THE LONGEST ACTIVE THINNED AND PRUNED LOBLOLLY PINE PERMANENT PLOTS: THE LAST MEASUREMENT

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Abstract—The longest active study of the effects of thinning and pruning on growth of loblolly pine (*Pinus taeda* L.) was established by Dr. James D. Burton in 1970 in a typical 12-year-old loblolly pine (plantation was 11 years old) stand planted by then the Georgia-Pacific Corporation in the southeastern corner of Arkansas. Basal area has been maintained at 30, 50, 70, and 90 square feet per acre by periodic thinnings. Within each level of basal area plots were pruned in two stages at 12 and 15 years, finally clearing the bole to heights of 33, 26, and 22 feet and reducing crown lengths to 25, 40, and 50 percent of the total tree height, respectively. Five control plots (without thinning or pruning) were installed at age 27. The 50-year remeasurement in the fall of 2007 will be the last since the study will be clearcut. Observed stand dynamics by thinning and pruning levels show that unthinned plots produced the maximum standing volume while moderate pruning did not substantially affect volume.

INTRODUCTION

Loblolly pine (*Pinus taeda* L.) has been one of the most widely planted tree species in the Southeastern United States, and its growth and yield has been extensively studied. Several long-term studies have been established across the Southeastern United States examining the yields of loblolly pine (e.g., Baldwin and others 2000, Sharma and others 2002). One of the longest continual studies was established in southeastern Arkansas and is referred to as the Monticello Thinning and Pruning Study. This study has been scheduled for termination and harvesting in the fall of 2008. Plot-level summary measures observed from this study beginning at seed age 12 (year 1970—plantation age 11 since 1-0 seedlings were planted) until the final inventory at seed age 50 (year 2007) are reported in this paper. All further references to age refer to seed age.

OBJECTIVES

This study was initialized to: (1) determine the optimal level of stand density to maximize stand productivity (intermediate and final harvest) and (2) determine the effect of pruning on long-term productivity and quality of wood.

METHODS

Study Site Description

The stand was established in the winter of 1958 to 1959 in a row-cropped old field at a spacing of 8 feet by 8 feet using 1-0 seedlings obtained from a State nursery located in Arkansas. Genetic stock was of a local seed source. Plots were originally established in 1970 when the trees were 12 years old. Four levels of thinning, three levels of pruning, and all their combinations were included in the study design. Each combination had three replications within a randomized complete block design. Four plots were also established for each of the 4 thinning treatments without pruning for a total of 40 plots. Each plot had a gross size of 132 by 132 feet and contained an inner plot 66 by 66 feet where all trees were individually numbered. Thus, the 0.1-acre measurement plot was surrounded by a similarly treated (including pruning) 0.3-acre buffer zone one-half chain wide. Site index (base age 25 years) was determined to be near 62 feet.

Thinning Treatments

Plots were initially thinned at age 12 to 40, 60, 80, and 100 square feet of basal area per acre. After the second inventory at age 15, basal areas were reduced to 30, 50, 70, and 90 square feet per acre. Plots were thinned again at ages 24, 27, 30, 35, and 40 to the same density levels (30, 50, 70, and 90 square feet). A natural reduction of growth rates observed after age 30 allowed for the use of a 5-year thinning period. Severely damaged plots 15 and 17 have not been thinned since the ice storm at age 16. Plot 4 recovered by age 35 and was thinned at age 40. After calculation of basal area for each measurement plot and its corresponding buffer area, trees were identified for removal to maintain the prescribed basal area. Trees were generally thinned from below. The following, somewhat overlapping criteria (in order of decreasing importance), was applied:

1. Inferior tree size (diameter and height)
2. Low increment
3. Poor stem form
4. Traces of insect infestation
5. Damaged stems (logging or lightning)
6. Damaged or lopsided crown
7. Uneven spatial distribution
8. Excessive cone production, an indicator of reduced increment

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Pruning Treatments

Only 12 numbered trees were pruned on each plot but 3 times as many trees were similarly treated on the surrounding buffer. These trees were pruned twice, at ages 12 and 15, to 25, 40, and 50 percent of total tree height.

