GROWTH POTENTIAL OF LOBLOLLY PINE PLANTATIONS IN THE GEORGIA PIEDMONT: A SPACING STUDY EXAMPLE

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SUMMARY

The B.F. Grant Spacing Study was installed in 1983 for the following purposes:

- To investigate stand dynamics and yield for different planting density treatments and,
- To demonstrate the growth potential of an intensively managed, old-field loblolly pine plantation in the Georgia Piedmont.

This report details the analysis of the B.F. Grant Spacing Study data with the aforementioned objectives in mind.

First, all available data are presented in tabular and graphical form in order to visualize stand development in terms of survival, average height, average Dbh, per acre basal area and per acre merchantable volume. The effect of planting density on these stand characteristics at age 14 was evaluated with an analysis of variance and least significant difference mean separation tests.

Stand structure at age 14 is shown in terms of the average Dbh distribution for the different initial densities. For each treatment of 400 trees per acre and greater, a low thinning removing 40% of the basal area at age 10 was simulated. The basal area, number of trees and merchantable volume removed in each of these thinning simulations is presented.

Finally, two current growth and yield prediction models were evaluated in terms of predictive ability for the B.F. Grant Spacing Study data. Using observed numbers of trees per acre, average dominant height and per acre basal area, the models were used to predict merchantable volumes at ages 8 and 14 for the 600 trees per acre plots.

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1. INTRODUCTION

During the past 10 years over one million acres of marginal agricultural land in Georgia have been converted to loblolly pine plantations. Much of this conversion can be attributed to the Conservation Reserve Program (Hays, 1989). A study to provide growth and yield information for genetically improved loblolly pine planted on an old-field site in the Georgia Piedmont was installed in 1983 at the B.F. Grant Memorial Forest. This forest, located in Putnam County, Georgia, is maintained by the Warnell School of Forest Resources, University of Georgia. If growth rates observed in this study are indicative of what can be expected from similarly treated loblolly pine plantations in the Georgia Piedmont, it will have a profound impact on fiber supply and profitability in the region.

2. STUDY DESCRIPTION

The study is located on a gently sloping hilltop which had been planted to soybeans in previous years. Soils in the area are dominated by Typic Kanhapludults (Cecil Series) and Rhodic Kandiudults (Davidson Series). The study was hand planted in March, 1983 at a 6 ft. by 6 ft. spacing with improved loblolly pine seedlings supplied by the state nursery. In May of 1983, a farm tractor was used to mow herbaceous competition between the rows and, one month later, to broadcast spray Oust (sulphometuron-methyl) with a boom sprayer at a rate of 8 ounces per acre. Herbaceous competition consisted primarily of Johnson grass *(Sorghum halepehse)* and vetch *(Vicia spp.)*. In the following July, 24 fifth-acre plots were installed, each with a tenth-acre interior measurement plot. Four plots were randomly assigned to each of 6 stocking levels, namely, 100, 200, 400, 600, 800 and 1000 trees per acre. Surviving seedlings on each plot were reduced to the required number by systematic selection to avoid bias and to assure uniform spacing.

A second herbicide release treatment with 8 ounces of Oust was applied in May, 1984 to control recurrent herbaceous competition in the second growing season. One year later in May, 1985, wildlings of both loblolly pine and sweetgum *(Liquidambar styraciflua)* that had seeded in from neighboring stands were eliminated on plots where this had occurred. As a result of these treatments all plots have been growing essentially free of competing vegetation throughout the life of the study.

3. MEASUREMENTS AND RESULTS

3.1 Survival

Survival values for each initial stocking density are shown in Table 1. Survival on the B.F. Grant spacing study was exceptional, in general. From the initial spacing through age 14, average survival across the four replications ranged from 100% for the 100 and 200 trees per acre densities to 89% for the 1000 trees per acre density.

Table 1. Survival (trees per acre) for different initial stocking densities.

Age	Initial Stocking Density (trees per acre)					
	100	200	400	600	800	1000
8	100	200	400	588	780	960
10	100	200	398	572	762	925
12	100	200	398	565	740	912
14	100	200	395	550	I 720	I 888

3.2 Average Height

Total heights of all trees on the measurement plots were measured with a telescoping height measurement pole after the 3`d, 5`h, 8'h and 10" growing seasons and with a Suunto hypsometer after the 12th and 14th growing seasons. The average dominant height for the entire study at age 14 was 55.2 feet. The following site index equation for old-field loblolly pine plantations in the Georgia Piedmont (Clutter and Lenhart, 1968) was used to estimate the site index of the B.F. Grant study site:

$$\log_{10}(SI) = 1.0907 + 10^{-2.911/Age}[-2.0226 + 1.3075\log_{10}(H_d) + 14.9136/Age] \quad \textbf{(1)}$$

The site index estimate for the B.F. Grant site is 81.0 feet (base age 25 years). Average heights by age and-planting density are listed in Table 2 and illustrated in Figures l and 2.

Table 2. Average height for different initial stocking densities.

Age	Initial Stocking Density (trees per acre)					
	100	200	400	600	800	1000
3	10.2	11.2	12.8	12.3	11.5	11.5
5	16.5	17.8	19.9	19.6	18.1	18.4
8	28.2	29.6	33.2	33.0	31.1	31.9
10	36.6	40.3	43.0	41.8	40.0	40.1
12	43.5	46.3	49.7	49.1	45.7	45.4
14	49.8	53.1	55.5	54.7	52.4	50.3

Based on an analysis of variance test, there were significant differences in average height at age 14 for different initial densities with $\alpha = 0.05$. There was, however, no trend in average height with increasing initial density. The average heights ranged from 49.8 feet for the 100 trees per acre plots to 55.6 feet for the 400 trees per acre plots. These differences are most likely due to random microsite variations rather than density effects. The least significant difference in average height was 3.88 feet.

