Growth in Volume and Basal Area in a Loblolly Pine – Shortleaf Pine – Hardwood Stand in Southeastern Oklahoma

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INTRODUCTION

The following report deals with growth in a mixed pine-hardwood stand in McCurtain County, Oklahoma. The original project, inaugurated in the fall of 1945, had as its primary objective the determination of the effects of improvement cuttings on quantitative and qualitative yield of merchantable material as well as on the chances of successful reproduction.

Problem

Changes in the organization of the property on which the work was done caused certain phases of the original plan to be abandoned or modified. Since the revision of the plan in the fall of 1949, the principal aims of the study have been the determination of (1) the yield under various levels of stand density, (2) the effect of tree size on growth, with the ultimate aim of determining the lower limit of merchantability, and (3) the effect of density on reproduction.

Results of the study on the effect of density on reproduction, though included in this bulletin, proved to be inconclusive because of an extremely severe drought during the last three or four years of the study. The one good seed crop during the period of study occurred in 1952. Reproduction resulting from this crop failed to survive, so the study of reproduction was confined to the seedlings already present on the ground and at least partly established when the project was started.

Experimental Tract

The work was done on an 80-acre tract owned by the Herron Industries, Inc., and located one-half mile north of Bokhoma, Oklahoma. The tract is practically level with a few small areas of poorly drained pockets. Because of heavy soil and lack of outlet for water, these pockets are swampy, or at least wet, in years of normal precipitation. Drainage on the rest of the tract is adequate.

The site occupied by the stand varies from very poor to very good. Variation in drainage is the principal cause of variation in site quality.

Commercial species on the tract are shortleaf and loblolly pines. The shortleaf is more abundant at the north end of the stand and loblolly predominates in the south half of the tract. Pine is well distributed throughout the tract with the exception of a few small, poorly drained areas where one finds predominance of such hardwoods as willow oak, water oak, sweetgum, and, to a lesser degree, white oak, red oak, post oak, and hickory. Red oak, post oak, and hickory are the principal associates of pine on fair and good sites.

Though the stand varies widely in ages of trees, the overstory consists principally of pine varying in age by 10 to 15 years. The oldest pines are approximately 45 years old.

METHODS

Growth Plots

In 1946, eight plots were established on the north forty acres of the tract. Each plot, rectangular in shape and located more or less in the center of a five-acre subdivision, is one-half acre in size (1 ch. by 5 chs.). See Figure 1.

Nine additional plots were established in 1950 on the south forty acres, making a total of 17 plots. These plots, each one-fifth acre in size, are circular. (Also in Figure 1.)

The total area of the growth plots is eight and one-half acres, representing somewhat more than 10 percent of the stand area. The plots are typical of the entire tract insofar as they include sites of various qualities, from extremely poor, almost completely lacking in pine, to very good, with original stocking of over 10 M.f.b.m. per acre.

At the time the first eight growth plots were established, 16 milacre plots also were located and marked, with reproduction of each counted and recorded. These plots were lost through causes beyond control of the research workers, however, and new reproduction plots were established in January of 1949.

Each new reproduction plot on the north forty acres is the east one-fifth of its corresponding growth plot (the northeast and southeast corners of the reproduction plots also being the northeast

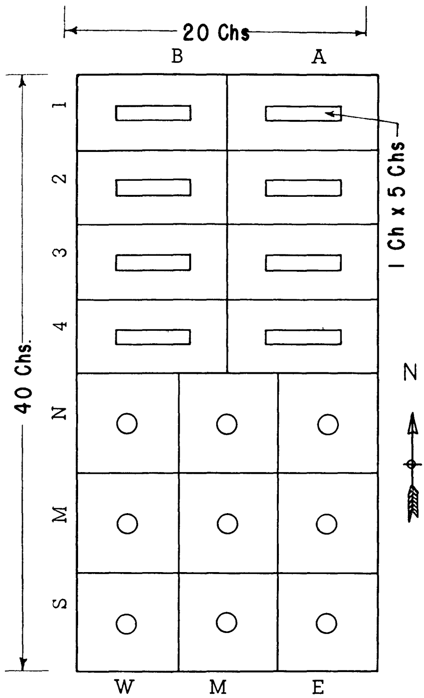


Fig. 1.—Growth Plots.

and southeast corners of the larger plots). Milacre reproduction subplots were located at the center of each circular growth plot on the south forty acres when they were established in 1950.

When the first eight plots were established, no record of individual trees was to be kept separately. Trees were tallied in a manner used in cruising, i.e., by species and size classes. Only a few pines, representing various sizes, were tagged.

By 1950, the number of tagged pine on each half-acre plot was increased, and every hardwood 3.6 inches d.b.h. and larger was marked and numbered with oil paint. On the nine newer plots every tree was numbered when the plots were established. During the next five

TABLE 1.—Cubic feet per acre in Pine trees 3.6″ d.b.h. and larger.

