seedlings over the entire area.

Given a sufficiently regular distribution, the normality of stocking is determined by the minimum number of seedlings that it is necessary to have at the start in order to produce a fully-stocked stand of

mature timber. For example, if 1000 seedlings per acre be sufficient to produce a fully stocked stand at fifty or sixty years of age, then a tract having that number evenly distributed over it may be said to be as well stocked as another tract having 10,000 seedlings per acre. Any figure fixed upon as the "critical" number below which a stand may not be considered fully stocked, must evidently be more or less arbitrarily chosen, but the results of this investigation and of other observations have led to the conclusion that on the average sandy loam soils of central New England, 1000 well-established seedlings (at least three years old) may safely be considered the minimum number. Cut-over areas, therefore, bearing 1000 or more seedlings per acre, evenly distributed, may be classed as fully stocked. Five hundred to a thousand per acre may be called a fair stocking. A tract having much less than ~~five hundred~~ 500 is sparsely stocked, and if less than

100 per acre the reproduction is negligible.

Five or six hundred well-distributed young pines per acre, especially if they grow up in mixture with but are not overtopped by valuable hardwoods, such as White Ash, Red Oak, Chestnut, White Birch or Black Cherry, will produce a large amount of high-grade material, but if less than 500 seedlings start on an acre and are not entirely suppressed by ~~worthless~~ hardwood sprouts, they will develop into open-grown, scrubby trees with heavy crowns, yielding only inferior lumber. In studying pine reproduction it is convenient to keep in mind a general classification of stand-density such as the foregoing.

As all farmers and timbermen well know, the productive capacity of the soil and, therefore, the tree growth upon it, will vary considerably even within a restricted locality. Especially is this true in a country of diversified topography. In this country foresters usually recognize

three site qualities: Quality I, the best; Quality II, medium; and Quality III, the poorest. In central New England, Quality I sites for White Pine are usually found on the lower, ~~well-drained~~ gentler but well-drained slopes with at least fairly deep and fresh loamy sand to sandy loam soils; also on river terraces and bottomlands if they are not swampy nor too sandy. Quality II sites cover the middle and upper slopes, except the highest and most exposed hills and ridges; also probably a considerable portion of the sand plains, except where the soil is ~~so~~ excessively sandy or gravelly. ~~that no tree grow except Scrub Oak and scrubby Pitch Pine will be found on it.~~ These latter sites would belong to Quality III, as would the exposed ridges and hilltops with shallow and sterile soil. Quality II sites, on which the tree growth is good but not so rapid as on those of Quality I, cover by far the largest areas of this region, but there is also a considerable amount of Quality I land.

The quality of the site is also often affected by local climatic factors and especially by the aspect, or direction of the slope; north-facing slopes being considerably moister than those with a southerly exposure.

In a moist climate like that of New England the quality of the site does not vitally influence the problem of regeneration, but produces its chief effect upon the rate of growth after the reproduction has been established. In any study of natural seeding, however, the site-quality is too important a factor to be disregarded.

Section 1. Examination of Cut-over Areas on the Harvard Forest.

The Harvard Forest, the property of the Department of Forestry of Harvard University, has been under management for continuous wood production since 1908. Obviously, no tract cut over within that period is as yet beyond the regenerative stage, but these areas furnish exactly the data that is required by this investigation.

The Forest is composed of three separate tracts, all lying in the town of Petersham, Massachusetts, and aggregating about 2000 acres. They are situated in hilly country typical of central New England, at an elevation varying from 800 to 1400 feet above sea-level. This country is on the borderland between what is known as the Northern Forest region and the Central Hardwood region of southern New England and the Middle States. It is a natural white pine region but on the loamy soils of the gentle to

moderately steep hillslopes, the pine must withstand strong competition for possession of the ground from a number of deciduous species,—chiefly White Ash, Red Oak, Chestnut,[1] Red and Hard Maple, Poplar, and the several species of Birch. Gray Birch and Red Maple are the worst enemies of pine reproduction on all except very sandy soils. On loamy upland soils an excellent reproduction of seedlings is practically certain to be largely or entirely suppressed and killed out by these weed trees unless the pine be released by timely weedings or liberation cuttings. The subject of weedings will be dealt with in a future publication.[2]

[1] Foot note on page 23a

[2] Foot note on page 23a.

All the merchantable stands of pure pine or of pine and hardwoods occur on two of the three tracts into which the Harvard Forest is divided. The third tract, which occupies higher land than the other two, is covered with small hardwood growth yielding only cordwood. This is gradually being cut off and the land

(Footnotes to page 23)

[1] The chestnut blight, however, is ravishing this species and threatens to exterminate it ~~throug~~ throughout the whole region.

[2] See also article by R. T. Fisher, The Yield of Volunteer Second Growth as affected by Improvement Cutting and Early Weeding, in Journal of Forestry for May, 1918; Vol. XVI, No. 5.

converted by planting into a coniferous forest of pine, spruce, and larch. (The European larch, a superior timber tree, and not the native tamarack, is used in planting). The soil on all three tracts is, in general, a fairly deep, stony, sandy loam, typical of the upland soils of this region.

Methods of Cutting that have been Practiced.

Since the forest was put under management several methods of cutting and reproducing the areas, conforming in a general way to a number of the recognized silvicultural systems, have been employed. These methods, as practiced on the Harvard Forest, may be designated as follows:

(a) Clear-cutting of previously thinned stands.
(b) Cleared-strip cuttings.
(c) Cleared-group cuttings.
(d) Selection cuttings.

The first method is a simple adaptation of the "Shelterwood Compartment System." The stand of mature timber is thinned, usually in a

seed year, the trees removed including all overtopped and suppressed pines, many intermediate, and such dominant trees as are in poor condition or have too wide crowns. All hardwoods, various species of which are generally scattered thru these "pure pine" stands, are also cut except where the removal of one or more would leave too large an opening. If this operation is done in a seed year, and especially on bare ground, the logging will tear up the layer of pine duff and other surface cover, exposing the mineral soil and thus preparing a good seed bed. If this results in a good reproduction of seedlings, the remainder of the stand may be removed within the next few years. If this final logging is done on snow only slight damage is apt to be done to the seedlings.

Cleared-strip cuttings, as the term indicates, consist in making clean cuttings in the form of comparatively long, narrow strips, usually not over 4 to 8 rods wide. If not cut in a seed year, the trees on the border of the strip are depended

upon to seed it up. After this has been accomplished an adjacent strip may be cut and so on until the whole area has been cut over and regenerated. Cleared-group cuttings likewise indicate the felling of the timber in small groups or patches and dependence upon the surrounding trees to seed up the openings. The familiar selection cutting consists in taking out the oldest and largest timber without leaving any openings of appreciable size. It is applicable only to uneven-aged forests, where trees of all ages and sizes from the seedling to the veteran are mingled together over the whole area.

The results of the application of these various methods on the Harvard Forest in securing a re-stocking of the cutover areas will next be described in some detail.

Results of Cutting on Previously Thinned Stands.

Four areas of pure pine (over 80 percent pine) have been cut

clean in accordance with this method. All four were fully-stocked, even-aged stands approximately 60 years old when cut. They had all originated on open fields that had once been tilled or pastured, and in their origin, rate of growth, composition and yield of timber they were representative of the best pine woodlots of the region. As the soil is favorable for hardwoods as well as for pine, the aim in re-generating these areas was not to reproduce stands of pure pine, but stands containing at least 50 per cent pine mixed with valuable hard-wood species, - chiefly White Ash, Red Oak and Black Cherry. It has been amply demonstrated that White Pine growing in mixture with hardwoods but not allowed to be suppressed by the latter, will grow more rapidly and yield a higher quality of timber than when it grows in dense, pure stands.

On each of these areas, after the thinning had been made, a considerable amount of hardwood reproduction came in. Immediately before the final

cutting the ground was moved over with brush hooks, cutting all hardwood reproduction and underbrush close to the ground. This insured straight-stemmed seedling sprouts and in the case of suppressed seedlings (especially of Ash and Red Oak), rapid growth. It also materially reduced the cost of logging as well as of brush piling. The slash was piled and burned as soonas possible after the cutting was finished, usually in the late winter or spring. These operations were practiced on all four areas. In describing the results obtained on each area, they will be taken up in the order in which the final cutting was made, and for convenience will be designated in this bulletin as areas A, B, C, and D.

Examination of Area A.

This area averages roughly 30 rods in width by 45 in length and covers approximately 8.5 acres. It lies on a gentle westerly slope and is well-drained; the soil is a light but fairly fresh sandy loam and the site is classed as a high Quality II. The

former stand was a densely-stocked, even-aged stand of pine 60 to 70 years old, with about 10 percent of hardwoods in mixture. It was thinned in the winter of 1908-9 so as to take advantage of the heavy crop of seed which fell in the fall of 1908. No pine reproduction existed before the thinning was made.

In the autumn of 1909, when one growing-season had passed, the area was examined and an abundant reproduction of pine seedlings was found. No more cutting was done for six years. During that time most of the seedlings survived but grew slowly and remained stunted and of poor color. This unsatisfactory showing was undoubtedly due to their receiving an insufficient amount of light. If a much heavier thinning (properly a partial clearance) had been made, they would doubtless have been much more thrifty, but on the other hand the remaining timber would have been dangerously exposed to windthrow.

At the end of six years it was observed that this reproduction could not, with such a poor start,

be counted upon to survive exposure and competition with the vigorous hardwood growth if the overwood were removed. Therefore, 1914 being another good seed year, it was decided to cut the area clean in the hopes that the seeding of that year would produce a crop of vigorous seedlings that would be able, if aided by timely weedings, to to compete successfully with the hardwood reproduction. Consequently the area was cut clean in 1914-15, the grounds being moved over with bush hooks before the felling and the slash afterward piled and burned. At the end of the first growing-season (1915) pine seedlings of the current year were abundant and well-distributed, while seedling sprouts of Ash, Red Oak, Cherry, Chestnut, and White Birch, one to two feet high, had come up densely over three-quarters of the area. Many of the pine seedlings of the 1908 crop were destroyed in the logging, but of the many that escaped nearly all perished before the first of September, some from exposure but most of them succumbing to the attacks of the Hylobius beetle[1].

The last examination of this

[1] Foot note on page 30a.

Hylobius pales (Herbst) is a small snout beetle or weevil that breeds in the bark of freshly cut or recently killed trees. It is a species long known to entomologists but it was not till 1914 that it was discovered by E. E. Carter, then Assistant Professor of Forestry at Harvard, to be a dangerous enemy of pine reproduction. [Hylobius Pales as a Factor in the Reproduction of Conifers in New England, in Proceedings of the Society of American Foresters for July, 1916; Vol XI, no. 3.] He carried out experiments in plantations of White Pine on recently cut-over pine land, with the result that in two years after planting Hylobius pales had killed 70 percent of the young plants. They injure the trees by eating the tender bark of the stems, thus girdling them.