3.3 Average Dbh

Diameter at breast height (Dbh) was measured on each tree in the measurement plot beginning at age 5. Average Dbh's for the different initial densities are listed in Table 3 and illustrated in Figures 3 and 4.

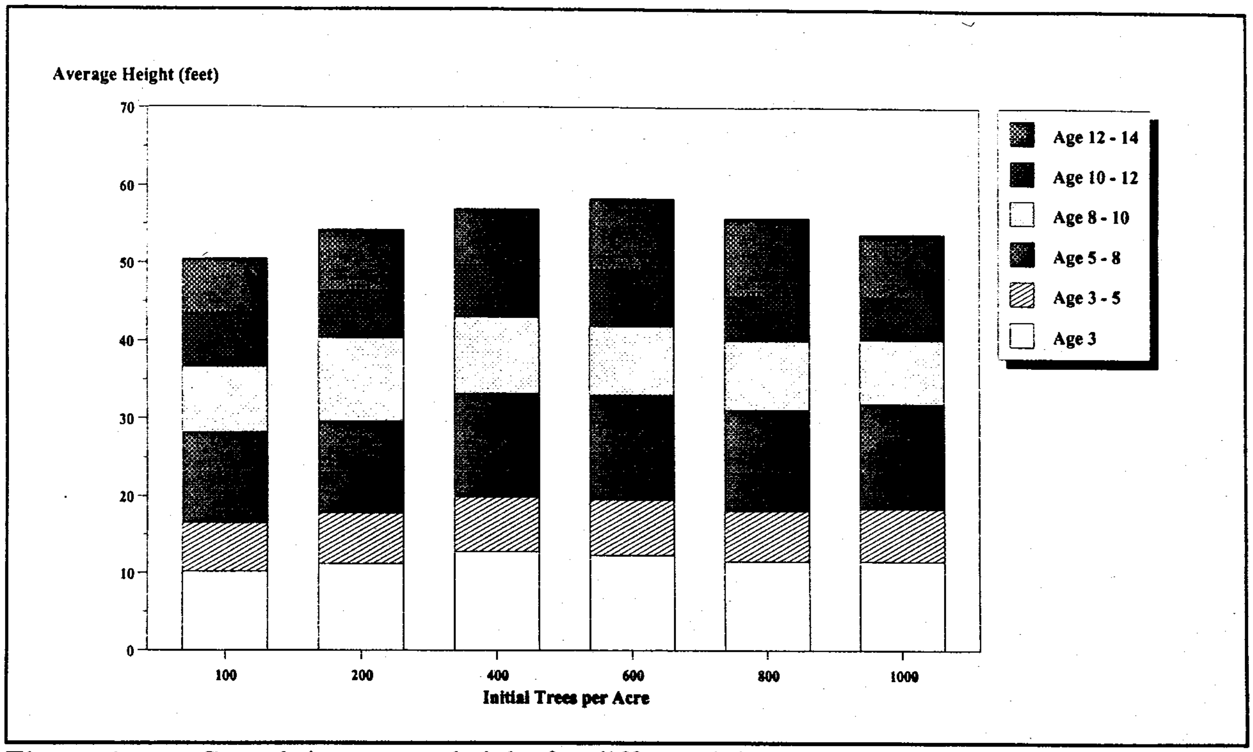

Figure 1. Growth in average height for different initial densities.

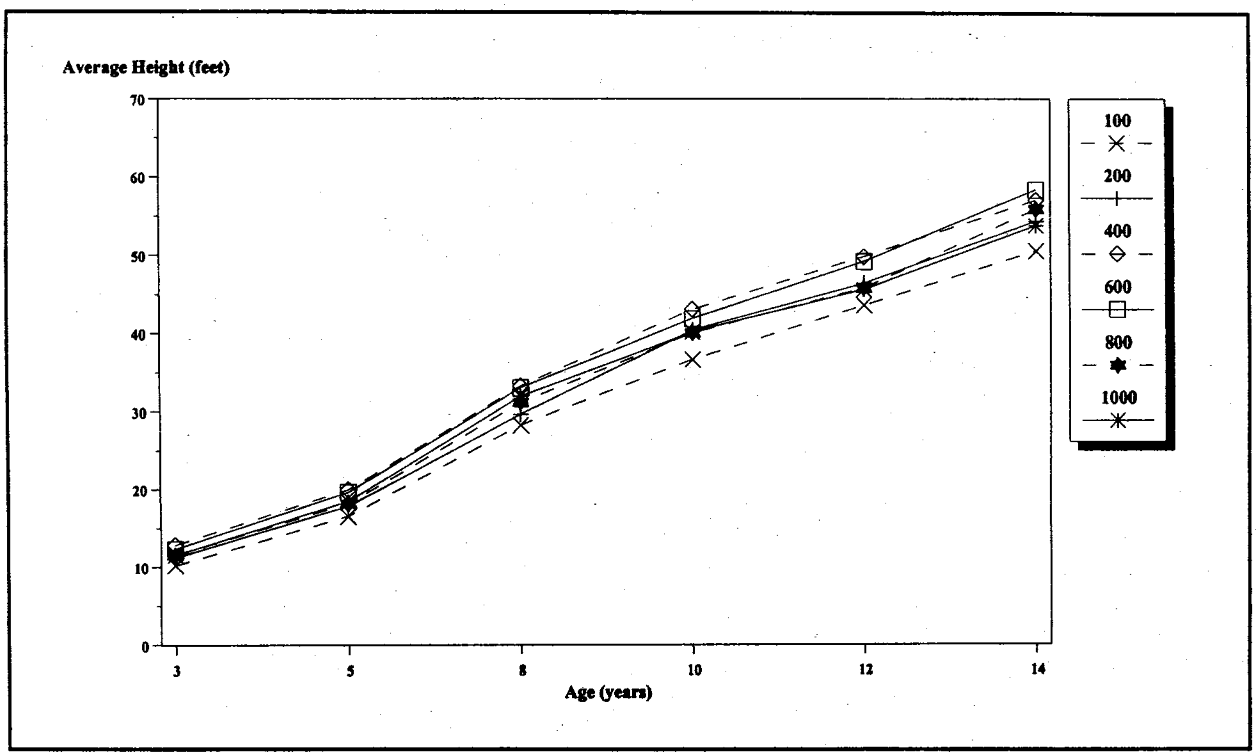

Figure 2. Average height growth curves for different initial densities.