Plot	Original Stand	Stand After 1950 Cutting	Stand In 1956	Increment 1950-55	Ingrowth (No. of trees)	Total Yield (1950 cut + 1956 stand)
4B	1529	1325	1730	405	3	1,934
3A	1365	1158	1597	439	3	1,804
3B	1690	1549	2024	475	7	2,165
2B	1142	1017	1392	375	2	1,517
W/S	966	700	984	284	--	1,250
4A	1603	1336	1798	462	2	2,064
W/N	1860	1428	1947	519	--	2,379
1A	984	854	1304	450	2	1,434
M/M	1298	1074	1449	375	--	1,673
E/N	1026	240	327	87	--	1,113
E/S	1198	1001	1530	529	--	1,727
1B	632	548	846	298	5	930
M/N	990	336	438	102	--	1,092
2A	823	524	734	210	--	1,033
E/M	746	414	618	204	--	950
W/M	1005	407	615	208	--	1,213
M/S	283	47	72	25	--	308

TABLE 2.—Cubic feet per acre in Hardwood trees 3.6" d.b.h. and larger.

Plot	Original Stand	Stand After 1950 Cutting	Stand In 1956	Increment 1950-55	Ingrowth (No. of trees)
4B	901	877	985	108	10
3A	838	793	894	102	50
3B	353	291	443	152	20
2B	782	614	882	268	
W/S	1434	842	946	104	
4A	214	188	252	64	6
W/N	719	0	0	0	
1A	490	490	603	113	
M/M	812	147	172	25	
E/N	1160	778	935		
E/S	1223	0	0	0	
1B	354	354	443	89	16
M/N	720	358	526	168	
2A	977	152	248	96	50
E/M	862	121	155	34	
W/M	463	81	150	69	
M/S	981	255	380	125	18

TABLE 3.—Cubic feet per acre in all trees 3.6" d.b.h. and larger

Plot	Original Stand	Stand After 1950 Cutting	Stand In 1956	Increment 1950-55	Ingrowth (No. of trees)	Percent Growth 1950-55*	Total Yield (1950 cut + 1956 stand)
4B	2430	2202	2715	513	13	4.2	2,943
3A	2203	1951	2491	540	53	4.6	2,743
3B	2043	1840	2467	627	27	5.8	2,670
2B	1924	1631	2274	643	2	6.8	2,567
W/S	2400	1542	1930	388		4.6	2,788
4A	1817	1524	2050	526	8	6.1	2,343
W/N	2579	1428	1947	520		6.4	3,098
1A	1474	1344	1907	563	2	7.2	2,037
M/M	2110	1221	1621	400		5.8	2,510
E/N	2186	1018	1262	244		4.4	2,430
E/S	2421	1001	1530	529		8.8	2,950
1B	986	902	1289	387	21	7.0	1,373
M/N	1710	694	964	270		6.8	1,980
2A	1800	676	982	306	50	6.6	2,106
E/M	1608	535	773	238		7.6	1,846
W/M	1468	488	765	277		9.4	1,745
M/S	1264	302	452	150	18	7.5	1,414

* Exclusive of ingrowth.

TABLE 4.—Basal area per acre (square feet) in trees 3.6″ d.b.h. and larger.

Plot	Original Stand			Cut In 1950			Stand After 1950 Cutting			Stand In 1956		
	Pine	Hardwood	All	Pine	Hardwood	All	Pine	Hardwood	All	Pine	Hardwood	All
4B	73.368	38.614	111.982	13.514	0	13.514	59.854	38.614	98.468	79.022	42.288	121.310
3A	63.578	36.564	100.142	9.616	2.268	11.884	53.962	34.296	88.258	74.966	38.684	113.650
3B	76.658	14.594	91.252	8.688	0	8.688	67.970	14.954	82.924	85.566	18.956	104.522
2B	54.392	37.124	91.516	6.908	.840	7.748	47.484	36.284	83.768	62.270	36.894	99.164
W/S	43.600	64.145	107.745	8.610	26.150	34.760	34.990	37.995	72.985	44.225	42.540	86.765
4A	75.004	8.700	83.704	15.780	0	15.780	59.224	8.700	67.924	79.382	9.478	88.860
W/N	90.815	31.065	121.880	25.085	31.065	56.150	65.730	0	65.730	86.705	0	86.705
1A	46.068	21.062	67.130	7.594	1.460	9.054	38.474	19.602	58.076	58.552	31.554	90.106
M/M	60.320	36.480	96.800	10.325	30.075	40.400	49.995	6.405	56.400	64.905	7.250	72.155
E/N	47.280	49.645	96.925	34.880	17.245	52.125	12.400	32.400	44.800	16.165	39.515	55.680
E/S	55.400	52.020	107.420	9.708	52.020	61.728	45.692	0	45.692	67.104	0	67.104
1B	33.206	14.110	47.316	5.354	0	5.354	27.852	14.110	41.962	37.722	17.632	55.354
M/N	46.375	24.225	70.600	30.535	8.245	38.780	15.840	15.980	31.820	19.850	20.150	40.000
2A	38.994	41.340	80.334	14.664	32.418	47.032	24.330	8.922	33.252	32.626	10.028	42.654
E/M	37.015	37.485	74.500	15.460	32.115	47.575	21.555	5.370	26.925	29.630	6.705	36.335
W/M	46.920	32.025	78.945	27.075	29.030	56.105	19.845	2.995	22.840	28.490	6.630	35.120
M/S	12.785	33.335	46.120	10.575	22.155	32.730	2.210	11.180	13.400	3.300	16.755	20.055