Serious damage, likely to cause the death of the tree, appears to be confined to seedlings under three feet high, and two- or three-year-old seedlings appear to suffer more severely than larger ones. The beetle does not appear to breed in the stumps of thinned stands, where the ground is still considerably shaded, but only on clear-cut areas and appears to die

out or to remove to more freshly cut areas after 2 or 3 years. It is now known to be committing its depredations over the whole pine region of New England, and is proving to be one of the most serious factors that must be dealt with in the regeneration of White Pine land. Further consideration will be given to its work in the pages of this bulletin.

area was made in September, 1918, at the end of the fourth growing-season after the final cutting. A census of the reproduction was taken by counting all the seedlings and sprout growth on 20 sample plots of one one-hundredth of an acre each, regularly located at equal intervals over the area, making a total of one fifth of an acre on which the young growth was actually counted. This census gave an average of slightly over 4000 seedlings per acre (see Table II) evenly dispersed over the area, all from the crop of 1914. They looked thrifty and had a good color although not large for four-year-olds, averaging about 8 inches in height.

The seedling-sprout growth ranged from 6 to 10 feet in height and was very dense over the greater part of the area. White Ash, Red Oak, Red Maple, and Black Cherry were the most numerous species. A weeding is needed (accomplished since the examination) to release the pine and also some of the better hardwoods from suppression by undesirable rivals.

Scented fern formed a dense

ground cover over the whole area. Apparently it had done little or no damage to the seedlings but probably has retarded their growth to some extent.

Examination of Area B.

This area, cut clean in 1913-14, is the smallest of the four that has been regenerated by this two-cutting method. It covers about an acre, is irregularly oblong in outline with its longest ~~north and south~~ diameter in a north-and-south direction, and lies on a gentle westerly slope. The soil is a light sandy loam, the site is quality II. The former stand was mainly pure pine 60 to 70 years old with scattering hardwoods, and formed part of a larger area that was thinned in 1911-12. A strip of hardwoods that adjoined this area on the west was cut clean in 1910-11.

When examined in October, 1917, two growing seasons had elapsed since the cutting and three since the last seed-year—that of 1914. The examination was made by counting all reproduction and noting the soil

and ground-cover conditions on 16 sample plots of one square rod each, the plots being regularly distributed over the area in four parallel rows running east-and-west across it. The total area thus examined was one tenth of an acre, or about ten per cent of the whole cutting-area.

The ground cover consisted of patches of coarse, thick grass, alternating with patches of scented fern, partridge berry and blackberry bushes, also generally a thin layer of pine duff and leaf-litter. Surface boulders were numerous. Humus was either lacking or, where present, formed a layer one-half to one inch in thickness.

The distribution of pine seedlings was fairly uniform over the area as a whole, tho the numbers often varied greatly between one sample plot and the next. Patches of dense or fairly dense reproduction would often alternate with spaces in which it was sparse. But no large portion of the area was wholly devoid of pine seedlings.

It will be seen from Table I that over of a total of 3350 seedlings per acre, 2870, or 86 percent, were three year olds, that is, when the examination was made in the fall of 1917 they had completed their third growing-season. They were the product, therefore, of the seed crop of 1914 and had grown for one season beneath the cover of the mature (but previously thinned) stand. About 400 per acre, or 12 per cent, were two-year-olds and must have come from seed of the same crop that had lain over one year before germinating. Only 70 seedlings per acre, or 2 percent, were more than three years old, and all of them were apparently from the crop of 1911. After this stand was thinned in 1911-12, a dense reproduction came in, the product of the 1911 crop. That reproduction practically all disappeared before the final cutting in 1915-16, four years after the thinning. The seedlings of the 1914 crop were not large for their age but appeared to be thrifty.

There is an excellent reproduction of White Ash, Red Oak, Black Cherry and

other hardwoods. Their average height at the end of the second season was about 3 feet. Chestnut sprouts were 5 to 6 feet high but many of them were already attacked by the blight. Red Maple seedlings were far more abundant than sprouts and occured mostly on the eastern or upper side of the area. Here they often numbered over 200 or 300 per square rod, most of them less than one foot high. Red Maple seedlings do not make rapid growth and most of them can be counted upon to die within a few years, altho Red Maple sprouts are among the most vigorous and rapid of growers.

The hardwood growth on this area is fairly typical of that on all four of these cuttings. As an example of the amount and character of the reproduction on these areas it is tabulated in Table I. Similar tables were compiled for all the areas examined but it was deemed unnecessary to publish them all in this bulletin. The essential factors bearing directly upon the objects of this investigation

are given in Table II and following tables. It will be observed in Table I that the hardwood reproduction was tallied in three classes for each species,—seedlings, seedling sprouts, and stump sprouts. An arbitrary distinction had to be drawn between seedling sprouts and stump sprouts, and in this examination all shoots originating from stools over one inch in diameter were classed as stump sprouts. In counting the sprouts each stool was counted as one plant regardless of the number of shoots springing from it. Seedling sprouts will develop into mature trees of the same size and form as those growing directly from the seed.

Table I

Examination of Area C.

This cutting covers about 13 acres, being roughly 60 rods in length and 35 in width. At the south end it joins Area A, which was cut clear in 1914-15. On all other

sides it is bordered by standing timber, chiefly pine on the east and hardwoods on the north and west. The land slopes gently to the west, the soil is sandy loam, the site is a good Quality II. The timber was of the same age, density and general condition as that on Area A — a 60-year old fully-stocked stand of pine with scattering hardwoods. It was neither thinned nor cut clean at the same time, however, being thinned in the winter of 1910-11 and cut clean six years later, in 1916-17.

i/

A census of the reproduction was taken in September, 1918, at the end of the second growing-season after the removal cutting. The seedlings were counted on both strips (transects) and plots regularly distributed over the area and aggregating two-fifths of an acre.

When examined the layer of pine needles was not yet entirely decomposed, but scented fern, which had come in since the cutting, formed the principal ground cover.

The fact that Area B was neither thinned nor cut clean in a seed-year appears to be reflected in

the scanty pine reproduction — an average of only 350 per acre being given by the census, all from the seed-crop of 1914. On the shade of the standing timber along the east side of the cutting the seedlings are more numerous but are sparsely scattered over the greater part of the area. The amount of pine reproduction was not observed at the time of cutting, but the Hylobius beetle was found to be eating the seedlings during the summer of 1918 and may be responsible, in whole or in part, for the small number found when the enumeration was made. Neither is it known whether any seedlings started under the thinned stand from the seeding of 1911. If they did and survived the logging operations of 1916-17 they would naturally be the first to be attacked by the weevil. But it is more likely that they died for lack of light before the removal cutting, as was the case on areas A and B. It should also be stated in this connection that the growing seasons of 1912 and 1913 — the first two after the seed year of 1911 — were exceptionally severe on young vegetation,

and may be the chief cause for the disappearance of the 1911 crop of seedlings. The weather conditions of these two seasons are described in the discussion of the woodlots cut over in 1911-12. (See page 45)

There is an excellent reproduction of White Ash, by far the most numerous of the hardwood species. Red Oak and Hard Maple are fairly plentiful while a considerable number of other species appear scatteringly. This sprout reproduction averaged 4 to 5 feet in hight at the end of the second growing season.

Examination of Area D.

This clear-cut area lies on a flat to very gentle westerly slope, is about 50 rods long in a north-and-south direction with an average width of 16 rods and covers approximately 5 acres. Bordering it on the east and south are mature or nearly mature stands of mixed pine and hardwoods. On the west it is bordered ~~by~~ partly by Area B, cut clear in 1915-16, and partly by cutover hardwood land. On the north is open pasture.

But if the seed-bed had been scarified up in the fall of 1911 or, if not then, the fall of 1914, it is likely that a good crop of seedlings from either of these seed years would have been established

The former stand was mainly pure pine about 60 years old, with scattering hardwoods. This stand, including Area B, was thinned in the winter of 1911-12, a seed year, but Area D was not cut clean until the winter of 1917-18, six years after the thinning.

On May 10, 1918, at the beginning of the first growing season but after the logging had been finished and the slash burned, a count of the pine reproduction was made by the transect method, which gave an average of 6000 seedlings per acre, practically all from the seed crop of 1914. (Altho the area was abundantly seeded after the thinning of 1911-12, as stated in the description of Area B.) On September, at the end of the first growing season, a second count was made the results of which are recorded in Table III. It shows that in this latter enumeration only 2450 seedlings four years old and and older were found, a loss of nearly 60 percent. Nearly all if not the entire loss can be surely attributed to the ravages of the Hylobius beetle. Inspections in July and

August showed that the weevil was killing many seedlings, and in September many more freshly chewed plants were found. Very few dead seedlings were found that did not show signs of having been chewed by the beetle.

From the seed crop of 1917 (a very light crop) only a few seedlings, averaging 150 per acre, were found. These were too young to be attacked by the beetle. Judging from the results of this and other examinations of woodlots cut in the fall ~~of~~ and winter of 1917-18, the crop of 1917 was apparently a failure. There is the usual abundant seedling-sprout growth of White Ash, Red Oak and Black Cherry, which at the end of the first growing season were from 3 to 4 feet high. The ground cover consisted principally of scented fern and pine duff 2 to 3 inches thick. The fern was not yet very dense anywhere on the area.

From a review of the facts brought out in the examination of these areas, we believe that the following conclusions

may be drawn with considerable assurance.
(1) That if a stand of pine 50 years old or upwards can be cut in a seed year (that is, between September of the year in which the seed ripens and the following June) the area may as well be cut clean in one operation, as a good reproduction is almost certain to be obtained and the seedlings will grow at their maximum vigor from the start.
(2) If a mature stand of pine cannot be cut in a seed-year it should be thinned or only partially cleared. The next seed year will then in all probability stock the area with an excellent reproduction, especially if the soil be roughly scratched or harrowed up in the fall of the seed year. The overwood should then be removed in a few years (2 or 3) after the seeding. If allowed to stand for a longer period the seedlings will not thrive and most or all of them will die within four or five years for lack of sufficient light (this will depend, however, on the heaviness, ~~of the~~ or severity, of the first thinning or partial clearance)
(3) The Hylobius beetle must be reckoned

with as an important factor in any shelterwood method of cutting. If a lot is cut clean in a seed year the beetles will have bred and left (for the most part) that cutting before the seedlings are large enough (when two or three years old) to be depended upon to any extent by them. Further consideration of this factor and proposed methods of control will be given in Part III.

Table II

Results of Cutting in Cleared Strips.

A number of strip cuttings have been made on the Harvard Forest, of which three, cut in different years and typical both of the method and of the results thus far obtained in regenerating these areas, will be described in this bulletin. One of these cuttings is in reality a "double strip" composed of two contiguous strips cut one year apart. For convenience the strips will be numbered

1, 2, and 3, in the order in which they were cut over.

Description of Strip Number One:

This cleared strip is about 24 rods long and 6 to 7 rods in width. It extends along the apex of a low rounded spur that lies between a maple swale on the south and a small brook on the north, the swale draining into the brook at the lower end of the strip. The apex of the spur slopes gently to the west. Across the upper end of the strip is a stand of immature pine and hardwoods, while at the lower end is a block of tall, pure pine. On the north it is bordered by mature pine and hardwoods. The maple swale on the south was cut over five years after the strip of pine was cut.