The analysis of variance on average Dbh at age 14 indicated a significant effect due to initial density. With a least significant difference of 0.61 inches, there was a significant difference in average Dbh among all of the density treatments at the $\alpha = 0.05$ level.

Table 3. Average Dbh for different initial stocking densities.

Age	Initial Stocking Density (trees per acre)					
	100	200	400	600	800	1000
5	3.6	4.0	4.2	3.8	3.5	3.3
8	7.8	7.8	7.0	6.0	5.5	5.1
10	9.9	9.2	8.0	6.8	6.2	5.8
12	11.1	10.0	8.5	7.3	6.7	6.1
14	12.0	10.6	8.9	7.7	7.0	6.3

By age 10 there was a clear trend of declining average Dbh with increasing initial density, even between the 100 and 200 trees per acre levels. It is evident that intra-specific competition significantly affects Dbh growth at early ages, especially for the lowest stocking densities. The difference between the 100 and 400 trees per acre treatments (3.1 ") was more than twice the difference between the 600 and 1000 trees per acre treatments (1.4").

3.4 Basal Area per Acre

Per acre basal areas for the different initial density treatments are summarized in Table 4 and in Figures 5 and 6. Basal area at age 14 ranged from 79.3 ft2 for the 100 trees per acre plots to 202 ft^2 for the 1000 trees per acre treatment. An analysis of variance indicated a significant effect of initial density on per acre basal area. The least significant difference for basal area was 14.1 ft^2.

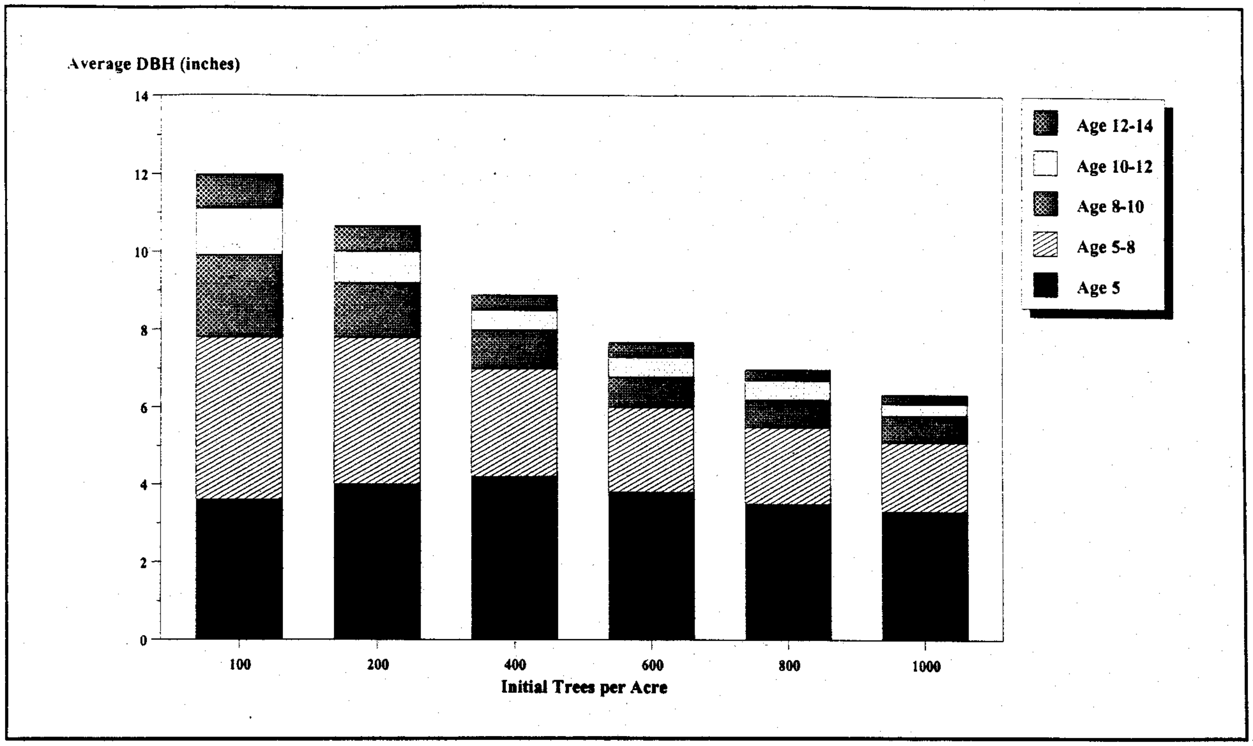

Figure 3. Growth in average Dbh for different initial densities.