Installation of Unthinned Control Plots

Originally, no unthinned plots were established. The need for such plots was later recognized, and at the age of 27 (in the summer of 1984) five control plots (without thinning or pruning) were established on the adjacent untreated part of the plantation. The size and arrangement of each plot was the same as that of the 40 original plots. To make growth comparable, hardwood competition was controlled on the plots by injecting Tordon® 101 R.

Ice Storm Modifications

A devastating ice storm hit the plots at a vulnerable age (16 years) and period (a year after thinning); see Bragg and others (2003). A salvage cut left three plots (4, 15, and 17) with basal areas below the intended densities. Plot 4 recovered in basal area at age 35; plots 15 and 17 recovered in basal area at age 43. Measurements included in the analyses for plot 4 were 12, 15, 16, 35, 36, 37, 40, 43, 45, 48, and 50; for plots 15 and 17 they were 12, 15, 16, 43, 45, 48, and 50. The two subsequent scheduled thinnings (at ages 18 and 21) were not conducted for any plot due to the reduction of density from the storm. Less severe ice storms occurred in 1979, 1994, and 2000.

Other Modifications

In 1986 the construction of a new road destroyed one of the control plots (after only one measurement—this observation was included in the analysis). This lost plot was replaced in 1986 and assigned the number 44. It was measured for the first time in 1987. Drought conditions during the spring and early summer of 1988 along with extremely high late summer temperatures placed many trees under severe stress. In August, three isolated areas of insect damage were located at the southeastern border of the study plots. An entomologist surveyed the area and found evidence suggesting the presence of southern pine beetles (*Dendroctonus frontalis* Zimmermann) and black turpentine beetles [*Dendroctonus terebrans* (Olivier)]. To control the infestation, 20 trees were cut just outside of the study area. Sixteen trees infested with turpentine beetles within the test plots were sprayed with Pestroy (9 ml/gallon of water). In 1997, six trees (including two damaged by lightning) had insect damage, possibly due to the southern pine beetle, and were salvaged. Prescribed burns were conducted in 1981, 1984, 1986, 1990, 1995, 2000, and the site was bush-hogged in 1972, 1986, 1987, 1997, 2002, and 2005 to reduce competition from hardwoods, shrubs, and herbaceous vegetation.

Remeasurement Procedures

Measurement methods and techniques have been maintained throughout the study to assure the compatibility of results from all inventories. The diameter of all trees located within the interior measurement plots was measured at a horizontal line originally placed at 4.5 feet aboveground level. Total tree height (to the top of the tree) and height to the base of the live crown were also measured for all surviving trees in the interior measurement plots.

A Zeiss teledendrometer was used to measure height to even-number upper stem diameters (2, 4, 6, etc., in inches) and the diameters themselves to calculate volume according to the Grosenbaugh height accumulation method (Grosenbaugh 1954). Lower even-number diameters were measured using a diameter tape or caliper. During the first 4 inventories, heights and upper stem diameters were measured for up to only 12 trees per plot. At subsequent inventories, these measurements were conducted for all living trees.

Plot-Level Summary Measures

Quadratic mean diameter [D (inches)], arithmetic mean height [H (feet)], basal area per acre [BA (square feet)], and cubic-foot volume per acre were calculated for each plot by measurement age. Summaries of the measurement plots for a variety of treatment combinations are presented.

RESULTS

During the course of the study, there was no single thinning or pruning treatment that appeared to vastly impact H (table 1). However, the lack of thinning reduced H growth, most likely due to excessive stand density. Thinning greatly impacted D (table 2) but pruning appeared to have little impact. Basal area per acre was greater as residual stand densities increased (table 3). Moderate rates of pruning did not appear to substantially impact basal area. As for volume per acre, the lack of thinning produced the greatest standing volume (table 4, fig. 1). Consistent with our expectations, more intensive thinning regimes reduced standing volume across a rotation. Moderate rates of pruning did not appear to largely impact volumes (table 4, fig. 2).