TABLE 5.—Cubic feet per acre in Pine trees 4"—9" d.b.h.

Plot	1950 – 1951 Original	Residual	1955/1956	5 year Growth	Ingrowth	Total Net Increment
3B	362.4	258.8	103.2	−162.4	+ 6.8	−155.6
4A	427.3	266.6	199.3	− 69.0	+ 1.7	− 67.3
W/N	785.2	413.2	253.2	−160.0	0	−160.0
E/S	369.0	171.8	18.8	−153.0	0	−153.0
4B	457.8	342.0	365.9	+ 15.4	+ 8.5	+ 23.9
M/M	356.5	264.7	142.7	−122.0	0	−122.0
3A	441.2	393.4	315.8	− 87.8	+10.2	− 77.6
W/S	208.0	180.0	228.0	+ 48.0	0	+ 48.0
1A	184.4	123.4	163.30	− 61.8	+ 1.7	− 60.1
2B	440.4	368.6	190.3	−180.0	+ 1.7	−178.3
1B	185.6	150.0	139.9	− 15.2	+ 5.1	− 10.1
2A	306.7	175.6	153.2	− 22.4	0	− 22.4
E/M	337.2	181.2	237.0	+ 55.8	0	+ 55.8
M/N	309.0	141.5	127.5	− 14.0	0	− 14.0
W/M	223.0	214.5	138.0	− 76.5	0	− 76.5
E/N	229.0	180.5	166.2	− 14.2	0	− 14.2
M/S	47.0	47.0	0	− 47.0	0	− 47.0
Averages	333.5	227.8	173.1			− 60.6

years, the record was kept individually for each tree.

Plot Treatment

In the winter of 1950-51, cutting or girdling removed certain quantities of timber, leaving various levels of stocking on the 17 growth plots (Tables 1 through 7). The residual stands represent several rather typical conditions in regard to composition, density, and the general potential of the site. Plots W/S and M/S, and parts of 1B and 2B are normally "swampy" with heavy soil, extremely poor drainage, and a predominance (or high proportion) of hardwoods. Others represent better drained pine sites with pine forming as much as 82 to 88 percent of the original natural stand (Table 4).

To bring about various levels of stocking, some plots were treated conservatively, with only a small part of the merchantable pine volume removed and a heavy stand left. Some lightly treated plots were 3B, 4A, and W/N, with residual volumes of approximately 6.9, 5.7, and 5.3 M.f.b.m. per acre (Table 6).

On plots W/M and E/N, stocking was reduced to less than 1 M.f.b.m. per acre, and the board foot volume was reduced to zero on plot M/S. The residual stocking of the other plots varied between these extremes. Figures representing the original stocking and the residuals on the 17 plots are presented in Tables 1 through 6 in terms of board feet, cubic

TABLE 6.—Board foot volume per acre in Pine trees 10″ d.b.h. and larger.

Plot	1950 – 1951 Original	1950 – 1951 residual	1955-1956	Growth[1] 1950-55	Ingrowth 1950-55	Total[2] 5 year increment	Percent[1] growth	Rate of[2] increment (%)	Periodic annual growth	Periodic annual increment	Total Yield 50-55
3B	7276	6924	10,970	2796	1250	4046	7.0%	9.6%	359	409	11,322
4A	6530	5676	9,626	3850	100	3950	10.9%	11.1%	770	790	10,480
W/N	5575	5325	9,735	3035	1375	4410	9.4%	12.8%	607	882	9,985
E/S	4460	4460	9,056	3296	1300	4596	11.7%	15.3%	659	919	9,056
4B	5060	4262	8,078	3316	500	3816	12.1%	13.1%	663	763	8,876
M/M	4770	4175	7,050	1875	1000	2875	7.7%	11.0%	375	575	7,645
3A	4786	3960	7,130	1820	1350	3170	7.8%	12.5%	364	634	7,956
W/S	4610	3855	5,490	1135	500	1635	5.3%	7.3%	227	327	6,245
1A	3756	3654	6,060	2306	100	2406	10.3%	10.6%	461	481	6,162
2B	3850	3600	6,734	1584	1550	3134	7.6%	13.4%	317	627	6,984
1B	2574	2112	4,380	1566	702	2268	11.7%	15.7%	313	454	4,842
2A	2750	1940	2,694	254	500	754	2.5%	6.8%	51	151	3,504
E/M	2265	1255	2,470	840	375	1215	10.8%	14.5%	168	243	3,480
M/N	3815	1155	1,590	435	0	435	6.6%	6.6%	87	87	4,250
W/M	4165	875	2,535	785	875	1660	13.7%	22.8%	157	332	5,825
E/N	4725	250	630	255	375	630	15.2%	20.1%	51	75	5,105
M/S	1260	0	375	0	375	375			0	75	1,635
Avg.	4249	3146	5,565	1,558	719	2,434					