The former stand was a strip of pure, heavy pine that had come in naturally on this low, flat ridge. The soil varies from a sandy loam at the upper end of the cutting to a heavy loam at the lower, where it is considerably fresher. The site is a good quality II or I/II for White Pine. Over most of the strip and especially

the lower half ~~the lower half~~ there was, when examined, either a dense growth of ferns or a layer of undecomposed leaf-litter often 3 or 4 inches thick.

When examined in November, 1917, six growing seasons had elapsed since the cutting. The examination was made by counting all seedling and sprout growth on ten square plots of one one-thundredth acre each (approximately 21 feet on a side), regularly distributed over the strip. The results for the pine and hardwood reproduction are given in Table III.

both

The cutting was made in the winter of 1911-12, and it was expected that the area would be regenerated from the seed of the felled trees, reinforced if need be by later seedings from the pines on the northern border and at either end. The examination revealed that this expectation had been realized. It showed nearly 4000 seedlings per acre very evenly distributed over the area. Of this number 1200 per acre were from the seed crop of 1911. In a report on this area made in November, 1914, the

statement is made that "reproduction of this species is plentifully present at the rate of 1200 thrifty young trees per acre."[1] The 1911 seedlings were then 3 years old and the examination of 1917 shows that no loss has been sustained by the seedlings of that crop during the last three years. But over 2500 trees per acre, or more than two-thirds of the total number found in 1917, were the product of the 1914 seed-crop, and of course had not yet germinated when the examination was made in the autumn of that year. This seed could have come only from the trees standing on the borders of the strip and the total amount of seed which fell upon the area in 1914 was probably much less than that from the crop of 1911. There are no records to show whether the ~~crop~~ germination from the crop of 1911 was much greater than appears from the present stand and ~~whether~~ if numbers of the seedlings were killed by the Hylobius beetle or died from unfavorable weather conditions during the first two or three growing seasons, but it is likely that both these factors were operative.

[1] Foot-note on page 46a.

(Footnote to page 46 of manuscript).

[1] Report by R. H. Tryon in the records of the Kurumul Forest.

When examined in the fall of 1917, the pine seedlings of the 1911 crop ranged from 18 to 24 inches in height; those of the 1914 crop averaged 4 to 5 inches. The pine reproduction was being suppressed by the hardwood sprouts and it was evident that a weeding was necessary in order to release the former. Table III gives both the pine and hardwood reproduction. The hardwood growth is typical of that on all three strips and is not tabulated for the other two. The essential facts concerning the pine reproduction on the three strips examined are given in Table IV.

Table III

Examination of Strip Number Two.

This really comprises two adjacent strip cuttings, each somewhat more than 50 rods in length and from 6 to 8 rods wide, making the total width from 12 to 16 rods and the total area about four and a quarter acres. It lies on a gentle slope in the valley of the Swift River, with westerly aspect. The strip lies in a north-and-south direction, parallel to the river.

The first cutting was made in 1912-13 and the second in 1913-14. The first strip cut was the more easterly, or higher on the slope. The east edge of this strip was determined by a stone wall running north-and-south which here forms the boundary of the Harvard Forest. The west edge of the second strip lies on the flat but narrow river terrace, but between the clearing and the river there is a belt of tall pines several rods wide. When examined in October, 1918, the two strips had been cut, respectively, four and five years, but they already formed a uniform area on which conditions were identical and the dividing line between the two cuttings could not be traced with any certainty. The whole area was therefore regarded and examined as one strip-cutting.

The soil is a fine, fresh loam, more than 8 inches deep and the site is quality I. The ground cover consists mostly of grass, ferns, spiraea and raspberry bushes.

The former stand was dense, pure pine, 50-60 years old. All the cut practically clean, a few small groups

of trees were left, mostly on the first cut or upper side of the area. Neither strip was cut in a seed year. The crop of 1914 fell at the end of the first growing-season after the second cutting was made.

A report[1] on the condition of this cutover area made in August, 1914, states that no pine reproduction had at that time appeared. The census in October, 1918, gave an average of 900 four-year-old seedlings per acre, fairly well dispersed over the area. This examination was made by a combination of the transect and sample-plot method. The seedlings were thrifty, averaging 8 inches in height with a maximum of 14 or 15 inches. No evidence of the Hylobius beetle was found during this examination.

This fair tho not abundant reproduction shows that areas cut clear in the form of comparatively narrow strips, even tho not cut in a seed year, may be thinly seeded from bordering seed trees, especially if the trees are on the windward side. The report of 1914 shows the ground cover to have been the same as was found in 1918, except that there was ~~then~~ in 1914

[1] See footnote on page 49a.

(Footnote to page 44 of manuscript)

'Report by S. M. Dohunian in the records of the Harvard Forest.

from one to four inches of pine duff and leaf litter in addition. The grass and herbage growing for one or two years on the cleared area before any seed fall would ~~produce~~ present a much less favorable seed bed than if cut in a seed year. Altho no direct experiments have yet been made to prove the assumption, there can be little doubt but that, if the seed bed had been given some preparation in the fall of 1914 — such as a rough harrowing of the soil — the pine reproduction would have been much more abundant.

The hardwood reproduction on this strip cutting, tho abundant, was not so dense or vigorous as is often the case on lower slopes and loamy soils. Seedling sprouts of Red Maple, numbering 430 per acre, are the most numerous of any one species. Cherry comes next with 230 seedling sprouts per acre, and there are 100 Hickory sprouts per acre. White Ash and Red Oak are but sparsely represented. Most of the sprout growth averaged 8 feet in height when the examination was made and a weeding would soon be required in order to release the pine.

Examination of Strip Number Three.

This is the smallest of the strip cuttings, covering about one-quarter of an acre. It is about 14 rods long and averages slightly more than 3 rods in width. It was cut clean in the winter of 1917-18, but formed part of a much larger area of even-aged pure pine, 50-60 years old, that was thinned in 1911-12. The treatment, therefore, was the same as that accorded to the four larger areas first described and were it not for the small size and the shape of this area it would be classed under the first method of cutting. The investigation of this cleared strip was of special interest because of the further light it threw upon the ravages of Hylobius pales on areas where reproduction had started before clearing.

The strip extends in a nearly east and west direction and lies upon a well-drained upland with a slight westerly slope. The soil is a light, fairly deep sandy loam and the site is quality II. The area is bordered on the north by tall mixed pine and hardwoods; on the south and at either end by the stand of pure pine of which it originally

formed a part. Owing to the narrow width of the strip and its east-and-west orientation, the ground receives a large amount of side shade from the dense stand of pine on the south.

After the thinning of 1911-12 an abundant reproduction came in over the whole area but entirely perished within three or four years. Another abundant seeding followed the crop of 1914 and the seedlings were still living at the end of the fourth growing season. Their average height at that time, however, was only slightly over 3 inches.

On the first part of May, 1918, after the logging was finished and the slash burned, a census was taken of the seedlings on the entire strip which gave an average of 28,000 per acre, evenly distributed. The seedlings were counted on a strip 10 rods long and 20 links wide running thru the middle of the area.

Several inspections during July and August revealed that *Hylobius pales* was killing large numbers of the seedlings on the cleared strip but none under the adjacent timber. On September a second count was made on the

sample

same strip that was examined in the spring. As there was very little ground cover except pine needles, and the sprout growth was small and comparatively sparse, it was easy to count not only the live seedlings but those that had been killed by the beetle, the latter still retaining their dried foliage. A separate tally was kept of these as well as of those still living that had been chewed by the beetle, and of weak and dead seedlings that showed no sign of beetle attack. As regards the total number of seedlings per acre this count corroborated the one taken in the spring, giving an average of 25,340, and therefore furnishes excellent proof in this specific instance of the damage done by *Hylobius pales* during the first growing-season after a clear-cutting (but when the seedlings are several years old). This information may be summarized as follows:

	Number of seedlings per acre.	Percent
Normally thrifty and unattacked by *Hylobius*	17160	60.5
Weak(80) and dead(320) but without sign of *Hylobius* attack.	400	1.5
Living but having been attacked by *Hylobius*	1280	4.5
Dead from *Hylobius* attack	9500	33.5

Practically all the seedlings that had been attacked by the beetle but were still living when examined, were withering and undoubtedly died later. This gives a mortality of 38 percent due to the beetle while only 1.5 percent were weak or dead from other causes. Carter found that in white pine plantations on recently cut-over land the beetles killed 70 percent of the stock in two years. To what extent this abundant natural reproduction will be reduced by their ravages in another year remains to be seen. The amount remaining at the end of the first growing-season (over 18000 per acre) was still super-abundant, and if the total loss from the beetle is not more than 70 percent, there would still be upward of 8000 seedlings per acre — more than enough to completely stock the area. This would indicate that one method of combatting Hylobius pales would be by securing such a dense reproduction that after the beetle had still taken his full toll there would be a sufficient number of seedlings left to fully stock the area. But the power of the beetle for destroying

natural reproduction has not been definitely determined and there are reasons for believing that in many cases the destruction is practically complete. (See Cutter's article previously referred to).

When this examination was made the seedlings had completed their fourth growing-season. As previously stated they were not large for their age nor very vigorous, due to having grown for the first three years in the shade of a still dense (tho previously thinned) stand of pure pine. A sparse reproduction of 1917 seedlings — 220 per acre — were counted in the September examination.

As previously mentioned, the deciduous seedling and sprout growth is relatively sparse on this area, due to the density of the original pure pine stand. Black Cherry, White Oak, White Ash and Red Oak, in the order named, are the important hardwoods most abundantly represented.

The results of cutting in narrow, cleared strips when plenty of seed trees remain standing on the borders, either in pure or mixed stands, confirms (strips 1 and 2) the natural assumption

that such areas may be regenerated even tho not cut over in a seed year, but to make sure of securing a complete reproduction when seed years come subsequent to the cutting, some working of the soil in the autumn of the seed year in order to prepare a receptive seed bed, is advisable.

Table IV

Results of Cutting in Cleared Groups.

Eleven small areas or patches from which the timber had been removed in accordance with this method were examined in the course of this investigation. These group-cuttings were all made on one tract of the Harvard Forest and their relative position and proximity were such that all eleven could be included in an 80-acre tract half a mile long and a quarter-mile wide oriented with its long diameter due north-and-south. These cuttings are irregular in size and outline, some roughly oblong from 2 to 3 rods wide and 6 to 8 rods long, others nearly circular or equilateral. Their

aggregate area is approximately 220 square rods or one and three-eights acres, which makes the average size of the cuttings one-eighth of an acre, or the equivalent of a circular plot about 5 rods (80 feet) in diameter.

All these group-cuttings lie upon a well-drained upland with gentle to moderately steep westerly slope, but with its surface grooved and roughened by slight subsidiary ridges, knolls and depressions. Four groups occupy quality I sites, the soil being a deep, fresh loam; the others are on quality II sites with a light sandy loam soil.