DISCUSSION

There is some discrepancy as to whether thinning increases height (Zhang and others 1997). Similar to the findings of others (Peterson and others 1997, Williston 1979), we found that H is not vastly affected by thinning intensity (table 1). However, extreme stand densities (unthinned) reduced H growth similar to the findings of Zhang and others (1997). During common regional economic and biological rotation ages (25 to 50 years), H in unthinned control plots ranged from 3 to 21 percent less than other treatments, percent reductions in H generally decreased with age. Height was not impacted by pruning treatments consistent with the findings of Sparks and others (1980).

More intensive thinning produced greater D similar to the findings of others (e.g., Baldwin and others 2000, Feduccia and Mann 1976, Sparks and others 1980, Williston 1979, Zhang and others 1997). Plots that received no pruning but thinned to a basal area of 30 square feet had the greatest D at all ages (table 2). Thinning resulted in much greater growing space for individual trees and the lack of pruning

Table 1—Arithmetic mean height across four pruning treatments and four residual basal areas (30, 50, 70, and 90 square feet of basal area per acre) and a control where no thinning or pruning treatments were conducted

	No pruning				Pruning 25 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	feet				*feet*			
12	34.4	35.2	32.4	34.4	36.1	36.9	36.7	36.7
15	43.1	41.7	38.3	40.1	42.5	43.3	42.6	42.6
16	46.8	45.4	40.7	43.4	45.5	46.3	44.8	45.0
19	51.7	50.8	47.7	50.3	50.3	54.2	50.4	51.3
24	63.7	61.4	55.7	59.1	59.5	62.0	59.7	61.5
27	66.5	68.0	67.6	66.4	66.3	68.6	65.6	66.6
30	74.7	79.0	72.5	72.7	72.2	73.8	72.1	75.4
35	77.7	80.6	79.7	79.4	78.2	79.8	78.6	78.8
36	84.8	81.7	82.0	82.1	81.4	83.0	80.9	80.9
37	84.8	83.0	82.5	83.0	82.3	83.8	81.5	81.8
40	89.7	87.4	84.6	86.4	85.7	87.4	84.7	85.2
43	92.0	89.5	86.3	88.1	86.0	90.0	87.4	86.0
45	93.8	93.0	88.7	89.7	88.2	92.1	89.3	87.5
48	99.4	95.2	89.4	91.7	90.7	94.3	91.7	90.1
50	99.5	95.7	90.3	92.3	92.5	95.7	93.2	92.2

	Pruning 40 percent of total tree height				Pruning 50 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	feet				*feet*			
12	36.3	35.3	35.6	34.5	35.5	36.9	36.7	35.0
15	42.8	41.6	41.5	40.0	42.0	43.4	42.8	40.4
16	45.8	45.4	44.7	42.4	46.1	46.7	46.0	43.8
19	50.3	51.1	51.5	48.8	51.4	51.5	51.3	50.1
24	61.1	64.2	60.6	58.5	60.8	62.9	61.5	58.3
27	66.6	69.6	67.5	65.4	66.8	69.1	68.6	66.1
30	72.3	74.1	74.2	71.6	72.5	74.6	74.3	72.0
35	75.8	80.5	79.6	79.0	77.8	80.1	79.9	78.6
36	76.6	81.3	81.6	81.4	78.6	81.7	81.6	79.8
37	77.7	82.1	82.3	82.4	80.1	82.8	82.4	80.8
40	82.2	85.2	85.3	85.9	84.4	86.9	85.5	84.1
43	82.2	88.3	86.7	87.9	85.2	89.0	88.0	86.5
45	83.7	90.6	87.9	90.1	87.9	91.9	89.3	88.1
48	85.8	93.0	89.8	93.0	90.8	92.7	91.8	90.9
50	87.2	94.8	91.1	94.2	91.5	93.3	92.9	92.5