[1]of residual only
[2]growth and ingrowth

feet, and square feet of basal area.

From the standpoint of the growing potential of each plot, the cubic foot volumes are more reliable for comparing the plots than the board foot volumes. The latter completely disregard trees under 10 inches in diameter. The smaller trees might form a large part of the stand, however, and thus draw strongly on the productive capacity of the site.

Board foot volume, on the other hand representing the bulk of the merchantable material, more correctly reflects the value of the stand as a source of income and profit.

The 17 plots located on the experimental tract represent original stands containing from 986 to 2579 cubic feet in trees 3.6 inches d.b.h. and larger before the 1950-51 cutting. The significance of this "original" stand is as an indicator of the comparative quality of the site, and it also permits determination of the total yield of each acre (total of the original stand and the increment).

TABLE 7.—The effect of density on growth in cubic foot volume*

Group	Plot	1950-51 Stand		1955-56 Stand	Growth 1950-1955		Total 5 Year Yield
		Original	Residual				
		– c u b i c	f e e t –		(cu. ft.)	%**	cu. ft.
	4B	2430	2202	2715	513	4.3	2943
1	W/S	2400	1504	1930	388	5.1	2788
	W/N	2579	1428	1947	520	6.4	3098
	E/S	2421	1001	1530	529	8.8	2950
	3A	2203	1951	2491	487	5.0	2743
2	M/M	2110	1221	1621	400	5.8	2510
	E/N	2186	1018	1262	244	4.4	2430
	2B	1924	1631	2274	641	6.9	2567
3	3B	2043	1542	2467	600	9.8	2670
	4A	1817	1524	2050	518	6.1	2343
4	2A	1800	676	982	256	7.8	2106
	M/N	1710	694	964	270	6.8	1980
5	E/M	1608	535	773	238	7.6	1846
	1A	1474	1344	1907	561	7.2	2037
6	W/M	1468	488	765	277	9.4	1745
	M/S	1264	302	452	132	8.4	1414
7	1B	986	902	1289	366	7.4	1373

*all volumes are on the per acre basis
**at a compound rate

RESULTS

Effect of Density on Growth

The cut of 1950-51 reduced stocking on the 17 plots to volumes ranging from 302 cubic feet per acre on plot M/S to 2202 cubic feet per acre on plot 4B.

By 1955-56, the stocking had increased to 452 to 2715 cubic feet per acre. This was a five-year gain ranging from 150 to 643 cubic feet per acre. On nine of the plots, part of this gain was due to ingrowth. The largest ingrowth percentagewise was found on plot 2A, where it constituted approximately 16 percent of the total five-year gain in volume.

The five-year increments of pines and hardwoods were in approximately the same proportion as the percentages of the two groups in the stand following the cutting in 1950-51. The average pine residual in all plots was 66.6 percent of the total and its growth was 70.9 percent of the total. Corresponding figures for the hardwoods were 33.4 percent and 29.1 percent.

Cubic Foot Increment

The effect of density on the rate of growth generally followed the expected trend. Increment in terms of cubic foot volume was higher in denser stands and lower in stands of low density. A curve representing cubic foot growth follows generally the trend shown by the curve representing the density of the residual stand (Fig. 2). Similarity of the two curves is only general, however, as the growth curve shows considerable fluctuation in its general downward trend. The most pronounced fluctuations, in plots W/S and E/N, are due to exceptionally poor sites and predominance of scrubby hardwoods.

The largest growth, 641 cubic feet, was found on plot 2B, which ranked fourth in volume of the residual stand. Plot 2B had a residual stand of 1631 cubic feet.

The growth of the stand with the largest residual volume (4B, with 2202 cubic feet) was 500 cubic feet. This growth was exceeded by growth on seven other plots. On five of these plots, the difference was not significant, only from seven to 50 cubic feet per acre.

The two plots with more growth than 4B were 2B and 3B, which exceeded the growth of the residual stand (exclusive of ingrowth) of 4B by 28 and 20 percent respectively. Some variation in the quality of sites of the three plots might be in part responsible for this significant variation.