The surrounding timber is mixed pine and hardwoods, 50 to 70 years old, except that surrounding the three most northeasterly clearings, which is composed of young to middle-aged stands of pure pine. The former stands on the cutover areas were nearly all groups of mature pine pine, but one (on quality I site) was composed of five or six over-mature chestnuts with several large maples and a few large pines. Six of these small areas

in 1911-12, so that, when examined in the fall of 1917 they had completed either six or seven growing seasons.

On making the examination, small sample plots, generally one square rod each, were laid out in the group clearings, four or five plots as a rule on each clearing. As in the other forms of cutting the census for each species in the reproduction was reduced to number per acre as the common basis of comparison. Considerable differences occurred in the amount and character of the reproduction between one group and another, but the object of the examination was to obtain the average for all groups, as / and that is the information most desired in examining the results of regeneration by this method. The results are given in Table V.

The ground cover on all the clearings was composed of ferns, duff and leaf litter. The duff and litter was not very thick nor were the ferns usually so dense as to menace the pine seedlings. On only one area was there a patch of grass which had

of humus from 1 to 2 inches thick was generally present.

A glance at the table shows an excellent reproduction of White Pine — between 6000 and 7000 seedlings per acre — and a relatively low amount of hardwood seedling and sprout growth. The average height, also, 6 to 8 feet for seedling sprouts and 15 to 18 for Chestnut and Red Maple stump sprouts, all six or seven years old, shows a considerably reduced growth-rate over that of the same species on larger clearings. Nevertheless, weedings were needed at the time of the examination in many of the clearings to release the pine.

On eight of the cuttings the seedlings average over 3000 per acre and on only one is the average less than 1000. This cutting is in a small "cove" at the foot of a ridge, with westerly aspect. The soil was a deep, fresh loam — Quality I site — and the ground was usurped by a dense growth of hardwood sprouts. These were suppressing the seedlings and may have killed many before the examination. Only 400 per acre were found ~~on this~~

It is apparent that a good reproduction is apt to be obtained by this method whether the felling be done in a seed year or not. In fact the six clearings made in 1910-11, one year before a seed year, give an average of 1430 seedlings per acre from the 1911 crop, while the five cuttings made in the seed year of 1911-12 show only 808 per acre from that crop. And for all eleven clearings the crop of 1914 seedlings is between four and five times as large as that of 1911. At the same time it was observed that on a number of the cleared areas the reproduction was very unevenly distributed, being dense over parts of the clearing and sparse in other parts. A more even distribution could probably to obtained by working the soil in the fall of a seed year. The seedlings were also showing evidence of too much shading, those of the 1911 class averaging not more than 12 to 16 inches in height, and those from the crop of 1914 being from 3 to 6 inches at the end of their third growing season.

To sum up, the principal con-

examination are:

(1) That the cleared-group method of cutting is very likely to secure an excellent reproduction of pine provided seed trees are standing on the border of the clearing.

(2) That it is relatively unfavorable to the growth of hardwood reproduction except on Quality I sites.

(3) That the obtaining of a good reproduction of pine is not dependent upon cutting in a seed year.

It may be added, however, that the scattered operations demanded by the group system of cutting increases the cost of logging over the ordinary methods of clear-cutting and, especially for portable mill operations, would in most cases be considered economically unprofitable

Table V

Results of Selection Cutting.

The area on which this cutting was made, four or five acres in extent, is level but well-drained, with a deep, fresh, sandy loam soil. The site is quality I. The cutting was made in the winter of 1904-10, so that when

examined in November, 1917, eight growing seasons had passed. This area was covered with a heavy stand of mixed pine and hardwoods — Chestnut, Red Oak, Black Cherry and White Ash — 60 to 70 years old, with much larger and older trees, chiefly pine, scattered thru it, and also groups of thrifty saplings. There was a fairly abundant advance growth of hardwood seedlings. The largest mature and over mature trees were the ones felled in the operation, leaving no opening more than 30 or 40 feet in diameter.

The examination was made by laying out 8 plots of 1 square rod each, 4 plots being arbitrarily located at equal intervals apart and without regard to the position of felled trees, the other four were purposely placed, one in one of the small openings or "holes" made by the removal of a large pine.

The total number of pine seedlings found on the eight plots was 62, of which 42 were found on the four plots in the small openings and 20 on the other plots. This gives an average

distributed yet sufficiently so to restock the area if the majority of them could be counted upon to grow to maturity. But there is no prospect that many of them will live and thrive under the shade of the timber now standing. Somewhat more than half the seedlings were from the crop of 1914. These were 3 years old when examined and from 2 to 4 inches high. The remainder were from the crop of 1911 and ranged from 8 to 12 inches in hight. All were stunted and not thrifty in appearance. The examination simply confirms the prevailing opinion that the selection system is not adapted to the regeneration of White Pine. The ground cover also was unfavorable for the germination and growth of pine seedlings, consisting over the whole area of thick leaf litter and a rank growth of lycopodium and other herbaceous plants.

At the same time the amount of hardwood reproduction was scarcely more than that of the pine and the rate of growth was likewise slow. Seedling sprouts averaged from 4 to 6 feet in

representation of thrifty young growth above the seedling stage — mostly Black and Yellow Birch, Red Oak, Black Cherry, Sugar Maple and White Ash — ranging from suplings to large poles. The stand is, therefore, in good condition to be managed by the shelterwood system for the production of mixed hardwoods. To increase the amount of pine and favor its growth, larger openings would have to be made in the crown cover, merging the selection into the group system of cutting.

selection /

Table VI

A general survey of all these cuttings reveals the fact that practically without exception the cutover areas have been well stocked with a new crop of seedlings, and that this crop was either on the ground when the timber was removed or within five years thereafter. Where the reproduction was already present at the time of cutting, the seeding of the ground had been

none of the methods as actually practiced are elaborate examples of the various silvicultural systems, they have accomplished the desired results.

The opinion has prevailed that, altho good seed years occur only periodically, "some seed" is produced every year. The records kept on the Harvard Forest for ten years and the results of this investigation appear to give fairly conclusive evidence that no seed whatever is produced in the intervals between seed years. Even if a small amount ^ be produced in off years, its effect in restocking a cutover area will be negligible. Neither was any evidence adduced to show that ~~pine seed~~ White Pine seed stored in the duff retains its viability for more than two years at the most, and only a small percentage of it will germinate after the first year. Only good seed years can be relied upon to thoroly reseed the ground and must be given primary consideration when working to obtain a full restocking of any cutover area. We believe

sometimes/

brought out by the data obtained in the examination of cutover woodlots outside the Harvard Forest.

Section 2. Examination of Cutover Woodlots.

Fifty-four woodlots that had been cut over since 1905 and the exact date of whose cutting was ascertained, were examined in the course of the investigation. The data for each woodlot were collected under the following heads:

1. Date of Cutting.
2. Situation, Aspect and Gradient.
3. Soil and Site-quality.
4. Ground Cover
5. Character of former Stand.
6. Pine Reproduction
7. Hardwood Reproduction.

The woodlots before cutting were all of the ordinary second-growth "pine hor" type characteristic of the region, that is, the timber ranged from at least 50 percent pine to pure pine stands, generally

been cut clean or practically so at one time, as is the common practice. No attempt on any of them had been made to dispose of the slash.

Most of the lots lay on the upland slopes or in the narrow V-shaped valleys of small brooks, but a considerable number lay, in whole or in part, on the flat bottomlands along the larger streams where such land was fairly well drained. Every degree of aspect and gradient from level land to steep hillslope was represented by the fifty-four woodlots taken together. Most commonly the soil was a light sandy loam, stony but of fair depth, and fresh or between dry and fresh. On the bottomlands it was generally a deep, fine loam or even, in a few cases, a clay loam, while on some of the lower slopes it was a loamy sand. None of the woodlots examined in this investigation was situated on a typical sand plain, altho several such areas were inspected. All the woodlots occupied either quality I or II sites, or sites that were classed as intermediate between I and II, except one

is the same as that in the Harvard Forest, excellent for pine but also good for hardwoods.

The ground-cover on all these woodlots consisted principally of grass, berry-bushes, fern and other low herbaceous plants in varying proportions and density of growth; also a layer of partly decomposed pine needles on the more recent cuttings, and more or less slash. On recently cut lots the slash, lying in windrows, often covered from 30 to 40 percent or even 50 percent of the area

Under the heading "Character of former Stand," was recorded the approximate age, rate of growth, and size of the trees when cut; the composition of the stand - whether pure pine or mixed stands and percentage of different species in mixture; the density of stocking and whether the trees were small or large crowned. This information could be obtained with sufficient accuracy from an examination of the stumps and of the cutover land in general. The amount of slash, considered in relation to the density of stocking and size of stumps, was indicative of the average size of the

crowns.

In estimating the amount of pine reproduction on each woodlot it was not necessary to lay out carefully a large number of sample plots, as was done in making the intensive investigation of both pine and hardwood reproduction on the Harvard Forest. A general reconnaissance of the area quickly revealed whether the amount of reproduction was negligible (averaging less than 100 per acre) or if, on the other hand, the lot was well or densely stocked. In every case where the reproduction was more than negligible the seedlings were counted on a number of small ~~sample~~ circular plots in order to determine the approximate number per acre. If between 100 and 500 per acre the stocking was classed as sparse; between 500 and 1000 as fair, and over 1000 as fully stocked. These general figures, however, were considered in relation to other factors, such as the distribution of the seedlings and the relation of ~~this~~ such distribution, if any was apparent, to the nature of the former stand, the ground cover and soil, and the hardwood reproduction. The amount of the latter

was not determined in exact figures but in the percentage of ~~relatively a-bundance~~ relative abundance.

In analyzing the data they were arranged in a chart or table similar to Table VII, except that additional columns were provided for Situation, Aspect and Gradient, Soil, Site-quality, Ground Cover, and Hardwood Reproduction, respectively. A study of this information, corroborating the direct observations that were made in collecting it, revealed that these factors were of slight importance in effecting the seeding or non-seeding of the cutover areas. Those columns, therefore, have been omitted from Table VII. The condition of the seed bed at the time of seeding is conceded to be of the utmost importance. But on all the woodlots examined the condition of the soil and ground cover for the first few years after cutting were practically the same. Those factors, therefore, are eliminated as the controlling ones in effecting the seeding or non-seeding of these lots. On the other hand, the investigation showed very plainly that if a cutover area be not

seeded within a ~~couple~~ few years after cutting, the growth of grass, herbaceous vegetation and hardwood sprouts renders conditions extremely unfavorable for the regeneration of pine.

On Table VII the woodlots are arranged in the order of years in which they were cut over. A cursory inspection reveals the fact that, with a few exceptions, the lots cut over in seed years are the only ones that are well or fully stocked. On the table the data for the lots cut in seed year are printed in **red** type. This factor naturally divides the woodlots into two groups — those cut in seed years and those cut in non-seed years. Forty lots were cut over in non-seed years and fourteen in seed years. A few of the lots cut over in non-seed years show a partial or a full stocking, while two lots cut in a seed year (1911-12) have failed to reproduce. The factors involved in these conditions need further consideration and will be dealt with in the following discussion of these two groups.

Woodlots Cut Over in Non-seed years.

