14 Year Results of the PMRC Species Comparison Study (Revised)

Plantation Management Research Cooperative

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Introduction

The expense of owning and managing land has increased steadily over the last three decades and it is now imperative that all lands are managed to obtain the most production possible under economic and environmental constraints. Cooperators in the Plantation Management Research Cooperative (PMRC) are currently using different management techniques in an attempt to increase productivity. Current PMRC studies are examining the effects of site preparation and fertilization (Shiver et al., 1994a), genetically improved planting stock and vegetation control (Shiver et al., 1994b), as well as thinning and density control (Pienaar and Rheney, 1994). According to Fisher (1981), the easiest way to increase the productivity of a site is to grow the proper species. In an attempt to find the proper species-site matches, the PMRC established a regionwide study in 1979-1980 to evaluate the performance of slash (*Pinus elliottii* Engelm) and loblolly (*Pinus taeda* L.) pines on eight well defined soil types of the coastal plain of Georgia and north Florida. This report presents the 14 year results for this PMRC species comparison study.

Data

The original study plan called for 160 installations on eight soil drainage classes (Table 1) throughout the lower coastal plain of Florida and Georgia (Figure 1). Twenty installations were randomly located in each of the eight soil classes during the 1978/79 and 1979/80 planting seasons. At each installation two plots were laid out with care taken to select areas with uniform soil conditions across both plots. The individual plots were then planted with bulk lot improved seedlings. Loblolly pine seedlings were planted on one plot and slash pine seedlings were planted on the other. Each plot contained 64 trees with an approximate density of 726 trees/acre. The age 2 results were reported by Clutter (1983), age 5 results were reported by Borders and Brister (1986), and age 8 results were reported by Borders and Harrison (1989). Age 14 information was collected in 1994 and is now available for analysis.

Methods

At the end of 14 growing seasons there were 141 complete installations remaining due to withdrawal of cooperators, fire, thinning, damage, etc. Originally the installations were evenly distributed over the eight soil drainage classes. However, there was also interest in the reliable performance of slash and loblolly pine plantations on Cooperative Research in Forest Fertilization (CRIFF) soil groups (Table 2). CRIFF groups were assigned to the existing plots in 1989 based on the soil descriptions made at study initiation. However there was some concern that the CRIFF groups assigned using soil descriptions

were not consistent with those assigned by the cooperators. In 1994 soils were reexamined by cooperators and CRIFF groups were modified where appropriate. Since some original plots were lost and installations were not originaly balanced by CRIFF groups, the design was no longer balanced (Tables 1&2).