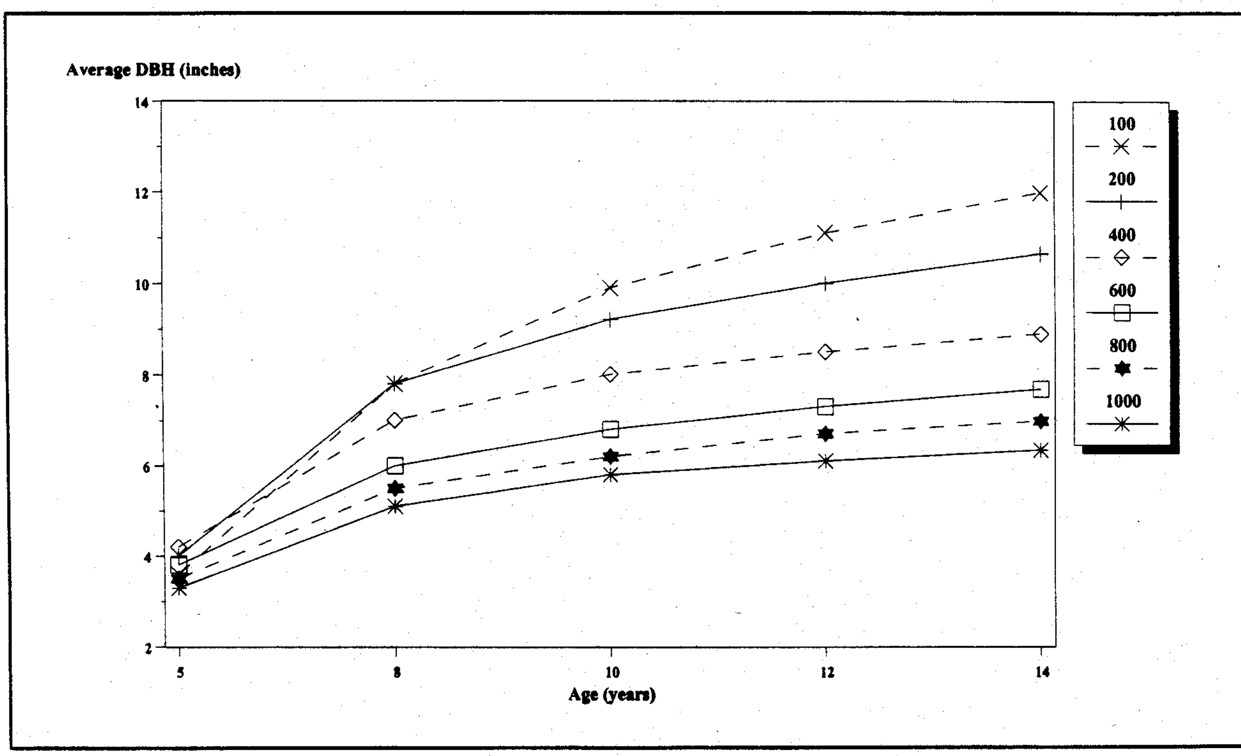

Figure 4. Average Dbh growth curves for different initial densities.

Table 4. Basal area per acre for different initial stocking densities.

Age	Initial Stocking Density (trees per acre)					
	100	200	400	600	800	1000
5	7.4	18.1	39.6	46.8	53.4	61.1
8	34.3	67.0	108.9	119.1	132.6	139.0
10	53.9	94.2	140.9	150.2	165.5	172.6
12	67.6	111.9	159.8	168.8	185.7	191.2
14	79.3	125.7	174.1	182.4	199.0	202.0
% change 10-14	47	33	24	21	20	17

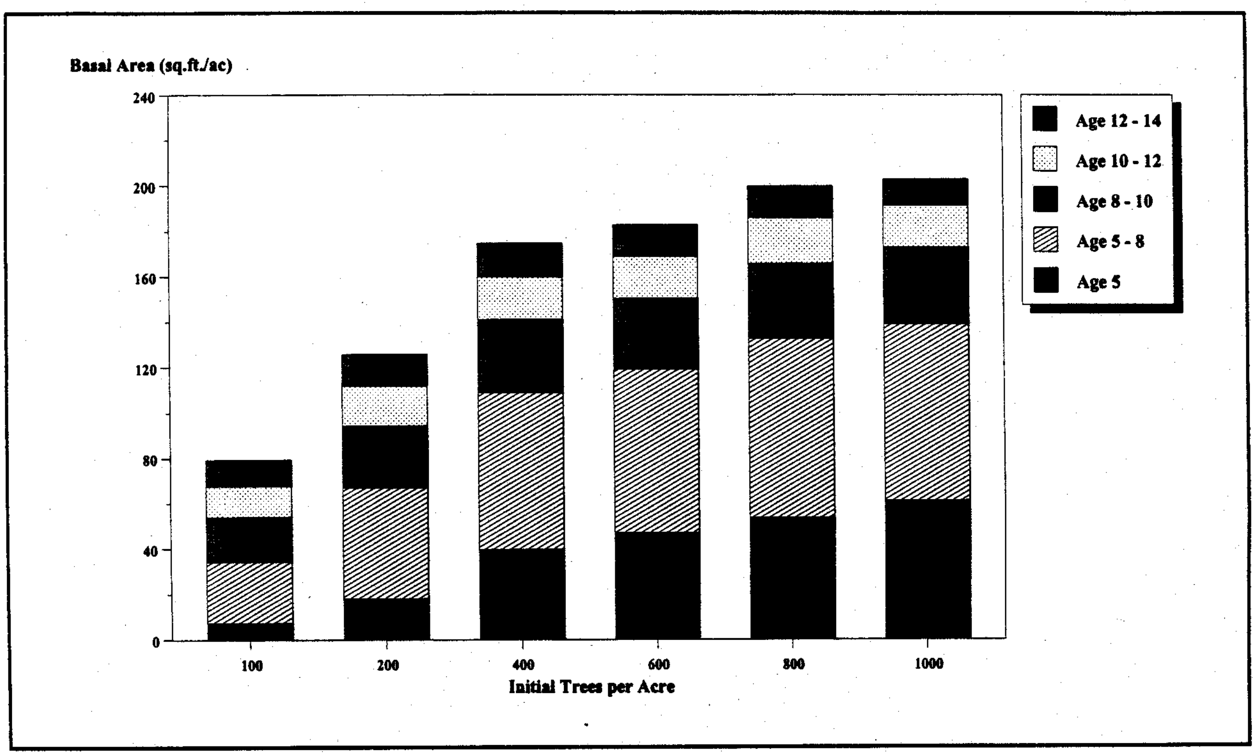

Figure 5. Growth in per acre basal area for different initial densities.