Of the 40 woodlots cut over in non-seed years the reproduction on 29 was negligible, averaging less than 100 seedlings per acre. In fact the number of seedlings on most of them was much less than 100 per acre, only here and there a seedling being found after close scouting. These 29 lots, like those cut in seed years and the remainder that were cut in non-seed years occurred on every variety of situation, slope, aspect and soil, while the ground cover and hardwood reproduction were similar on all. None of these lots, therefore, on which regeneration was a total failure, needs individual consideration. Most of them were good-sized lots but whether large or small were surrounded by hardwoods, immature pine and open land.

On 11 woodlots cut over in non-seed years, an amount of pine reproduction ranging from sparse to a full stocking over the whole or a portion of the area was observed. The origin of this reproduction is of special interest and can be presented most clearly by giving a brief description of each lot in turn

and noting the conditions under which the regeneration took place.

Lot No. 1. — This cutting consisted of a number of small cleared strips and patches where the former stand had been pure pine of comparatively large size surrounded by immature pine or mixed pine and hardwoods. The cutting was made in 1909-10. When examined in April, 1918, after eight growing-seasons had passed, the reproduction on some of the areas was negligible, while on others there was a sparse reproduction of 300-400 per acre and on one strip where a number of fair sized pines had been left along or near the border there was a fair reproduction of over 500 per acre. All seedlings were from the crops of 1911 and 1914. Grass was the principal ground cover and but little hardwood growth had come in. The obvious reason for the lack or sparseness of pine seedlings is that very few or no seed trees were left standing on the borders of the areas, most of the pine in the vicinity being too young to cast much if any seed. This is because combined with the fact that

the cutting was not made in a seed year. Except for the lack of seed trees on the edges of most of the openings, this cutting was similar to the cleared group and strip fellings on the Harvard forest.

Lot No. 16. — This lot, cut over in 1910-11, affords an interesting example of side-seeding and the extent to which side-seeding may be depended upon under favorable conditions. The lot covers in part the rather broad and flattened summit of a high hill and also the south~~ern~~ and southeast slopes of the hill. The west side of the lot is bounded by an old lane running north and south along the western crest of the hill, below which is a hillside pasture on a steep westerly slope. The old lane (about 40 feet wide and bounded by stone walls) had long been disused and the pine had seeded in and grown up on it the same as on the lot to the east. It naturally formed a part of the same stand of timber and belonged

woodlot was sold a wealthy and benevolent citizen of the town bought from the lumber company the trees standing in the lane in order to preserve them for their scenic value. The timber on this lot formed a fully-stocked stand of pine and hardwoods over 100 years of age, the trees being considerably larger and older than on most of the second-growth woodlots of the region. The trees in the lane had grown up from youth exposed to the prevailing westerly winds and were, therefore, windfirm. Consequently there was no loss from windthrow when the trees east of them were removed.

old/

The woodlot was examined in October 1918, seven growing seasons after cutting. Over the whole lot of 30 or 40 acres the pine reproduction was negligible except on a strip averaging 5 to 6 rods in width lying immediately east of the row of pines in the lane and parallel to them. On this portion of the tract there was a magnificent reproduction of thrifty four-year-olds (from crop of 1914) well distributed within that distance from the

seed trees and averaging more than 2000 per acre. At a distance of 6 rods from the row of pines the reproduction abruptly diminished and at 8 rods was as scanty as elsewhere on the lot.

It is significant that no seedlings from the 1911 seed crop were found on the regenerated strip. The failure of that year's reproduction can hardly, in this case, be attributed to the Hylobius beetles, which would have left the cutting before the young seedlings were large enough to receive their attention. It is most likely due to the unfavorable weather conditions of the first two growing seasons after the crop of 1911 fell. (See page – Page 95 of manuscript.)

Lot No. 17.– Cut over in 1910-11. This lot covered a ridge or "hogback", its axis extending in a north-and-south direction, with a steep slope to the west and more gentle slope to the east. The northern part of the lot had been covered with a mixed stand of pine and hardwoods (mostly chestnut); the southern part was a pure pine stand. Over

that portion that had been covered by the mixed stand there was a sparse reproduction of about 300 seedlings per acre; over the part previously covered by the pure pine there was no reproduction. The seedlings on the northern part were apparently from the crop of 1908, tho some may have been older.

Lot No. 18.- Cut over in 1910-11. This lot is on level land in a shallow upland depression, a small brook which runs thru the lot draining to the south. It is bordered by large pine on the north, west, and part of the south side. Within ~~four~~ 4 to 6 rods of the standing timber there is a good reproduction of pine, but over the remainder of the lot it is scanty. The seedlings are from the crops of 1911 and 1914. The site is quality I and the soil a fresh to moist loam.

Lot No. 24.- The upper part of this lot lies on a narrow, level "bench" and the remainder on a steep eastern slope descending from this bench to the creek

On the slope the reproduction was negligible but on the upland bench there was a good distribution of between 500 and 1000 young pines per acre. The lot was cut over during the spring and summer of 1913. An examination of the area showed that on the slope the former stand was nearly pure pine, while on the bench it was mixed pine and hardwood. There was also much more soil moisture on the bench, which, tho well drained, almost approached the condition of a maple swale. That it was not swampy, however, is attested by the abundant growth of Hard Maple and Yellow Birch. The pine seedlings are bound to be suppressed by this hardwood growth (10 to 15 feet high when the lot was examined in May, 1916) but had made their best growth in the last three or four years,-that is, since the lot was cut over. The seedlings were either from the crops of 1908 or 1911, probably from both. Their survival under the old stand and amongst the dense hardwood reproduction was undoubtedly due to the moist site.

Lot No. 30. — Cut over in 1913-14; examined in June 1918. This was not a large lot, was irregular in outline and was surrounded, for the most part, by good-sized pine. In addition some groups of pine and single trees too small or too scraggly to be ~~cut~~ merchantable were left standing on the lot. Under the dense growth of chestnut, oak, maple and ash sprouts there was found a considerable number of 1914 seedlings, occuring in small, irregularly distributed patches. These had evidently seeded in from the adjacent timber.

Lot No. 32. — Unintentionally made as such, this is an excellent example of a cleared-strip cutting. A strip 3½ rods wide and 10 rods long had been cut thru a block of pure pine on a gentle northwest slope. The trees were 40-50 years old. It represented the initial cutting of a logging operation that had been intended to take the whole block of pine, but operations had been discontinued after the trees on this strip

suddenly | ^

cutting was done in the winter of 1913-14, so that one growing season intervened between the cutting and the fall of the seed crop of 1914. When examined in October 1918, the entire area was covered with an excellent reproduction of vigorous four-year-old seedlings averaging about 2000 per acre. Because of the large amount of side-shading received by the strip the hardwood reproduction was comparatively sparse and had not made rapid growth. It had not yet begun to menace the growth of the pine seedlings. It was noticeable that under the standing timber on either side, this reproduction gave out within a rod or two from the borders of the strip. Of the eleven cuttings made in non-seed years on which some reproduction was found, this is the only one with the whole area completely restocked. To insure the complete seeding of cleared areas not cut over in seed years, such areas must be of small size and surrounded by numerous seed trees.

Lot No. 42 — This is a partially [illegible]

on nearly level upland but with gentle slopes in different directions. The timber had been a mixt stand of pine and hardwoods (the latter mostly chestnut), medium to good sized trees 60-70 years old. The proportion of chestnut was large but varied considerably over the lot. The timber was cut off in the winter of 1915-16 and the lot examined in October 1918. Over different portions of the lot a very good reproduction was found while on at least half the area it was very poor or negligible. The examination showed that these irregular areas of good reproduction generally occurred where the percentage of chestnut or other deciduous species had been greater in the mixture. Where the stand had been composed of pure or nearly pure pine, densely stocked, little or no reproduction occurred.

The amount of reproduction on all the regenerated areas taken together averaged between 500 and 1000 per acre, but patches could be found on which it was much denser. The majority

of the seedlings were from the crop of 1914, tho many older seedlings were observed. The 1914 seedlings had grown during their first year beneath the uncut timber, and the oldest must have lived thus for four years or more, but apparently very few if any originated from an earlier crop than that of 1911.

Lot No. 43. - This was a small lot of about five acres (20×40 rods) lying on nearly level, well-drained land at the foot of a westerly hill-slope. The soil was loamy, fairly deep and fresh. The lot had been well-stocked with good-sized, rapid-growing pine 50-60 years old, with some large hardwoods in mixture. On the hillside above the lot pine had ~~had~~ seeded in on an old pasture, forming a young stand; on the west was a stand of large hardwoods; beyond the north and south ends of the lot was open pasture. The timber was cut off in 1915-16 and the lot examined in October 1918.

About one-quarter of the area was found to be well-stocked with 1914

very irregular. Most of the seedlings were found near the borders of the lot and in the vicinity of large hardwood trees, some of which had not been felled. On such patches the seedlings would run over 2000 per acre. On the remainder of the area the reproduction was negligible.

Lot No. 50. — A large lot on well-drained upland with gentle westerly exposure. It was covered with a densely-stocked stand of pine about 60 years old, with a considerable amount of hardwoods in mixture. The pine was cut off in the winter of 1917-18 but the hardwood was not removed. The examination was made in October 1918, at the end of the first growing-season after cutting.

Over the greater part of the lot pine reproduction was lacking or very sparse, but on small scattered areas, chiefly in moist depressions where a group of hardwoods (from among which the pine had been removed) are now standing, there is a reproduction varying on different patches from 1000 to 5000 seedlings per acre. Nearly all were four-year-olds

were / was /

(crop of 1914), small and stunted. For the first three years they grew under the mature timber. In all probability many seedlings were destroyed in the logging. The heavy pine slash covered 50 percent of the area.

If there had been a good crop of seed in 1917, there should have been a good reproduction of one-year-old seedlings, but only four or five were discovered on the whole lot.

Lot No. 52.- A small, roughly oblong area on elevated but nearly level ground. A small swamp bounds the lot on the west while stands of immature pine surround it on all other sides. The former stand was a densely stocked stand of pure pine 50-60 years old, except in one corner where there was a group of mixed pine and hardwoods. This was in a depression bordering the swamp and the conditions approached those of a maple swale. One large, over-mature chestnut occurred in this group. This lot was also cut over in the winter of 1917-18 and examined the following November.

Pine reproduction was lacking or very sparse over all the area except that on which the mixed stand had occurred and from which the hardwoods had not been removed. Here there was an excellent reproduction of 1914 seedlings averaging 1500-2000 per acre, not large for their age but fairly thrifty.

As on Lot Number 50 — cut over in the same year — scarcely any seedlings from the seed-crop of 1917 were found. It may here be stated that no 1917 seedlings were found on the four lots cut over in 1917-18 (Lots 49, 51, 53, 54) on which the reproduction was negligible. This certainly warrants the conclusion (unless it shall be disproved by the evidence of future years) that the seed crop of 1917, known at the time of maturing to be very light, has been a total failure in restocking the areas cut over in that year. It has not, therefore, been ~~regar~~ classed as a seed year and the lots cut over in 1917-18 have not been printed in red in Table VII. It marks a break in the succession of three year periods that have been known to occur

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A survey of these eleven woodlots cut over in non-seed years but on which more or less reproduction has become established, appears to warrant the following conclusions:

(1) That clear-cut areas may be fully restocked by side-seeding if they are not too large for an abundance of seed to reach every part of the clearing and if a sufficient number of seed trees are left on the borders.