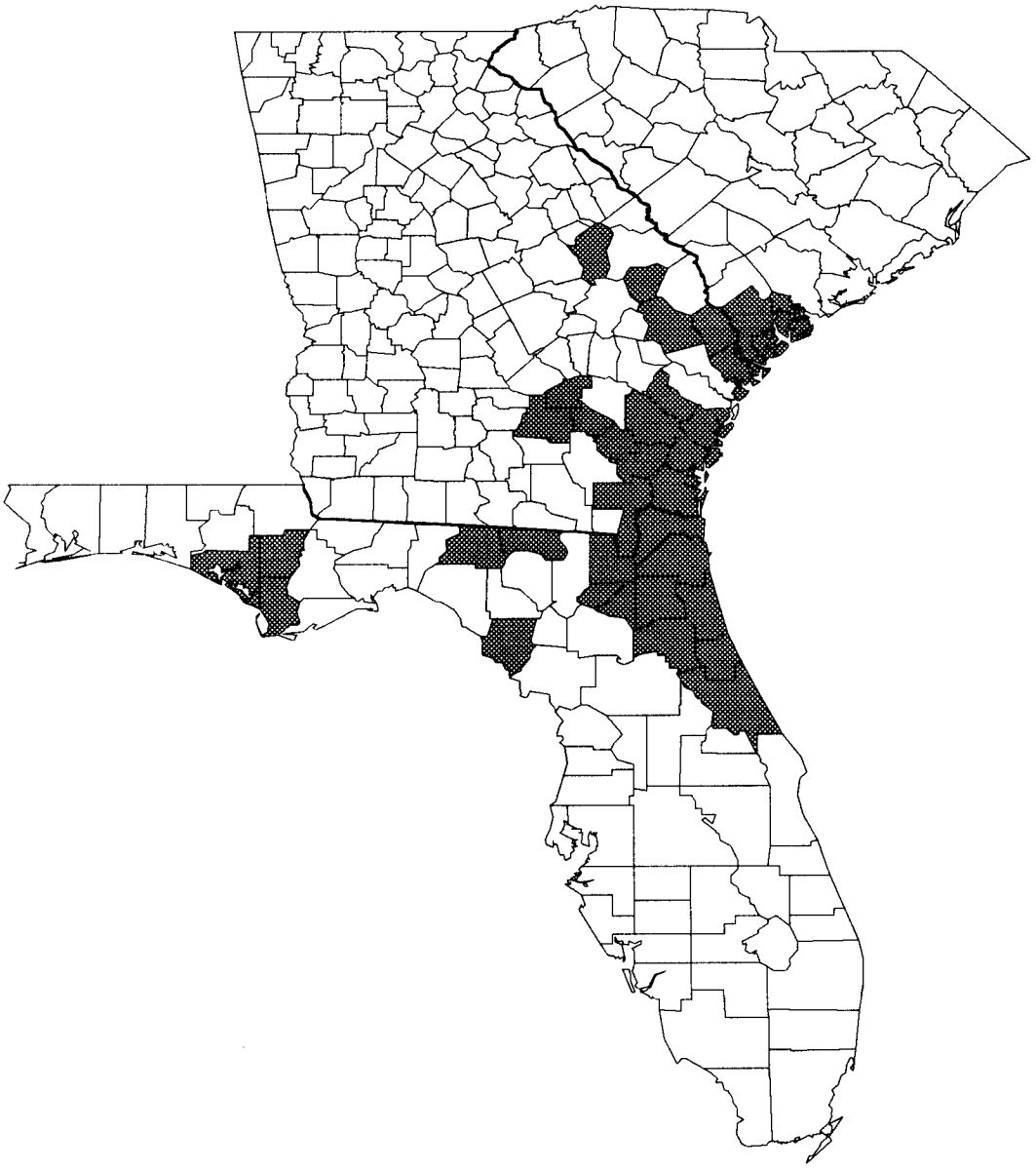


Figure 1. Geographic distribution of species comparison installations.

Each surviving tree at a location was measured for DBH in inches (.1"), presence of fusiform rust, (*Cronartium fusiforme* Hedge. and Hunt.), and total height. There were rare occurrences where a tree did not have a recorded height. In these cases the height was estimated using a height/DBH equation proposed by Curtis(1967):

$$\ln(\mathrm{Ht}-4.5) = B_0 + \frac{B_1}{\mathrm{DBH}}$$

The equation was fit to each plot and heights were estimated using the stand specific regression coefficients. Total volumes and merchantable volumes to a 4 inch top, as well as total green weight and green weight to a 4 inch top were calculated for loblolly pine and slash pine using equations developed by (Borders et al., 1990) and Pienaar et al.(1988) respectively. Basal area per acre, trees per acre, percent cronartium infection and survival were also calculated.

Table 1. Description of UGA soil groups with number of installations in each group for the species comparison study.

UGA Soil Group	# of installations	Drainage Class[1]	Description
1	17	P, VP	spodic with argillic horizon
2	15	P, VP	spodic without argillic horizon
3	17	P, VP	non-spodic soils
4	19	SP, MW	spodic with argillic horizon
5	19	SP, MW	spodic without argillic horizon
6	19	SP, MW	non-spodic soils
7	17	W	non-spodic soils
8	18	SE, E	non-spodic soils
Total	141		

Table 2. Description of CRIFF soil groups with number of installations in each group for the species comparison study.

CRIFF Soil Group	**# of Installations**	**Drainage Class[1]**	**Diagnostic Horizons**	**Depth to Horizons**
H	0	VP	Histic	surface
A	7	VP, P, SP	Argillic	< 20 inches
B	23	VP, P, SP	Argillic	> 20 inches
C	32	VP, P, SP	Spodic, Argillic	any
D	38	VP, P, SP	Spodic	any
E	0	MW, W	Argillic	< 20 inches
F	22	MW, W	Argillic	> 20 inches
G	19	SE,E	none or Argillic	deep
Total	141			

[1]VP=very poorly drained, P=poorly drained, SP=somewhat poorly drained, MW=moderately well drained, W=well drained, SE=somewhat excessively drained, E=excessively drained

Analyses were done by UGA soil class, CRIFF soil group, and across all soils. Analysis of variance was used to examine species*soil interactions as well as species and soil differences. The variation among installations within each soil class was used to test species differences among soil classes. The analysis of variance table format used is presented in Appendix A. When species*soil interactions were not present, the analysis of species differences was done using a paired T-test.