The more likely cause of the differences in total growth is the stand structure. Plot 4B contained 258 "measurable" stems per acre as compared with 204 on plot 2B and 172 on plot 3B. The basal area of the average tree was .381 square feet on plot 4B, .411 square feet on 2B, and .482 on 3B. The average five-year growth in d.b.h. of

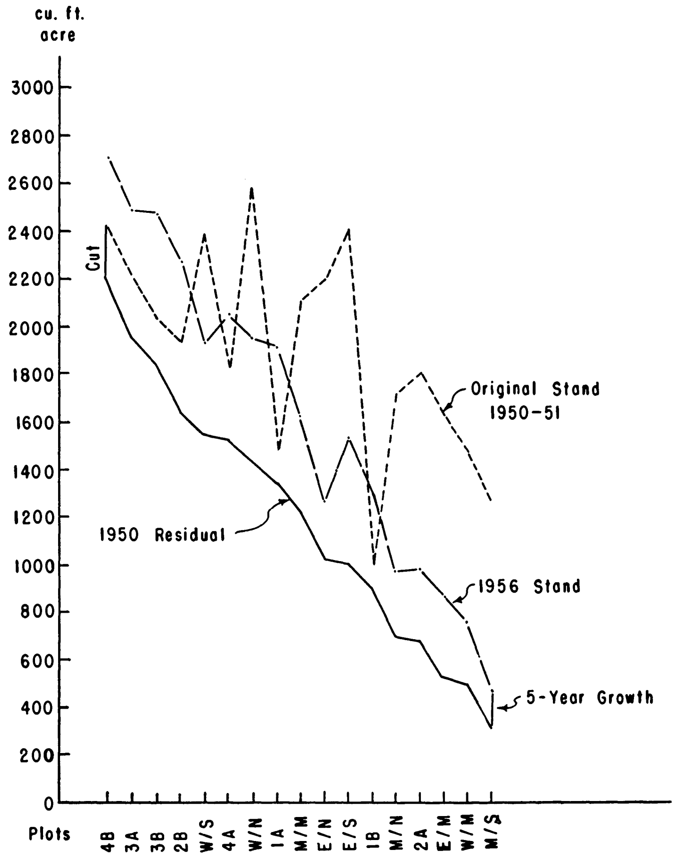


Fig. 2.—Relationship between growth and residual stocking.

trees 10 inches and larger on plots 4B, 3B, and 2B was 1.2, 1.4, and 1.5 inches respectively. In other words, plot 4B had more smaller trees than plots 3B and 2B, resulting in slower average growth in d.b.h. and, thus, smaller volume increment.

The relationship between the residual volume and the growth expressed as percent of the volume also shows a normal general trend. As in the case of growth in cubic foot volume, the trend is subject to fluctuations. In fact, deviations from the "normal" trend are quite similar in their location and magnitude for growth expressed in terms of cubic feet to those in terms of percent of the residual volume (Table 3).

Because of variations in site

quality, and in the resulting type and condition of stands on 17 plots, comparison of growth on the basis of density alone is not justifiable. Therefore, for the sake of comparison, the plots have been distributed into seven small groups (Table 7). All plots within each group are somewhat similar in the original composition and density, which are taken as indicators of the potential productivity of individual stands.

Plots W/N, 4B, W/S, and E/S in the first group represent the best sites on the tract, while the seventh group contains the two plots, 1 A and W/M, which happened to support the smallest original volumes. The original stocking within each group is approximately the same for all plots. The residuals vary, however, offering a basis for observing the effect of density on the rate of growth.

Within each group of comparable stands, the relationship between the volume of the residual stand and the growth is the same. The heavier the stocking, the higher the cubic foot increment; and the heavier the stocking, the lower the growth percent. The exception, plot E/N, was caused by the predominance of large hardwoods.

The last column in Table 7 contains the total five-year yields which are composed of the volume cut in 1950-51 plus the stand in 1956. Compared by groups, the total yields are reasonably alike for residual stands of high and low densities. The significance of this similarity in total yields might lie in the relative opportunity for reproduction following a good seed year. On the other hand, it might mean a danger of invasion of more open stands by undesirable hardwoods or other vegetation, should pine reproduction fail to appear soon after cutting.

From the standpoint of growth and total increment during the five years, the available data indicate that none of the 17 plots has been overstocked. That is, there is no evidence of a significant reduction in growth caused by high density.

Board Foot Increment

In terms of pine sawtimber, which constitutes the principal commercial product on the experimental tract, the situation is similar to that of the stand as a whole. With some exceptions, such as poorly drained land, the site is favorable for growing pine, both loblolly and shortleaf. Table 6 contains the summary of information on sawtimber in the same form as was reported in terms of cubic foot volume.

The original stand on the 17 plots in 1950-51 ranged from 1260 to 7267 board feet (International, ¼-inch kerf) per acre in pine 10 inches in d.b.h. and larger. From zero to 4475 board feet per acre was removed from various plots during the 1950-51 cutting. The averages in board feet per acre for the entire tract were: original stand, 4,249; cut, 1,103, and residual, 3,146.