Age	Control
	feet
27	55.4
30	62.4
35	70.1
36	71.2
37	72.3
40	75.9
43	78.7
45	80.3
48	82.6
50	84.7

Table 2—Quadratic mean diameter across four pruning treatments and four residual basal areas (30, 50, 70, and 90 square feet of basal area per acre) and a control where no thinning or pruning treatments were conducted

	No pruning				Pruning 25 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	inches				*inches*			
12	7.1	7.0	6.0	6.2	6.7	7.0	6.4	6.7
15	9.6	8.6	7.1	7.0	8.5	8.5	7.4	7.6
16	10.8	9.5	7.7	7.9	8.9	9.0	7.8	8.1
19	13.4	11.1	9.1	9.2	10.5	11.1	9.2	9.8
24	15.7	12.3	10.3	10.1	12.5	13.0	10.8	11.7
27	17.7	14.8	13.3	11.7	14.4	14.7	12.2	12.9
30	19.4	16.4	14.8	12.7	16.7	16.3	13.9	14.6
35	21.8	18.6	16.8	14.8	20.6	18.9	15.8	15.3
36	22.9	18.9	17.2	15.4	21.0	19.8	16.1	15.9
37	23.2	19.2	17.5	15.7	21.3	20.1	16.3	16.2
40	24.2	20.3	18.3	16.2	22.2	20.9	17.1	17.0
43	25.7	21.5	19.3	17.3	23.5	22.4	18.1	17.4
45	26.4	22.3	19.6	17.7	24.0	23.0	18.4	17.8
48	27.3	23.0	20.4	18.4	25.0	24.0	19.1	18.5
50	28.1	23.8	21.1	19.1	25.9	24.8	19.7	19.0

	Pruning 40 percent of total tree height				Pruning 50 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	inches				*inches*			
12	6.9	6.6	6.4	6.7	6.3	6.7	6.9	6.3
15	8.8	8.0	7.6	7.5	8.5	8.1	8.1	7.2
16	9.8	9.1	8.4	8.1	9.8	9.1	8.9	8.1
19	11.9	11.1	10.0	9.4	12.1	11.1	10.7	9.3
24	14.3	12.9	11.4	10.8	14.3	12.9	12.1	10.5
27	16.7	14.8	13.3	12.2	16.5	15.1	13.8	12.0
30	18.4	16.1	14.6	13.3	18.4	16.6	14.9	13.2
35	21.0	18.5	16.7	15.4	20.8	18.9	17.1	14.8
36	21.4	18.9	17.3	16.0	21.6	19.6	17.8	15.4
37	21.8	19.1	17.7	16.2	21.9	19.9	18.1	15.7
40	22.8	19.9	18.4	16.9	22.6	20.6	18.9	16.4
43	24.3	20.8	19.9	17.8	23.7	22.0	19.8	17.3
45	25.0	21.3	20.5	18.1	24.3	22.4	20.3	17.7
48	25.9	22.1	21.3	18.7	25.1	23.1	20.9	18.4
50	26.7	22.8	22.0	19.3	25.8	23.8	21.6	19.0

Age	Control
	inches
27	9.5
30	10.5
35	11.6
36	11.7
37	11.8
40	12.8
43	13.5
45	13.7
48	14.1
50	14.7

Table 3—Basal area per acre across four pruning treatments and four residual basal areas (30, 50, 70, and 90 square feet of basal area per acre) and a control where no thinning or pruning treatments were conducted