Results

Age 14 Stand variables

Analysis of variance was performed on the 1994 stand data. Variables tested included percent cronartium, survival (%), basal area per acre (ft^2), trees per acre, total volume (ft^3), merchantable volume to a 4" top (ft^3), total green weight (tons), and merchantable green weight to a 4" top (tons). The analyses showed no significant (α=0.05) species*soil type interactions for the UGA soil groups. This means that one species does not perform differently than the other species across soil types. In other words one species performs about the same as the other across all soil types. There was a significant species*soil type interaction for percent survival (p=0.0062) and for trees per acre (p=.0062) when the analysis was done using the CRIFF soil groups, but there were no significant (α=0.05) species*soil type interactions for the remaining stand variables. Since there were no important species* soil group interactions, it is possible to examine the species differences using a paired T-test across all soil classes.

Paired T-tests were performed to examine differences due to species across all soil groups. Loblolly pine showed better survival carrying higher basal area per acre, total and merchantable volumes, and total and merchantable green weights per acre than slash pine in spite of having a slightly higher incidence of fusiform infection (Table 3). At least some of the difference in these values is a result of significantly higher survival rates and therefore higher numbers of trees per acre. The p value for difference column indicates that all of these differences are significant using an alpha value of .05 since all p values are less than .05. These results agree with those found at age 8 by Borders and Harrison (1989).

An analysis was also performed to examine differences in productivity by soil group. When the ANOVA was performed with UGA soil groups, soil groups 6 and 3 were clearly superior to soil group 8 (α=0.05) for every variable analyzed (Table 4). These two soil groups cover the range of drainage classes from moderately well to very poorly drained on non-spodosols.

Table 3. Mean species values across all soil types in the species comparison study.

Variable	# of installations	loblolly value	Slash value	P value for difference
% cronartium	141	19.7	17.6	**0.0146**
% survival	141	71.0	65.9	**0.0002**
basal area (ft^2/ac.)	141	97.5	81.4	**0.0001**
trees/ac.	141	515.5	478.6	**0.0002**
Total Volume (ft^3/ac.)	141	1856.6	1720.5	**0.0482**
Merch. Volume (ft^3/ac.)	141	1496.97	1310.2	**0.0023**
Total Weight (tons/ac.)	141	52.5	46.5	**0.0078**
Merch. Weight (tons/ac.)	141	41.8	35.1	**0.0006**

Table 4. Mean soil group values in the species comparison study (both species combined).[2]

	Soil Group							
Variable	1	2	3	4	5	6	7	8
% Cronartium	15.6 ^{abc}	12.2 ^{c}	18.7 ^{abc}	13.2 ^{bc}	16.1 ^{abc}	24.2 ^{ab}	26.7 ^{a}	21.8 ^{abc}
% Survival	70.4 ^{ab}	68.0 ^{ab}	73.0 ^{a}	73.8 ^{a}	65.7 ^{ab}	72.4 ^{a}	65.2 ^{ab}	59.1 ^{b}
Trees/ac.	511 ^{ab}	494 ^{ab}	530 ^{a}	536 ^{a}	477 ^{ab}	525 ^{a}	473 ^{ab}	429 ^{b}
Basal Area (ft^2/ac.	89.71 ^{a}	88.93 ^{a}	100.96 ^{a}	95.39 ^{a}	88.79 ^{a}	102.85 ^{a}	86.59 ^{a}	61.89 ^{b}
Total Volume (ft^3/ac.)	1849.7 ^{a}	1805.3 ^{a}	2087.0 ^{a}	1948.4 ^{a}	1641.2 ^{ab}	2173.2 ^{a}	1640.3 ^{ab}	1158.4 ^{b}
Merch. Volume (ft^3/ac.)	1405.5 ^{a}	1409.7 ^{ab}	1657.9 ^{a}	1499.2 ^{a}	1300.4 ^{ab}	1750.9 ^{a}	1268.6 ^{ab}	894.0 ^{b}
Total Weight (tons/ac.)	51.152 ^{a}	49.970 ^{a}	57.829 ^{a}	53.880 ^{a}	45.289 ^{ab}	60.346 ^{a}	45.225 ^{ab}	32.047 ^{b}
Merch. Weight (tons/ac.)	38.447 ^{ab}	38.627 ^{ab}	45.456 ^{a}	41.018 ^{ab}	35.503 ^{ab}	48.205 ^{a}	34.600 ^{ab}	24.612 ^{b}