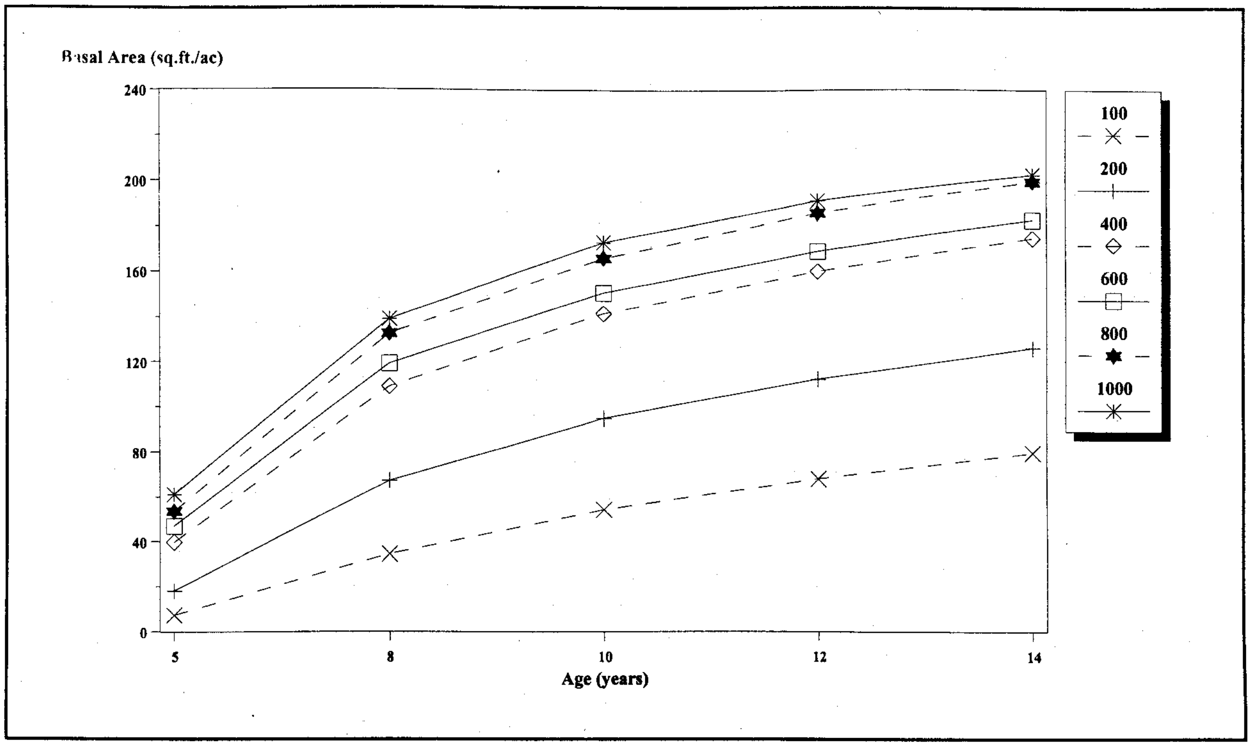

Figure 6. Per acre basal area growth curves for different initial densities.

The percent change values shown in Table 4 indicate a trend towards stabilization of per acre basal area with respect to initial density. The lower density plots are able to compensate for the lack of initial biomass with an increased relative basal area growth rate. On the other hand, the plots with higher initial density have experienced an increasing mortality rate and a decreasing basal area growth rate. This stabilization in per-acre basal area, however, does not indicate similar stand dynamics for the different densities. For example, the 800 and 1000 trees per acre treatments have nearly equal basal area but the average tree sizes, in terms of mean Dbh, are significantly different.

3.4 Merchantable Volume

Individual tree volumes (o.b.) for trees greater than 4.5" Dbh to a 3" top (o.b.) were estimated with a merchantable volume equation for old-field loblolly pine developed by Bailey and Clutter, 1970, namely,

$$V_m = -0.13681 + 0.00247\, Dbh^2 H \qquad (2)$$

Per acre volumes by initial density for ages 8, 10, 12 and 14 are shown in Table 5 and illustrated in Figures 7 and 8.

Table 5. Merchantable volume per acre for different initial stocking densities.

	Initial Stocking Density (trees per acre)					
Age	100	200	400	600	800	1000
8	434	880	1581	1687	1659	1652
10	892	1710	2709	2796	2886	2878
12	1330	2343	3580	3737	3764	3726
14	1790	3030	4374	4536	4673	4483
MAI 14**	1.64	2.77	4.00	4.15	4.28	4.10

**MAI 14 is expressed in cords per acre per year assuming 78 ft^3 per cord.

At age 14 a difference of 572 ft^3 between any two means was found to be significant at the α = 0.05 level. Therefore, the 100 and 200 trees per acre plots were significantly different from each other as well as from the other densities. None of the density treatments of 400 trees per acre and higher had significantly different merchantable volumes at age 14. This is a case where stand dynamics interact and result in approximately the same volume per acre. The basal areas of the 400 and 600 trees per acre plots are significantly different from the 800 and 1000 trees per acre plots. The 400 and 600 plots compensate with larger average tree size and produce roughly the same merchantable volume at age 14. The 800 trees per acre plots had the most merchantable volume with an MAI of 4.28 cords per acre per year.