Cutting of 1950 reduced pine volumes to levels varying from 250 to 6,924 board feet per acre. On plot M/S, every pine 10 inches d.b.h. and larger was removed, leaving only the hardwoods in the sawtimber-size trees.

By 1955-56, the various plots supported from 375 board feet to almost 11 M.f.b.m. per acre in sawtimber. The average for the tract was 5,565 board feet per acre. The five-year growth was closely correlated with the residual stocking on individual plots.

The largest growth in board feet volume was found on plot 4A, where the residual of 5,676 board feet per acre added 3,850 board feet in volume in five years, averaging 770 board feet per year. The average periodic annual growth for the tract was 312 board feet per acre. It is of interest that on four of the 17 plots, the periodic annual growth has been more than 500 board feet per acre, exclusive of ingrowth.

Ingrowth was heavy on some plots but light or completely lacking on others. This was due to the presence or absence of trees just below the sawlog size in 1950-51. The highest ingrowth in the five years was the 1550 board feet per acre on plot 2B, which had 28 trees of eight and nine inches d.b.h. per acre at the beginning of the growth period. During the five years all these trees attained sawtimber size.

The average ingrowth for the tract was 719 board feet per acre which added 144 board feet per acre each year to the total average increment. The highest annual total increment (growth and ingrowth) was 919 board feet per acre on plot E/S. The average annual increment for the entire tract was 487 board feet per acre.

Considering the few very poor sites, which added little to the volume of the residual stand, and the fact that the last three years of the growth period were unsually dry, the potential productivity of the tract appears to be very high. The average annual growth, exclusive of ingrowth, during the five-year period has been at the compound rate of 6.4 percent, and the total increment at the rate of 12.1 percent.

The existing data do not indicate the maximum stocking volume beyond which the annual growth will decline. Within the range of the levels of stocking found on the experimental tract, the five year growth in board feet increases with the increase of the residuals. A reduction of approximately 1 M.f.b.m. in the growth of the largest residual (the 6,924 board feet of plot 3B) as compared with the one next to largest (5,676 board feet on plot 4A) may or may not be significant.

Certain irregularity in correlation between the residual and growth is evident throughout the entire series of plots. Variation in the site quality, including degree of competition on the part of hardwoods, is probably responsible for lack of closer correlation. In this connection, it might be of interest that the plot with the largest pine residual also had a hardwood residual 55 percent larger than that on plot 4A.

The answer to the problem of optimum stocking can be obtained by following the relative rates of growth through several more years and noting a definite reduction in growth as the levels of stocking continue to rise above those found now.

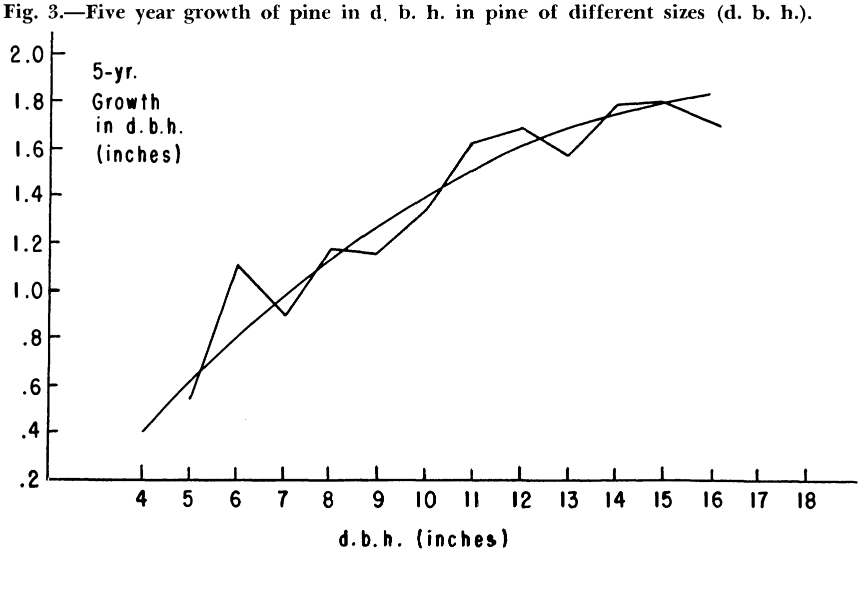
Percentagewise, the increment does not show a definite trend upward from the high to the low residuals. They do show a comparatively high rate of growth on practically all plots, however, again suggesting that optimum stocking has not yet been reached on any part of the tract.

Effect of Tree Size on Growth

In addition to the attempt to determine optimum stocking, the project included a study of the effect of tree size on growth, with the ultimate aim of determining the lower limit of merchantability. A total of 278 pine trees were tagged at the beginning of the study and their growth was recorded annually until the end of 1955.