The same analysis was performed using the CRIFF soil groups. Average basal area/ac., total volume/ac., merchantable volume/ac., total (ob) green weight/ac., and merchantable (ob) green weight/ac. for soil group G was less than that for soil groups A, B, C, D, and F(α =0.05), despite the fact that survival was not significantly different for soil groups A, D, F, and G. Additionally, cronartium infection rates were lower on soil group G than for soils A and F (Table 5). The higher cronartium infection rates on A and F soils are likely a function of the faster growth rates on those soils (Zutter et al. 1987).

[2]Means with the same superscript are not significantly different ($\rightarrow$=0.05).

Table 5. Average stand values for the various CRIFF soil groups in the species comparison study.[3]

	Soil Group					
Variable	**A**	**B**	**C**	**D**	**F**	**G**
% Cronartium	29.7 [a]	17.0 [b]	14.2 [b]	14.7 [b]	30.2 [a]	18.7 [b]
% Survival	71.4 [ab]	75.6 [a]	72.7 [a]	67.2 [ab]	59.0 [b]	65.1 [ab]
Trees/ac.	519 [a]	549 [a]	528 [a]	488 [ab]	428 [b]	473 [ab]
Basal Area (ft^2/ac.)	105.05 [a]	93.81 [a]	94.72 [a]	90.95 [a]	95.64 [a]	59.57 [b]
Total Volume (ft^3/ac)	2198.9 [a]	1913.4 [a]	1974.6 [a]	1757.1 [a]	1929.3 [a]	1074.0 [b]
Merch. Volume (ft^3/ac.)	1788.7 [a]	1465.3 [a]	1522.8 [a]	1385.8 [a]	1611.9 [a]	744.6 [b]
Total Weight (tons/ac.)	61.081 [a]	52.911 [a]	54.687 [a]	48.549 [a]	53.436 [a]	29.634 [b]
Merch. Weight (tons/ac.)	49.155 [a]	40.153 [a]	41.756 [a]	37.873 [a]	44.145 [a]	20.491 [b]

Growth Analysis

Results of the analyses of variance for 3 year growth from age 11 to age 14 indicated that there were no species*soil interaction (α=0.05). The same analyses indicated that loblolly pine had significantly higher basal area per acre, total volume, total green weight, and merchantable green weight growth when compared to slash pine for the 3 year period (Table 6).

Table 6. Average per acre growth for the species comparison study from age 11 to age 14.

Variable	**Loblolly Pine**	**Slash Pine**	**P Value for difference**
Mortality (trees/ac.)	9.6	14.9	0.0686
Basal Area Growth (ft^2/ac.)	29.23	23.32	**0.0032**
Total Volume Growth (ft^3/ac.)	832.88	736.93	**0.0171**
Merch. Volume Growth (ft^3/ac.)	833.30	776.21	0.1642
Total Weight Growth (tons/ac.)	23.748	20.571	**0.0054**
Merch. Weight Growth (tons/ac.)	23.428	21.237	**0.0494**

[3]Means with the same number are not significantly different at the →=0.05 level.

The results of the ANOVA for 3 year growth of both loblolly and slash pine on UGA soil types indicate that soil group 8 had lower basal area/ac., total volume/ac., merchantable volume/ac., total weight/ac., and merchantable weight/ac. growth than all other UGA soil classes (Table 7).

Table 7. Average per acre growth for both speices for all UGA soil groups in the species comparison study from age 11 to age 14.