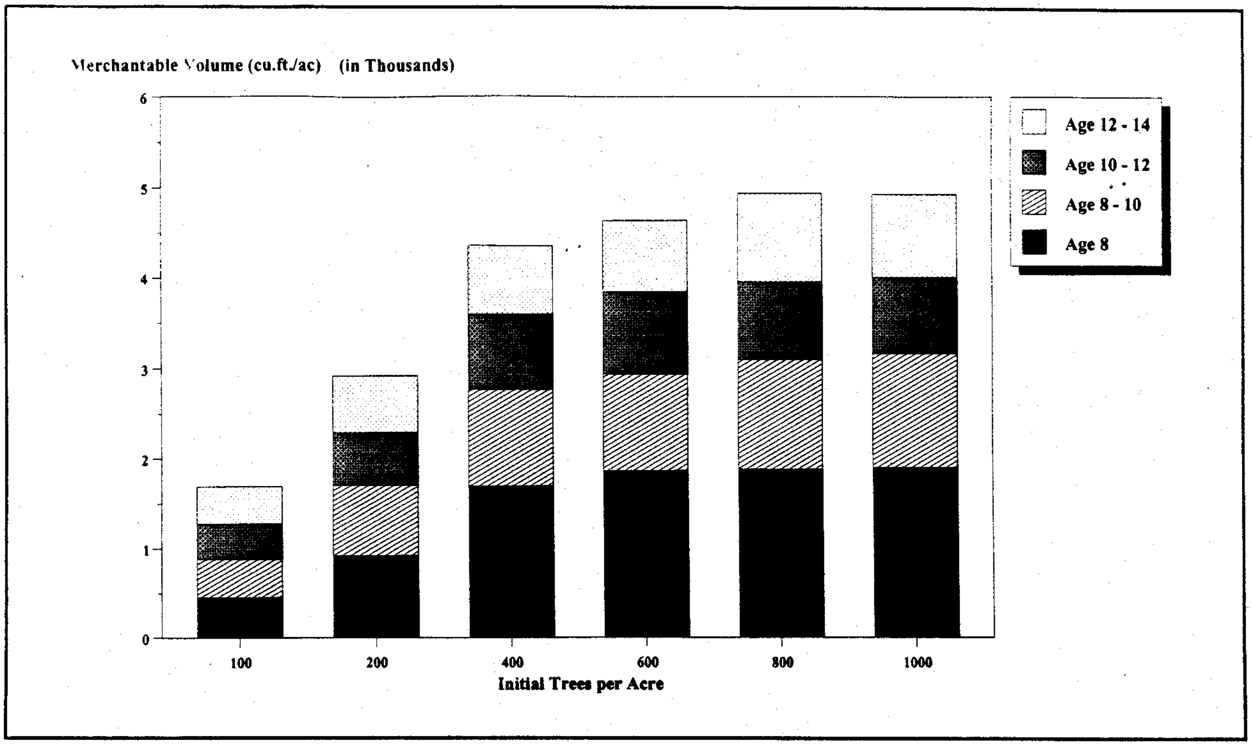

Figure 7. Growth in per acre merchantable volume for different initial densities.

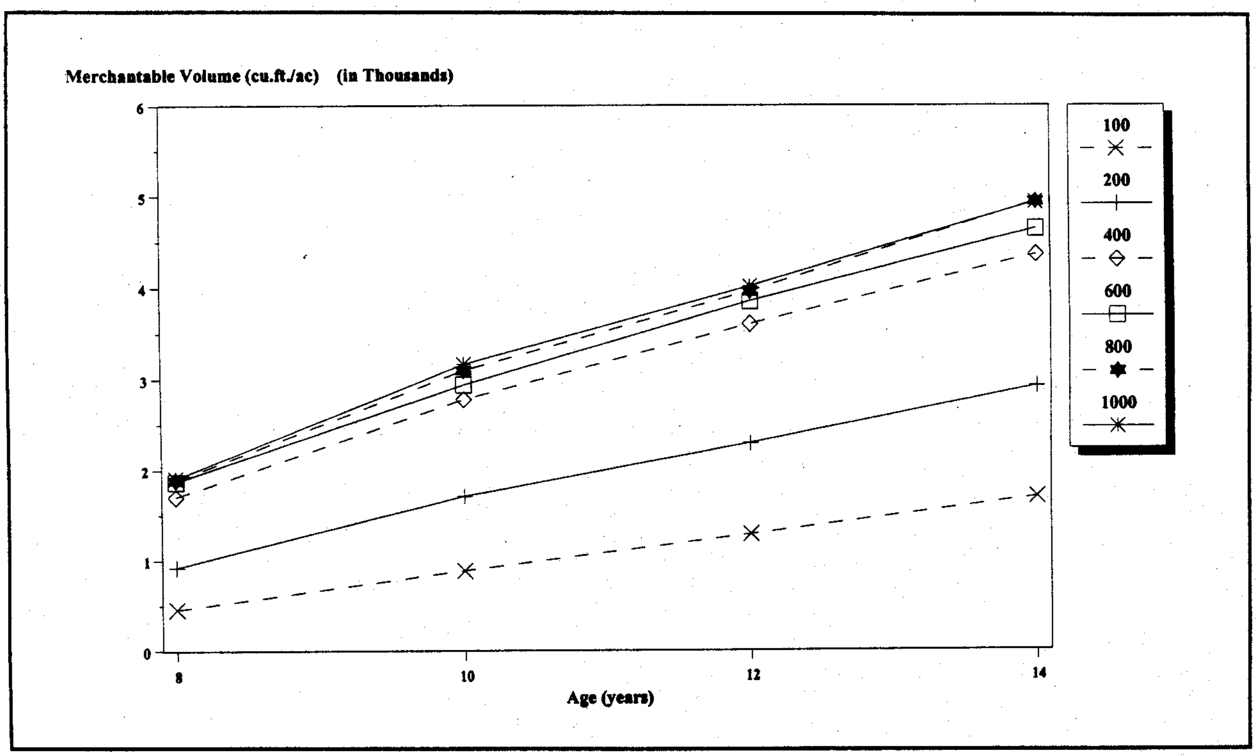

Figure 8. Per acre merchantable volume growth curves for different initial densities.