(2) That under fully stocked stands of pure pine little or no reproduction will survive for more than two or three years (provided it germinates at all), but under more open mixed stands, especially where the soil is fresh to moist even in dry weather, a good reproduction may come in and survive for a number of years. The growth of the seedlings will be slow, however, and if the overwood be not removed they will finally succumb.

Woodlots Cut Over in Seed Years.

As the large majority of these lots were uniformly well stocked, it is unnecessary to describe each one in detail, but several of them present features of special ~~detail~~ interest which will be pointed out. It will be noticed that Lots 3 and 4 (see Table VII) have each been divided into two sections (A and B), one section of each having been cut in a seed year and the other in a non-seed year (consecutive years in both cases). The sections cut in non-seed years may logically be classed with the lots in that group but are considered here along with the sections cut in seed years because of the emphatic contrast which they present.

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Lots 1 and 2, which had been covered ~~with practically pure stands of~~ with fully-stocked stands of practically pure pine 40 to 50 years of age, had been cut over in 1905-6. When examined in November, 1918, they were each found to be well-stocked over the whole area with a stand of small pine saplings 13 years old. They undoubtedly came from the seed crop of 1905. That the

reproduction on these two lots, altho sufficient to produce a complete stocking, was not so dense as on most the lots cut in later seed years, is doubtless due to the dense and vigorous growth of hardwood sprouts on both lots, which is already suppressing the pine reproduction and has probably caused the death of large numbers of seedlings. Nevertheless the young pines when examined were not so badly suppressed but that most of them, it is believed, would recover if soon released by a thoro weeding.

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Lot 3 was a large lot situated on level to rolling land in a small valley between two low ridges. The timber consisted of good sized pine with considerable hardwoods (White Oak, Red Maple and Chestnut) in mixture. The logging operations were begun in the spring of 1906 and finished in the spring or early summer of 1907. Only that portion (Section A) which was cut in the spring and early summer of 1906 could be considered as being cut over in a seed year. For the most part Section A lies on the west side of a small brook that runs thru the lot

year (1906-7) lies on the west side. On Section A a fair to excellent reproduction (600-1000 per acre) of saplings from the crop of 1905 were well dispersed over the area. On Section B the reproduction was sparse or, over the greater portion, negligible (100-.)

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In the next seed year, that of 1908-9, we have a similar illustration on Lot 4, but in this case the first portion cut over (Section A) was cut in the year previous to the seeding.

This lot, one of the largest examined, comprises some 400 acres. By far the larger part lies on a long, moderately steep west slope; a smaller detached area, situated on nearly level land stretching west from the foot of the slope, occupies a triangular piece of ground between the forks of two roads. The timber on both portions of the tract formed a fully-stocked, practically pure pine stand 50-60 years old. The hillside portion of the tract (Section A) was cut over between October 1907 and October 1908 (before the seed year 1908); the triangular piece (Section B) was cut

January (in a seed year). Over the whole of Section A the pine reproduction was negligible; over the whole of Section B there was a magnificent reproduction of over 2000 seedlings per acre, from the crop of 1908. The even distribution and complete stocking of the whole area was characteristic of all the lots cut over in seed years.

Lot 37 is recorded in Table VII as having been cut in the seed year 1914-15. As a matter of fact it was cut and logged between June and August, inclusive, of 1915. As the germination of pine seed in this region normally takes place in June, any cutting done after that month cannot properly be said to be done in a seed year. The lot in question lies on a gentle to moderately steep west slope, extending from the broad, rounded summit of the ridge down to the bottom of the narrow valley. In general the lower part of the lot was the first to be cut over, while most of the timber from the upper portion was not removed until after the middle of July. On the

a fair to good reproduction of 500 to 1000 seedlings per acre (much denser in patches) of 1914 seedlings, while on the upper slope the reproduction was either very sparse or entirely lacking. This lot evidently furnishes an example of what may be expected from the seeding when cut over at the very end of a seed year. The resulting reproduction cannot be expected to be as full or evenly distributed as on lots cut over between the fall and spring, inclusive, of the seed year. All the lots in this group were cut within that period except where otherwise noted.

five Each of the other (5) lots cut over in 1914-15 had been completely restocked with a growth of thrifty 1914 seedlings, the reproduction being dense on all except number 39. (See Table VII).

On only two of the lots cut over in seed years was the regeneration a failure, and that was on the two examined that were cut in 1911-12. It is known that the seed crop of 1911 was much lighter than those of 1908 and 1914 [illegible]

forest that lie within a mile of one of these lots (Lot no. 20), a good reproduction of 1911 seedlings was obtained where thinnings were made in that year. A different but probable explanation for the failure on each woodlot is here given, but in view of the fact that information concerning the conditions on these lots during the first few years after felling is entirely lacking, these explanations are avowedly hypothetical and are set forth simply with the hope that further and closer research may be undertaken that will shed more light upon the problem of White Pine regeneration.

Lot 19 covered about 30 acres on a gentle easterly slope. The soil was a fairly deep sandy loam, the site was quality II. The lot was cut over in the winter and spring of 1912, and when examined in October 1916 the ground cover consisted, as usual, of grass, fern, and low herbaceous vegetation. The slash covered about 25 per cent of the area.

The former stand was composed of

rapidly up to the time they were felled, with a few larger and older trees scattered among them, and also patches of young pine in the supling or small pole stage. The great majority of the low-cut stumps exhibited between 30 and 40 annual rings of growth. The reproduction was practically nil over the lot except for a few small patches on which the seedlings would average 200-300 per acre.

The natural explanation for the failure on this lot is, that even in a seed year a stand of this age cannot be expected to produce much, if any, fertile seed. The accumulated experience of many observers confirms the general belief that under forty years of age White Pine will bear very little seed and that will be of low fertility. This is especially true of second growth pine coming up in dense, even aged stands. The few patches of seedlings that were observed on the lot appear to confirm this theory, as in every case one or two stumps of the larger, older trees

of each patch. These were evidently the parent trees from which the seed had come.

But this explanation will not answer for the failure of regeneration on Lot 20. This is a small lot on high but level ground, on which the timber, like that on the majority of woodlots examined, formed a fully-stocked stand of pine 50 to 60 years old with a scattering of hardwoods in mixture. The trees were of large size and must have been good seeders.

On this area practically no reproduction was found when examined in November 1918. Scattering seedlings from the crop of 1914 had evidently seeded in from trees standing on the border. A very few seedlings from the crop of 1911 were discovered, but the fact that any seedlings of that age were found on the tract is strong evidence that there had been a general seeding in that year. If a good reproduction had appeared from the crop of 1911, its disappearance within seven years from the

accounted for.

With our present knowledge of the prevalence and work of the Hylobius beetle, the explanation appears to be at hand. This small lot is adjacent on the south to Lot 40, which was cut over three years later (1914-15) The beetles breeding in the freshly-cut stumps and slash of that lot in 1915 would find in the seedlings on Lot 20, then in their fourth growing season, young pine of exactly the age which they appear to feed upon with greatest avidity, and for the following year or two their depredations would be continued. This explanation is certainly sufficient to account for the disappearance of the seedlings, provided the area was actually restocked. While that appears to be highly probable there are no data to substantiate the ~~fact~~ hypothesis.

But one other explanation, for which there are adequate and exact data, is sufficient to explain the absence of pine reproduction not only on the two woodlots examined but on others in this region if further research reveals the fact that

1911-12 was a failure generally. This explanation is found in the weather conditions that prevailed during the growing seasons of 1912 and 1913. The Climatological Report of the United States Weather Bureau for the New England section states that for 1912 the spring rainfall was the greatest since 1901 and completely filled the ~~ponds~~ springs, ponds and streams. But the precipitation for the month of June (0.93 of an inch) was 2.18 inches below the normal and the least of any June in the record extending back to 1888, inclusive. In fact for central New England the amount was slightly less than one-half inch. This drought continued to the middle of July. Not only was June an extremely dry month but the average temperature was below the normal. Cool nights prevailed and considerable damage was done by frost to vegetables and cranberries in some localities.

When it is remembered that June is the month in which the greatest amount of pine seed normally germinates, and that for at least a month after germination

moisture, the inimical conditions of this season are manifest. On recently cutover woodlots there is usually a layer of pine needles 2 to 3 inches thick. The young seedling, germinating upon or near the surface of this layer, must penetrate the duff before it can establish its roots in mineral soil. The layer of pine needles quickly dries out and unless the new-born seedling is supplied with an abundance of moisture during this critical period, it will wither and die. The very wet but normally warm spring, (April and May) would tend to hasten the germination period, so that most of the seed had, in all probability, either germinated or was on the point of germinating when the drought of June began. For a month of exceptionally dry weather to have followed this germination period would naturally result in the death of practically the entire crop ~~— at least~~ on cleared lands, at least. On small cleared strip or group cuttings, or under thinned stands, the results might not have been so disastrous, as in fact they were not on some

of the cuttings of that nature on the Harvard Forest.

In addition it should be noted that during the following summer (1913) one of the severest droughts on record occurred in central New England, causing great injury to vegetation and growing crops. As stated in the Climatological Report for that year: "In some localities in north-central Massachusetts the rainfall for June and July was stated to have been the least for nearly 50 years." Two successive seasons like these following a seed year would naturally effect the complete or well-nigh complete destruction of the young pine reproduction, especially on cleared land.

In this connection it is interesting to compare the first growing season of each of the other seed years of which we have record, and a survey of which furnishes confirmatory evidence, tho of a negative character, in support of the foregoing explanation. The seasons of 1906 and 1909 were both normally moist, the rainfall being abundant during the first part of the growing season.

 A casual reading of the Weather Bureau's

report for 1915 may appear to indicate a season fully as unfavorable as that of 1912. But a closer study of the record will show that the factors vitally affecting the germination and subsequent growth of the new seedling are quite different. The general summary of the report for that year reads in part as follows:

Quotation in smaller type.

> The marked feature of the year was the abnormal distribution of precipitation during the growing season, the spring being the driest and the summer the wettest in the record of the section extending back to 1888. The average rainfall for March, 0.21 inch, was without doubt one of the smallest, if not the smallest, of record for any calender month in this section. The rainfall continued below the normal during April, May and June, the average for the four months, March to June, inclusive, being only 6.75 inches, which was 6.88 inches below the normal amount for this period. Owing, however, to the moderately cool temperatures that prevailed and the absence of drying winds, the drought was not as injurious as it

Quotation continued

would otherwise have been. During July and August the precipitation was much above the normal, and rain fell nearly every day in some portion of the section. The average for the section for the two months was 13.10 inches, which was 5.69 inches above the normal. The fall months were unusually pleasant, being warmer than usual, with less than the average amount of rainfall. .... Killing frosts [in October] occurred later than usual.