	No pruning				Pruning 25 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	square feet				*square feet*			
12	55	76	86	101	56	76	90	105
15	71	85	105	124	61	83	101	123
16	38	59	77	99	32	53	73	92
19	59	73	96	110	30	42	60	68
24	81	91	122	132	43	58	76	90
27	34	59	87	104	37	59	85	110
30	41	59	84	106	40	63	84	105
35	52	56	92	108	31	65	88	100
36	29	58	81	90	32	56	70	95
37	29	60	83	94	33	58	72	98
40	32	67	91	100	36	63	72	102
43	36	76	81	98	30	55	71	98
45	38	81	84	103	32	58	74	102
48	41	87	91	110	34	63	80	110
50	43	93	97	119	37	67	84	117

	Pruning 40 percent of total tree height				Pruning 50 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	square feet				*square feet*			
12	51	69	87	100	55	71	90	107
15	63	87	106	117	65	87	109	125
16	33	56	75	98	34	57	78	99
19	47	60	81	82	44	73	87	107
24	67	82	106	105	62	98	110	134
27	40	60	80	98	39	57	80	107
30	37	61	81	103	43	59	81	104
35	41	62	86	108	40	64	85	111
36	34	45	76	95	25	48	69	95
37	36	46	79	97	26	49	72	98
40	38	50	86	102	28	53	78	102
43	32	48	78	96	31	45	86	98
45	34	50	83	100	32	47	90	103
48	37	54	90	107	34	50	96	110
50	39	57	96	113	36	53	102	118

Age	Control
	square feet
27	123
30	145
35	158
36	157
37	163
40	134
43	142
45	147
48	154
50	160

Table 4—Cubic-foot volume per acre across four pruning treatments and four residual basal areas (30, 50, 70, and 90 square feet of basal area per acre) and a control where no thinning or pruning treatments were conducted

	No pruning				Pruning 25 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	cubic feet				*cubic feet*			
12	1013	1346	1544	1841	952	1335	1517	1770
15	1544	1885	2296	2779	1427	1959	2189	2646
16	851	1354	1790	2326	781	1335	1705	2143
19	1508	1962	2484	2944	865	1262	1707	1997
24	2378	2875	3842	4084	1428	2026	2533	3055
27	1009	2028	2856	3429	1279	2100	2841	3802
30	1364	2165	3045	3865	1504	2394	3032	3848
35	1852	2308	3722	4369	1276	2580	3369	4048
36	1215	2503	3418	3843	1417	2508	3126	4181
37	1224	2598	3605	4064	1474	2598	3223	4361
40	1436	3022	4059	4598	1670	2937	3368	4745
43	1686	3528	3718	4622	1416	2668	3471	4625
45	1855	4067	4175	5579	1545	3043	3806	5133
48	2083	4398	4457	5652	1734	3269	4186	5781
50	2237	4765	4827	6077	1910	3578	4526	6220

	Pruning 40 percent of total tree height				Pruning 50 percent of total tree height			
Age	30	50	70	90	30	50	70	90
	cubic feet				*cubic feet*			
12	904	1200	1531	1750	973	1286	1574	1865
15	1447	1987	2388	2612	1498	2026	2503	2815
16	820	1336	1791	2303	821	1372	1885	2323
19	1286	1686	2279	2158	1206	2028	2394	2896
24	2115	2754	3509	3270	1924	3219	3604	4114
27	1366	2016	2731	3205	1277	1944	2740	3545
30	1371	2296	3141	3662	1487	2210	3108	3782
35	1551	2372	3520	4176	1453	2590	3432	4516
36	1422	1927	3303	4133	1036	2029	3041	4090
37	1486	1990	3461	4324	1092	2124	3174	4265
40	1711	2266	3940	4769	1236	2412	3549	4654
43	1443	2250	3725	4635	1388	2139	4072	4639
45	1517	2433	4308	5157	1491	2413	4710	5169
48	1753	2753	4528	5567	1702	2539	4959	5658
50	1909	3002	4951	6004	1832	2731	5294	6165

Age	Control
	cubic feet
27	3621
30	4519
35	5791
36	6246
37	6591
40	5733
43	6337
45	6991
48	7529
50	8061