4. STAND STRUCTURE AND THINNING

Forest managers contemplating thinning an intensively managed, old-field plantation will be interested in the effect of different planting densities on the diameter distribution. Since the numbers of trees per acre and the average diameters are significantly different for the different planting density treatments, it will come as no surprise that the diameter distributions of these plots will also look very different. Figure 9 shows the average diameter distributions for the four plots in each density treatment at age 14. Figure 10 shows the distributions in relative terms with each dbh class frequency expressed as a proportion of the total number of trees per acre (on the average) for each density treatment. It is interesting to note that all but the 100 trees per acre treatment had some number of trees below six inches dbh at age 14.

For each treatment of 400 trees per acre and greater, a low thinning removing 40% of the basal area in trees greater than four inches dbh at age 10 was simulated. Trees were removed from the smallest dbh classes until the target removal was reached. Obviously an operational thinning would be slightly different since spacing considerations and defects on larger trees would result in the removal of some trees larger than those represented in the simulation. This simulation will, however, give an indication of how much volume would be removed in a thinning of this intensity on stands of different initial densities as well as the condition of the remaining stands. Table 6 shows the results of these simulations.

Table 6. Results of a simulated 40% low thinning at age 10.

Initial Density	Before Thinning			Removed in Thinning			After Thinning		
	BA (ft^2/ac)	TPA	Volume (cords)	BA (ft^2/ac)	TPA	Volume (cords)	BA (ft^2/ac)	TPA	Volume (cords)
400	142.6	398	35	57.0	189	13.6	85.6	209	21.4
600	150.9	572	36	60.4	272	13.8	90.5	300	22.2
800	163.3	762	38	65.3	363	14.3	98.0	399	23.7
1000	163.4	925	38	65.4	440	14.4	98.0	485	23.6

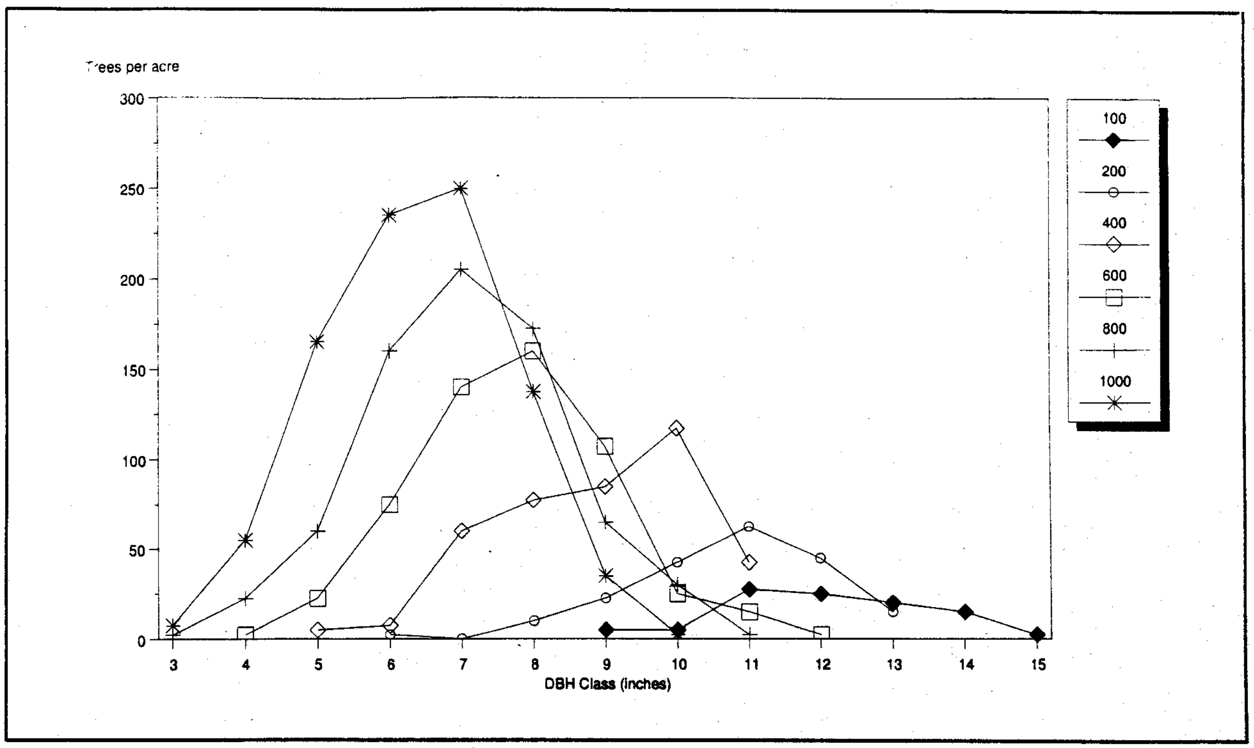

Figure 9. Average dbh distributions at age 14 for different initial densities.