In this case the abnormally and consistently dry and cool spring season, including June, would retard the germination period till July, when the copious rains of that month and August would give the seedlings all the moisture they required during their critical period, and the unusually long, warm autumn would permit them to develop and become lignified before they could be affected by severe frosts and cold weather.

Comparing these two groups as a whole

the difference in the restocking of the woodlots cut over in seed years and in non-seed years is indeed most striking. Including the sections of Lots 3 and 4 that were cut in non-seed years, 31 out of 42 such lots examined, or 74 per cent, showed a total failure. Of the other 11 lots, the reproduction on 10 was sparse or partial and very unsatisfactory. Only on the small strip cutting, Lot 32, was there a complete restocking. On the other hand, 12 of the 14 lots cut over in seed years, or 86 per cent, showed a complete reproduction, and the failure on the 2 lots cut over in 1911-12 is undoubtedly due to the adverse weather conditions of the first two growing seasons, even if there were no other contributing causes.

When a woodlot is cut over in a seed year, the disturbance of the soil by logging, especially when logged on bare ground or when the snow is not too deep, creates a favorable seed bed at exactly the time it is needed. The accidental coincidence of these two factors practically insures — under otherwise favorable conditions — a complete re-generation of the area. Under ordinary

methods of logging – where no thought is given to future growth – it is only when the cutting is done in seed years that the combination of these two essential conditions is obtained.

Conclusions

A close study of the data in addition to a general survey of the results obtained in this investigation, both on the cutover areas in the Harvard Forest and on the cutover woodlots, is believed to justify the following general conclusions regarding the natural regeneration of White Pine in central New England.

(1). The regeneration of cutover pine land is extremely unsatisfactory. On land cut over in the last ten to fifteen years reproduction is scanty or entirely lacking, except where the cutting has been done under some degree of silvicultural practice.

(2) The only general exception to the

pine lots that have been cut off between the fall and spring, inclusive, following a seed year. On such lots a good reproduction is almost invariably found.

(3) If regeneration is not effected within a few years after cutting (generally less than ten) it is not likely to take place at all, because the quick, rank growth of grass, herbaceous vegetation and of hardwood sprouts will prevent or choke out the pine reproduction. This is especially true on loamy soils; less true on sandy soils or very dry sites.

(4) The age of the stand undoubtedly affects the abundance and viability of the seed, but stands of pine in New England that are large enough to be cut are ordinarily of sufficient age to produce good crops of seed. If, however, they have grown in a densely crowded stand and have small, poorly developed crowns, they may for that reason produce little or no seed even in a good seed year. The

average age of second-growth stands when cut in central New England is around 50 to 60 years. Stands younger than 40 years are not likely to produce much seed nor seed of high fertility.

(5) There is no evidence that in this region White Pine seed stored in the ~~ground~~ duff or leaf litter will retain its vitability more than a year, under the uncut stand.

, or two growing seasons at the most,

(6) Under the cover of dense pine stands reproduction is seldom found. Under mature pine of medium density, or under mixed pine and hardwoods, an abundant reproduction may follow a seed year, but the seedlings will not thrive and will generally die within a few years except on quite moist sites. On moist situations they may live for a number of years and be able to recover and grow vigorously after the overwood has been removed.

(7). If dense stands are thinned, even

lightly, an abundant reproduction is apt to follow the first seed year after thinning, but it will remain stunted and may be counted upon to die out within six years – often within four – if the overwood be not removed. In order to assure the survival of such reproduction the overwood should be removed at the end of the ~~first or~~ second or third growing season. If a heavy thinning, or partial clearance, is first made – leaving an open shelterwood – an early removal cutting is not so urgent, but no advantage is gained by letting the reproduction remain under the shelterwood more than two or three growing seasons.

(8) On the great majority of woodlots for a number of years after cutting, the slash – lying in windrows – covers from 30 to 50 percent of the area, almost wholly preventing any regeneration beneath it. To obtain a complete restocking of the tract the slash must be burned. If burned in winter or early spring, when the ground is covered with snow or still saturated

with water, very little if any damage to the soil will result.

(9) The forest floor very rarely offers, either before or after the cutting of a pine lot, a favorable bed for the germination of the seed or for the growth of seedlings. If cut off in a seed year, after the seed has fallen and before it germinates, and especially if logged on bare ground, the disturbance of the soil will put the seed bed into good condition. If the stand is not logged in a seed year, the growth of grass, weeds and herbaceous vegetation will obliterate the beneficial effects of logging before the arrival of another seed year.

(10) A weevil (Hylobius pales) occurs in great numbers throughout this region and on newly cut-over pine lands, where it breeds in the stumps and slash, it girdles and kills the young seedlings by eating the bark, and is now known to be a serious menace to the reproduction of White Pine in New England. No methods of control have as yet been tried.

Summarily:— The two essential conditions for the satisfactory regeneration of White Pine are, (1) an abundance of seed evenly distributed over the regeneration-area and (2) the seed bed in a proper state of receptivity at the time or immediately after the distribution of the seed.

The first condition must be provided by making the felling or fellings so that a sufficient number of trees for seeding the area will be standing when a seed year arrives. The seed bed must then be put into proper condition by thoroly stirring up the soil and mixing it with the duff and leaf litter. This can usually be done most easily and cheaply by roughly harrowing up the ground with a wide forest harrow. If the stand be cut and logged "in a seed year" (between the fall and spring, inclusive, following the fall of the seed) the harrowing may not be necessary.

Table VII

[May be inserted anywhere in Section 2 of Part II]

Part III

Methods of Silvicultural Treatment indicated by the Investigation.

The ultimate purpose of this investigation, as stated in the Introduction, was to determine the most effective and practical methods of regenerating the cut-over pine lands of this region. The whole history of the region shows that unless such lands be restocked within a few years after cutting, they will almost invariably reproduce nothing but "brush", or a stand of inferior hardwoods that at best will make only cordwood in about the same time that another valuable stand of White Pine could be reproduced if properly regenerated and tended. The land may be restocked by planting, but that involves a cash outlay which will, especially with high cost of labor, so far reduce the profits from the cutting as to render it prohibitive in probably a great majority of cases. If simple but effective methods of securing natural regeneration can be devised, involving but little extra expense over the ordinary methods of logging, it can easily be demon-

such methods. A critical survey of the problem, however, in the light of the results obtained from the investigation, clearly indicates that methods which may be successfully practiced from the financial standpoint upon large tracts of land, cannot be practiced with profit on small isolated ~~woodlots~~ woodlots. This naturally divides the subject of the treatment of these pine lands into two sections, the one dealing with large tracts and the other with small lots. But just where the line of demarkation between large and small tracts is to be drawn is not so easy to determine as it at first appears. The mere acreage is by no means an infallible index of the kind of management that will be most profitable for a certain tract. A great deal depends upon situation, propinity to market and the objects of the owner in handling his property. A method of treatment prescribed for large tracts may often be practiced with profit on a medium-sized woodlot, — at least

while from that of another the same treatment would not be regarded as profitable. But in general, considering the financial returns that may reasonably be expected from the average pine lands of this region, and considering also the nature of the ownership — that the larger tracts are generally and will more and more be owned by the wood-working industries of the region and will be managed with the object of furnishing the raw material to these industries — we may say that tracts of more than 500 acres may be treated as "large" tracts under our classification. Some might put the dividing line as low as 300 acres, and without doubt there are many tracts of between 300 and 500 acres that may profitably be accorded a method of treatment prescribed for large tracts. The essential difference is that by "large" tracts is here meant those that are of sufficient size to be handled profitably on a sustained-yield basis. Small lots cannot be expected ordinarily to be handled for a continuous supply of timber; but if the land is better

fitted for growing timber than for any other use, they should, from the purely economic standpoint, be regenerated when cut over in order to grow another crop of timber as soon as possible. Or may frequently be the case that a "large tract" on which systematic forest management may profitably be practiced, may in reality be composed of a number of small ~~separate~~ non-adjacent lots, but all situated in the same general locality so that the property could be managed in the same manner as one compact tract of the same size as the aggregate acreage of the separate lots. The methods prescribed for large tracts would ofcourse apply to such a property. These methods will first be considered.

Section 1. The Treatment of Large Tracts that are to be Managed for Annual or Frequent Periodic Yield.

The results of the investigation indicate two or three methods of treat-

be both practicable and reasonably certain of securing a prompt and complete re-stocking of the cutover area. Which method to adopt for any particular tract may depend upon the composition or condition of the original stand, the nature of the logging, or upon other circumstances. These methods are, as they must be, nothing more than special adaptations of certain broad and fundamental principles of forest management known as "Silvicultural Systems". But simply to say that a certain silvicultural system is adapted to the management of second-growth White Pine comes far short of giving the specific information that is absolutely necessary for the intelligent handling of pine woodlands. Such information can be gained only thru experimental practice and the careful investigation of all the factors affecting the reproduction of the species. On the other hand, the methods as here outlined are by no means intended as a detailed set of rules to be explicitly followed on any and every tract. Various modifications will

almost always be necessary and special plans of operation must be made for every tract.

The Removal of the Mature Stand in Two Cuttings: an Adaptation of the Shelterwood System.

We have seen that if a stand of mature pine be cut off in a seed year, an excellent reproduction is likely to replace it at once. But as good crops of seed are produced only at intervals of three or more years, it is obviously impossible to defer all cutting till a seed year. On the other hand but few seedlings ever appear beneath the dense, even-aged, second-growth stands of White Pine. These few are never vigorous and disappear within a few years. Therefore, if the timber is cut in a non-seed year, some trees must be left to provide the seed when the next seed-year arrives, if the area is to be restocked by natural seeding.

One method that has frequently been advocated is known as the seed tree

clean except that a few trees, usually not more than 6 or 8 per acre, are left scattered over the area to furnish seed. In the second-growth pine stands of New England this method is generally doomed to failure, chiefly because the trees in these stands are not windfirm and when exposed by the removal of their neighbors, are almost certain to blow down within a short time. In rather open or somewhat irregular and uneven-aged stands, and also often in mixed stands of pine and hardwoods, some large, heavy-crowned pines which are sufficiently windfirm may be found, but the number and distribution will generally not be such as to insure a full stocking of the cutover ~~area~~ land. In the best stands of second-growth pine - the fully-stocked, even-aged stands - few if any such trees will be found. The seed-tree method cannot, therefore, generally be recommended for the regenerating of pine tracts.

The method here proposed is essentially that described in Part II for the four areas on the Harvard Forest that were cut clean after a previous thinning. The first cutting may

properly be called the seed-cutting; the second is the final or removal cutting.

The degree of severity is the first question to consider in making the seed-cutting. On mixed stands ranging up to 50 per cent hardwood, all or nearly all the hardwood timber should be cut, and if the pine forms not over 50 to 60 per cent of the stand, but very little if any of that species. On dense stands of pure pine the first cutting should not remove more than 40 to 50 per cent of the total number of trees. In addition no trees should be cut on a strip 1 to 2 rods wide on the windward borders of the area. If there is considerable slash it should be piled and burned, but if the tops and branches can be utilized for cordwood, the amount of slash remaining can usually be disregarded. Then, until the removal cutting is made, there should, as a rule, be no cutting on contiguous areas, but each annual cut should be located in a different section of the tract. This partial clearance naturally tends to increase the amount of seed produced in subsequent seed years over what it will be in dense

unthinned stands.