Five-year growth of pine in d.b.h. shows a definite increase with the increase of d.b.h., from slightly over .5-inch in trees of five inches d.b.h. to 1.8-inches in 15- and 16-inch d.b.h. trees (Fig. 3). At the d.b.h. of 14 to 16 inches, the increase in d.b.h. growth begins to level off, suggesting that growth

Fig. 3.—Five year growth of pine in d. b. h. in pine of different sizes (d. b. h.).



of approximately 1.8 inches in five years would be the maximum attainable under the existing conditions even for the larger trees.

The average growth of pine sawtimber (d.b.h. of 10 to 16 inches) was from 1.4 to 1.8 inches in d.b.h., from .164 to .332 square feet in basal area per tree, and from 46 to 75 board feet in volume per tree. In terms of percent of merchantable volumes, trees 10 inches d.b.h. have increased by more than 90 percent, and those 16 inches d.b.h. by approximately 25 percent in the course of five years. This is an increase at a compound rate of growth of 13.8 percent and 5.9 percent respectively.

Whether the trees 16 inches in d.b.h. and larger, growing at an average of 5.9 percent annually, have reached financial maturity is a matter for the owner to decide. "Financial maturity" in its full technical meaning implies considerations of the monetary value of stumpage, costs of converting trees into usable products, and the value of such products. In this bulletin, the term is used simply to denote the lack of ability of a tree to continue increasing in volume at an attractive rate.

Even if the current rate of growth is considered attractive by the owner, it does not mean that all trees comprising the stand should necessarily be allowed to remain standing. Some trees are slow growers, others are of poor quality and getting poorer, and still others are located so that they interfere with growth of more desirable individuals. The reference to a possible failure of pine on the tract to reach financial maturity at this time was meant to show that the present rate of growth would not justify harvest cutting simply because a tree has reached the size of 16 inches in d.b.h.

TABLE 8.—Five year growth in d.b.h., resulting in volume growth (bd. ft.) at 3 compound rates of interest.

d.b.h.	at 4%	at 5%	at 6%
inches	(inches)		
10	.5	.6	.7
11	.6	.8	1.0
12	.8	1.0	1.2
13	1.0	1.2	1.5
14	1.1	1.3	1.6
15	1.2	1.4	1.7
16	1.3	1.5	1.8
17	1.4	1.6	1.9
18	1.5	1.8	2.1
19	1.6	1.9	2.3
20	1.8	2.1	2.5

Because the choice of the so-called alternative rate of return rests with the owner, no attempt is made here to fix the size of the financially mature trees on the experimental tract. Instead, the relationship between the size of trees and the rate of five-year d.b.h. growth for three levels of return is presented in Table 8.

Table 8 might serve as a rough guide in deciding whether to cut or to leave a tree, depending on what the owner considers to be an attractive return on his timber capital. For example, if six percent is accepted as the minimum desirable return, the five-year growth in d.b.h. in 16-inch trees must be at least 1.8 inches. On the other hand, if a four percent return is considered to be acceptable, the five-year growth in d.b.h. must fall below 1.31 inches before the tree growth in volume becomes unsatisfactory.

It must be re-emphasized that the existing rate of growth is not the only basis for the selective cutting, yet it plays an important part in the final decision on whether to cut or to leave a certain tree.

Reproduction

Quantity

A count of reproduction on 16 milacre plots in 1945 revealed an average of approximately 700 established pine seedlings per acre, ranging in height from two to 18 inches. This number is adequate for a reasonably well stocked uneven-aged stand. The distribution of reproduction was very uneven, however, with only seven out of 16 milacres containing pine seedlings.

A count of seedlings and saplings made in 1949-50 on eight 1/10-acre plots showed similarly wide variation in distribution of seedlings over the tract. In some instances, there were a few small areas on which young pine (two inches in height to 3.5 inches in d.b.h.) was found growing at a rate of more than 2,000 per acre, and in other instances, there were several areas on which no pine seedlings were found. The unevenness of distribution of reproduction was caused by a considerable variation in sites regarding feasibility of seedling establishment.

In addition to the pine seedlings in 1945, there also was very abundant hardwood reproduction, averaging 2,500 stems per acre. It consisted mainly of oaks with small quantities of sweet gum, elm, and hickory.

Ten of the 16 milacre plots recorded in 1945 were destroyed within one year of their establishment, and therefore lost for further study. The remaining six contained three pine seedlings in 1945 (two-, four-, and seven-inch), and nine in 1949-50, of which only two were alive.

Eight 1/10-acre plots were established on the experimental tract in 1949-50. Changes within these plots were noted and recorded through the rest of the study period. Changes in the number and size of the young pine during the six-year period are presented in Table 9.

The drought, combined in some cases with keen competition (see plot 4A, Table 9), took a heavy toll among the seedlings and saplings found in 1949-50. While 635 young pines per acre were counted on all plots in 1949-50, only 252 such trees were found in 1955. Of the 252, perhaps between 75 and 100 were estimated to be less than six years old, and therefore produced since the count of 1949-50.