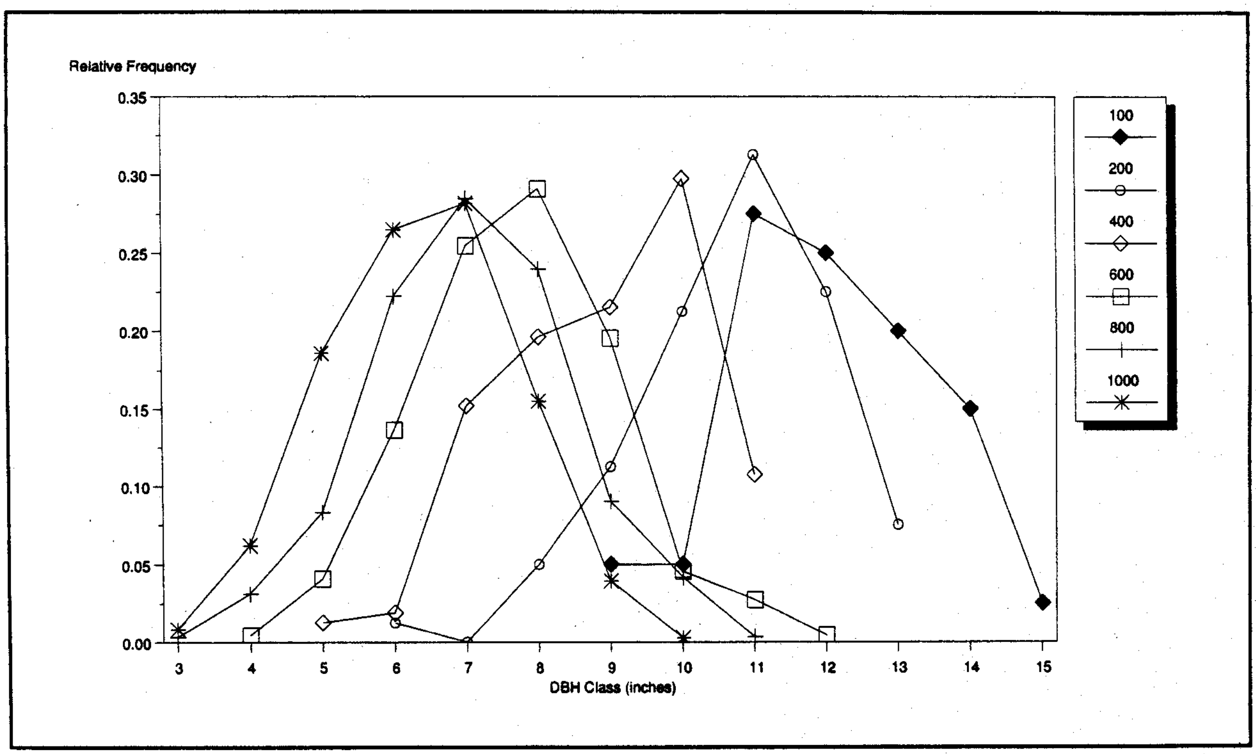

Figure 10. Average relative frequency by dbh class at age 14 for different initial densities.

The simulation indicated that 13 or 14 cords could be removed in a 40% low thinning at age 10 with a wide range in the number of trees removed. After thinning, the 400 trees per acre plots would be left with 8-10 inch trees, the 600 with 7-11 inch trees, the 800 with 6-9 inch trees and the 1000 with 6-8 inch trees.

5. SUITABILITY OF CURRENT PREDICTION MODELS

Questions have arisen as to the suitability of current growth and yield models for predicting the growth of old-field loblolly pine plantations which have received some degree of chemical competition control. Harrison and Borders (1996) presented a growth and yield model for cutover loblolly pine plantations in the Piedmont region of the Southeast U.S. Using the observed average dominant heights (35.1 and 58.0 feet), the observed numbers of trees per acre (588 and 550) and the observed basal areas (119.1 and 182.4 ft^2) for the 600 initial density plots at ages 8 and 14, the cutover plantation whole-stand yield model was used to predict merchantable volumes (o.b.) for trees greater than 4.5 inches to a 3 inch top o.b. These results were compared with the observed age 8 and 14 merchantable volumes for the 600 trees per acre plots. These same comparisons were carried out using a model developed by Lenhart and Clutter (1971) for old-field loblolly pine plantations in the Georgia Piedmont. Table 7 shows the results of the model comparisons.

Table 7. Predicted stand characteristics for the B.F. Grant 600 trees per acre plots using a model for cutover plantations and an old-field plantation model.

Model		Observed				Predicted
	Age	TPA	HD	BA	MVOL	MVOL
Cutover	8	588	35.1	119.1	1687	1751
	14	550	58.0	182.4	4536	6087
Old-Field	8	588	35.1	119.1	1687	2202
	14	550	58.0	182.4	4536	5720

Both the cutover plantation model and the old-field model performed reasonably well in terms of merchantable volume predictions at age 8. For age 14, however, both models seriously overpredict the merchantable volume. This small example emphasizes the growing need for appropriate growth and yield models for intensively managed, highly productive loblolly pine plantations.

6. CONCLUSION

Old-field loblolly pine plantations in the Georgia Piedmont for which existing site index and yield prediction equations are available (Lenhart and Clutter, 1971) were established without any further weed control and had an average site index of 62 feet. The old-field plantation in this study with comparable stocking and in which herbicide was used to control competing vegetation has been growing at about 2.5 times the rate of previous, average old-field and cutover, mechanically site prepared plantations without weed control. Early results of a PMRC study (Rheney and Pienaar, 1993) indicate that similar growth rates can be achieved on cutover sites with chemical control of competing vegetation.

These results have three main implications. First, because of the increased growth rate due to intensive management, foresters may have more management options available. Significant yields can be obtained in low thinnings as early as 8 or 10 years of age. The second implication is illustrated by the inadequacy of existing old-field and cutover plantation growth and yield models to estimate the growth and yield of intensively managed old-field plantations. Studies of the type described here will provide the data for growth and yield models appropriate for these fast growing plantations. Finally, future development of intensively managed plantations and research trials will be of great interest since the results are likely to have a major impact on investment decisions and on future timber supply in this region.

7. LITERATURE CITED

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