The further treatment of the area would depend on the decision whether or not to make the final cutting in a seed year (usually but not necessarily the first seed year following the seed cutting). If the seed crop is a good one it can be relied upon to restock the area, especially when the logging in that year will prepare a favorable seed bed. But often it will be impracticable or even impossible to make the removal cutting in a seed year. In that case the ground during the autumn of the seed year (October and November) should be scratched up or roughly harrowed in order to expose the mineral soil.

No implements especially designed for this purpose have as yet been thoroly tested. One design that is recommended is that of a small A-shaped harrow with stout teeth about 6 inches long and pointing backward. The backward slant of the teeth will prevent them from catching on roots, rocks and other obstacles. It would not be necessary to harrow the entire surface as is done in agriculture. Running the

slightly
would

harrow over the area in roughly parallel strips 6 to 8 feet apart would be sufficient.

On steep hillsides and some very rough ground the harrow could not be used. Here the ground could be dug up in "seed spots" about 2 feet square and 6 to 8 feet apart, made with a grub-hoe or a very heavy rake. A seven-pound rake designed for the purpose has been used in making seed-spots for artificial seeding on some of the National Forests in the West. Altho a good reproduction may often come in under the shelterwood after a seed-year without any working of the soil, an abundant reproduction will almost absolutely be assured, even in a comparatively light seed-year, by such preparation. The longer the interval between the seed-cutting and the following seed-year the more necessary such working of the soil will be.

The removal cutting should be made within 3 or 4 years after the area has been successfully restocked. If the logging is done on fairly deep snow only a comparatively few seedlings

will be destroyed or injured.

In the continuous management of a tract of timber by this system, the question naturally arises as to the average size of the area that could be cut over each year perpetually. For clear-cutting methods the rule is that the annual cutting-area equals the total area of the tract divided by the number of years in the rotation. For example, on a tract of 600 acres managed on a 60-year rotation, the area that could be cleared every year would be 10 acres. But in this method an equal area may be partially cleared during the same year that the removal cutting is made on another area. During the first few years under systematic management most of the cuttings would be seed cuttings, or partial clearances, made on non-adjacent areas of the tract. After the first seed year, however, a removal cutting could generally be made on a previously-thinned area while another seed-cutting would be made elsewhere. By a judicious distribution of the annual cutting-areas it could generally be brought about that the removal cutting and seed-cutting for each year could be made on adjacent areas.

This would usually permit the logging of the whole year's cut to one mill set, thus keeping the cost of operation at a minimum.

If it is planned to conduct only periodic instead of annual operations on a certain tract — making a cut, say, every five years — then five times the area allowed for the annual operation could be cut over each time.

The danger from the Hylobius beetle to which this method subjects the seedlings is now realized to be one of the most serious objections to it. The beetles do not appear to breed beneath the shade of partially cleared stands, but if the final cutting were made when the seedlings were 2 to 4 years old (as would usually be done) they would be exposed to the depredations of the beetle at exactly the age when it appears to work its greatest damage. Complete destruction of the reproduction would almost surely result. The only hope lies in finding a cheap and efficient remedy, or method of control. If the slash be thoroly burned up, the freshly-cut stumps furnish the only breeding-places for the beetles. The suggestion has been made that small

piles of slash might be burned over each stump, thus charring the bark and outer wood, which would probably render it unfit as a breeding-place. Another suggestion is to give each stump a thin coating of creosote, which might be applied either with a brush or a spraying apparatus. We believe that both these proposed methods are worth giving a thoro trial in order to determine their efficiency and cost of application.

The Cleared-Strip Method.

This method can also be recommended for the regeneration of White Pine, and on many tracts may have decided advantages over a method in which the mature stand is removed by partial clearances. As previously explained, the fellings are made in the form of narrow strips that are cut clean in one operation. It is generally held that the direction of the strips should be approximately at right angles to the direction of the prevailing winds at the time of seeding. On open and comparatively level land in

central New England this would mean to cut the strips in a north-and-south or northeast-southwest direction. But local topography will often affect the direction of prevailing winds. Other authorities contend that the strips should always be cut in an east-and-west direction in order to afford the greatest amount of protection from the direct ~~sunlight~~ rays of the sun. But this factor again will vary according to the topography and aspect. When we remember that in New England the wind-direction is almost constantly shifting, it may be said that if the strips are cut no wider than 5 or 6 rods (the effective distance for complete seeding) the seed will be abundantly dispersed over the whole strip regardless of its direction, and, unless conditions render it impracticable, the preferable cutting-direction will be that which will afford the greatest amount of side-shading.

All slash on the cut-over strips should be burned or otherwise disposed of in such a manner as to leave an uncovered seed bed. If not cut in a seed-year, the ground on the cleared strips should

be roughly harrowed or exposed in seed-spots in the fall of the first seed-year after cutting. Such treatment will practically assure an abundant seeding in one seed-year.

The size of the area to be cut clean in each annual operation is theoretically determined in the same way as for the previous system. (Total Area ÷ Rotation). To take the same example of a 600-acre tract managed on a 60-year rotation, there will be an annual cutting-area of 10 acres or 1600 square rods to be cleared in the form of strips. Fixing 5 rods as the desired width of strip, this would mean a total length of 320 rods, or one mile. The cutting does not have to be made, of course, in one continuous strip, but the strips for each year's operations can be laid out in the most convenient method for logging so as to make a total "strippage" of approximately 320 rods. In the first operations on any division of the tract, parallel strips should be cut not closer than 20 rods apart. After the entire strips have been fully restocked and the reproduction well established,

additional strips alongside the first may be cut and similarly restocked, and so on indefinitely. But with this method there is no need of cutting an adjacent strip within 3 or 4 years or within any definite period, for the seedlings enjoy full overhead light from the first and the side-shading they receive will be beneficial rather than detrimental.

It was remarked in Part II that the cleared-group method of cutting is usually impractical for commercial operations. But when cutting in strips, there will often be groups of especially heavy or large pine (or a group of pure pine among hardwoods) standing between the strips, which can conveniently be logged when one of the strips is cut. A combination of the strip and group methods may often be practiced to advantage.

Section 2. The Treatment of Small Woodlots.

Pine woodlots covering from less

than ten to more than 100 acres are thickly scattered over central New England. When a number of such lots in the same general vicinity are combined under one and the same ownership, systematic forest managment may, as previously pointed out, be practiced upon them. But upon small lots individually owned, managment for a continuous yield of timber cannot be expected to be practiced at a profit. These pine lots, it should be pointed out, must be distinguished from the "farm woodlot" of the Middle Atlantic and Central States, upon the managment of which much has been written. Such woodlots may occur in New England and may furnish the farmer with a continuous supply of wood to meet his needs, but they are usually hardwood lots or mixed stands in which hardwoods predominate, — the treatment of which is not considered in this bulletin. The pure, even-aged pine lots are usually cut clean in one operation and it will seldom if ever pay to cut them in any manner radically different. A lot of ten

acres or even less will produce enough timber for a profitable portable mill operation, but a lot of 100 acres could not produce a large enough annual cut, if managed on a sustained-yield basis, to make such managment profitable. If the land is not to be put to other uses after the timber is removed (and most of the lots are not and cannot profitably be put to other uses, even to grazing) they should be promptly restocked with pine upon the removal of the mature stand.

The most obvious and the easiest way in which this can be accomplished is to cut off the timber in a good seed year. The results of the investigation show that in all probability a cutting at that time will produce the desired restocking of the lot. The owner of a small woodlot does not usually have to sell it or cut the timber at any particular time and may, if he chooses, wait until a seed year arrives without incurring any inconvenience or pecuniary loss. What is chiefly needed is to impress

upon the owners of such lots the economic importance of restocking promptly their cut-over woodlands and then point out to them the advantage of cutting in a seed-year. The burning of the brush is the only measure that needs to be taken in addition to the regular logging operations.

But it will always be necessary to cut a great many pine lots in other than seed years. The problem of cutting these lots clean in one operation and at the same time providing means for restocking them by natural seeding when a seed year arrives, can be seen at once to be rather difficult. The seed-tree method would serve very well for such lots if a sufficient number of properly distributed, windfirm trees ~~could be~~ were available. The limitations of this method have already been touched upon. On many small lots, however, an adequate number of trees may be found that will very well answer the purpose. The economical feature of this method is that those specimens which make the best seed-trees are usually the

forest for lumber. The ideal seed tree is one with a stout trunk and large crown, or a tree that forks near the ground into several large limbs, known locally as "cabbage pine." Such trees are scarcely worth cutting for lumber but they are likely to be windfirm and they produce the most seed. If this method is adopted, the slash should be burned and the soil harrowed or otherwise stirred up and exposed during the autumn of the first seed year after cutting.

Under regular managment where the forest growth is tended from youth to maturity, it would not be difficult to give such treatment to even-aged stands of pine that a sufficient number of excellent seed trees could be left standing evenly distributed over the whole area when the stand should be felled. The individuals destined for seed trees would be selected early in the rotation. On a successfully-regenerated area the pine saplings would be so thick that a thinning would be required

probably by the twentieth year, if not before. At that time the owner or manager could go systematically over the stand and pick out at regular intervals dominant young trees to be trained up for the remainder of the rotation as predestined seed-trees. This could be accomplished by cutting away all other trees immediately surrounding them so as to give them more room than the other trees in the stand would ~~enjoy~~ have even after the thinning had been made. This would enable the selected trees to develop large, full crowns — much the same as tho they had grown in the open — and they would develop their root systems accordingly. In each subsequent thinning the space surrounding these trees could be enlarged if necessary, but they should be given no more space than was actually required to fulfil their purpose. To insure a complete reproduction the trees should stand not more than 4 to 5 rods apart, which would mean 6 to 10 trees per acre. In addition a row of trees should be selected from those standing on the extreme windward

side of the stand, which would insure complete seeding along that side of the lot.

At the end of the rotation the stand would be cut clean except for these seed trees. But these trees, altho heavy-crowned, would generally be far different specimens from the crooked, knurly trees or the "cabbage pines" that on the present wood-lots are selected for seed trees. If they could never be used they would represent a comparatively large investment in seeding that would be locked up in good timber. But they could stand and grow thru another rotation, by the end of which they would produce a considerable amount of large, valuable timber. Another set of seed-trees would be selected in the early part of each rotation, or one set could be left to grow thru several rotations. This method could be applied on large tracts as well as small lots.

But coming back to the pine lots as we find them today, there are many on which the seed-tree method, if tried,

is bound to result in total or partial failure. If such lots cannot be cut over in a seed year the only alternative is to turn from natural to artificial regeneration and plant up the lot with young stock. A number of forest nursing companies in New England are now engaged in raising pine and other forest-tree seedlings for commercial purposes, and will also do the planting if desired by the owner. Altho the cash outlay for planting will amount to more than when methods of natural regeneration are employed, there is today an abundance of direct evidence supported by reliable statistics which demonstrate that the planting up of these cutover lands is a safe and profitable investment.