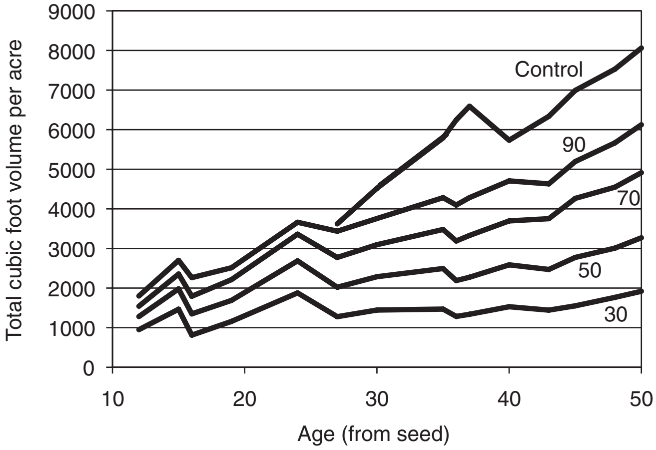

Figure 1—Standing cubic-foot volume per acre of four residual basal areas (30, 50, 70, and 90 square feet of basal area per acre) averaged across all pruning treatments. Control refers to the lack of both thinning and pruning.

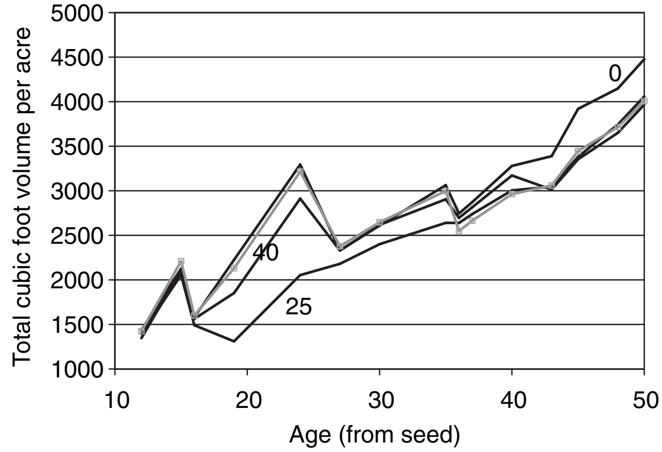

Figure 2—Standing cubic-foot volume per acre of four pruning treatments (no pruning–0, 25, 40, and 50 percent of total tree height) averaged across all thinning treatments (controls were not included in the no pruning–0 treatment for consistency among measurement ages). The gray line in the pruning figure is the 50-percent pruning treatment.

likely resulted in optimum crown conditions for diameter growth. At all ages, the control plots had a D much smaller than those of any of the thinned plots. However, differences in D were not consistently different among the pruning treatments.

Data from all ages showed that more intensive thinning regimes reduced BA (table 3). Similar results have been observed (Baldwin and others 2000). Standing cubic-foot volume was greatest in plots with less intensive thinning treatments (table 4, fig. 1) consistent with the findings of others (Feduccia and Mann 1976, Williston 1979). The heaviest pruning treatment (25 percent) substantially reduced volume up to age 35 (table 4, fig. 2). For the 40 percent pruning treatment, yields were not affected after age 27 when compared to the no pruning treatment.

CONCLUSIONS

Based on our results, it does not appear that moderate pruning substantially impacts yields. Hence, to improve wood quality, managers may want to consider pruning.

If the purpose of tree management is to have a higher standing yield, then the best stand density management regime would be to avoid thinnings. However, since revenues per tree are generally greater as diameter increases, thinning is an economically viable alternative. An optimal trade-off between standing yield and average diameter appears to be obtained when residual BAs are 50 or 70 square feet. Based on our results, differences in yields across a rotation for various residual stand density levels appears to be more related to differences in diameter than height growth.

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