TABLE 9.—Quantity and size of Pine reproduction in 1949 and 1955 on 1/10-acre plots.

Plot	1949						1955					
	2″ - 6″	7″ - 12″	13″ - 18″	2′ - 4′	5′ +	Totals	2″ - 6″	7″ - 12″	13″ - 18″	2′ - 4′	5′ +	Totals
	number					of		stems				
1A	1	0	1	0	0	2	0	0	0	0	0	0
1B	13	21	7	14	2	57	0	2	1	5	9	17
2A	11	11	1	9	5	37	1	3	0	8	11	23
2B	0	0	0	0	0	0	4	2	0	1	0	7
3A	50	20	11	6	1	88	2	0	0	5	1	8
3B	45	17	7	2	0	71	11	18	11	31	4	75
4A	70	53	33	40	49	245	4	14	8	24	21	71
4B	4	3	1	0	0	8	0	0	1	0	0	1
Avg. per acre	268	156	76	89	71	635	28	49	26	92	58	252

Only about 150 to 175 of the total of 635 seedlings and saplings present in 1949-50 were still alive in 1955.

The movement of pine from "reproduction" class to measurable trees (ingrowth) averaged only three trees per acre. Practically the entire reduction in total number of trees classified as reproduction should be attributed to mortality caused by drought and competition.

Comparison of average quantities of reproduction in several size classes in 1949 and 1955, shows that the loss, percentagewise, was greatest among the smallest seedlings. Loss of 240 seedlings out of a total of 268 in the two to six inch class was caused in small part by growth which moved the seedlings into the larger size classes. Most of the seedlings in the smallest size class, however, simply perished from drought.

Presence of a large number of well distributed seed trees suggests a strong possibility of adequate reproduction in the future, provided that two conditions are met.

One condition is the production of at least a fair crop of seed at reasonably short intervals. This condition has been met during the ten years of this study.

The second condition—the one lacking during this study—is the environment favorable to germination of seed and the establishment of seedlings. A good crop of first year seedlings was lost almost completely in 1952 because of drought and excessive heat. Even with this loss, the quantity of existing reproduction can still be considered satisfactory for maintaining good stocking in an uneven-aged stand such as is found on the experimental tract. A fair crop of seed within the next three or four years, plus reasonably favorable weather conditions, should further insure continuous supply of young pine and ingrowth of pine into the merchantable sizes.

Distribution

The reproduction problem in need of solution is distribution. Small areas devoid of reproduction are either covered with a thick layer of litter, preventing the seed from reaching mineral soil, or the low, poorly drained spots of heavy soils, which are either too wet or too dry and hard to provide a satisfactory seedbed.

Exposing mineral soil prior to seedfall would help markedly the areas now covered with a heavy layer of litter. This technique has proved successful in establishing reproduction in other regions.

The handling of low spots presents a much more difficult problem. Its solution may not prove economically feasible at this time. The cost of drainage ditches may not be justifiable for the small sizes of swampy areas found on the experimental tract.

SUMMARY

1. Changes in board foot and cubic foot volumes and in basal area were recorded during the period of five years in a pine—hardwood stand in McCurtain County, Oklahoma.

2. The original volumes on 17 growth plots in 1950 ranged from 986 to 2430 cubic feet per acre. After cutting in 1950-51, the volumes were reduced to 202 and 2202 cubic feet per acre. During the five-year period, 1950 to 1955, the gross increment ranged between 150 and 643 cubic feet per acre.

3. In terms of pine sawtimber (trees 10 inches d.b.h. and larger), the density of the residual stand varied from zero to 6.9 M.f.b.m. per acre, and the five-year increment from 375 to 4596 board feet per acre. The average residual volume in 1950 and the average periodic annual growth were 3,146 and 312 board feet per acre, respectively. The total average increment in pine sawtimber was at the compound rate of 12.1 percent.

4. Growth in cubic feet and board feet varied directly with the density of the stand. In terms of percent of the residual volume, growth varied inversely with the density, although differences in site quality brought about deviations from this general trend.

5. Judging by the continuous increase in growth in volume, with the increase in density, the maximum possible growth should be expected with density exceeding 98 square feet of basal area per acre, which was the largest residual at the beginning of the growth period in this study.

6. The rate of d.b.h. growth of sawtimber increased with the increase in d.b.h. of the trees. The average d.b.h. growth of 16-inch trees was 1.6 inches in five years. At this rate of d.b.h. growth, the 16-inch trees increased in volume (board feet) at the compound rate of six percent. The average compound rate of growth in volume in trees with 10-inch d.b.h. was 10.95 percent.

7. Pine reproduction, despite the presence of an average of some 250 small trees per acre, was not satisfactory in 1955. Only about 25 percent of the area was adequately stocked with reproduction. Barring continuation of the drought, however, even a fair crop of seed should insure abundant reproduction on at least 75 percent of the area.

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