	Soil Group							
Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mortality (trees/ac.)	17.7 [a]	8.6 [a]	16.3 [a]	-0.30 [a]	12.5 [a]	14.9 [a]	12.7 [a]	15.8 [a]
Basal Area Growth (ft^2/ac.)	26.94 [a]	26.57 [a]	29.77 [a]	29.99 [a]	28.82 [a]	26.93 [a]	26.76 [a]	14.22 [b]
Total Volume Growth (ft^3/ac.)	850.3 [a]	795.5 [a]	945.6 [a]	909.2 [a]	722.1 [a]	885.7 [a]	760.3 [a]	416.0 [b]
Merch. Volume Growth (ft^3/ac.)	850.5 [a]	824.7 [a]	962.1 [a]	904.4 [a]	743.0 [a]	899.2 [a]	781.7 [a]	402.0 [b]
Total Weight Growth (tons/ac.)	24.05 [a]	22.41 [a]	26.76 [a]	25.63 [a]	20.34 [a]	25.08 [a]	21.36 [a]	11.81 [b]
Merch. Weight Growth (tons/ac.)	23.61 [a]	22.84 [a]	26.74 [a]	25.05 [a]	20.55 [a]	25.11 [a]	21.59 [a]	11.17 [b]

The average stand growth variables were also analyzed by CRIFF soil groups. Results of this ANOVA indicate that, like the age 14 analyses, there are significant species * CRIFF soil type interactions for survival and trees per acre. There are no species*CRIFF group interactions for any of the other variables. Significant species differences (α =0.05) were found for basal area/ac., total volume/ac., merchantable volume/ac, total green weight/ac and merchantable green weight/ac with loblolly having higher growth rates for each of these variables. Soil Group G was inferior to all other soils for both loblolly and slash pine in terms of basal area growth, volume growth, and weight growth (Table 8).

Table 8. Average per acre growth for each CRIFF soil group in the species comaprison study from age 11 to age 14.[4]

	Soil Group					
Variable	**A**	**B**	**C**	**D**	**F**	**G**
Mortality (trees/ac.)	29.2 [a]	-10.4 [a]	9.2 [a]	9.7 [a]	14.4 [a]	15.8 [a]
Basal Area Growth (ft^2/ac.)	27.15 [a]	27.81 [a]	28.21 [a]	28.79 [a]	28.67 [a]	13.00 [b]
Total Volume Growth (ft^3/ac.)	924.5 [a]	860.7 [a]	893.8 [a]	782.8 [a]	861.4 [a]	375.3 [b]
Merch. Volume Growth (ft^3/ac.)	953.9 [a]	876.9 [a]	891.8 [a]	799.7 [a]	881.5 [a]	343.6 [b]
Total Weight Growth (tons/ac.)	26.251 [a]	24.305 [a]	25.264 [a]	22.044 [a]	24.277 [a]	10.642 [b]
Merch. Weight Growth (tons/ac.)	26.616 [a]	24.355 [a]	24.778 [a]	22.118 [a]	24.470 [a]	9.514 [b]

[4]Means with the same number are not significantly different at the α=0.05 level.

Discussion

The results of this analysis suggest that loblolly pine will exhibit equal or superior growth when compared to slash pine throughout the species comparison study region. In addition UGA soil group 8 and CRIFF soil type G appear to be inferior to the other soil types in this study. These soils comprise the somewhat excessive to excessively drained soils with no, or at least a very deep histic or argillic horizon. The droughty sand sites of the lower coastal plain would fit this description. There were no important species*soil interactions, and therefore no need to analyse the species differences on a soil by soil basis. Because some readers will be curious as to the gains of loblolly pine on certain soil types and the information is available, this information is included (Tables 9 and 10). It is interesting to note that loblolly pine performed as well or better than slash pine in terms of merchantable greeen weight across all soils except UGA soil 1 despite the fact that cronartium levels were higher for loblolly pine (Figures 2 & 3). Soil class 1 is a wet spodosol and would be the traditional slash pine site. It is also apparent that loblolly pine is growing more basal area per acre than slash pine at ages 11- 14 (Figure 4).

Another interesting trend is the that though there was no early advantage in terms of total volume or green weight, loblolly pine has attained more total volume and green weight as of age 14. The data from this study suggests that this has largely occurred since age 8 and that the production for the two species is diverging over time (Figures 5 & 6). Merchantable volume and weight have been higher for loblolly pine since age 5, perhaps because of differences in taper for the two species (Figures 7 & 8).

Conclusions

Information from this study is still being gathered, and rotation age information for most cooperators is still several years away. However, midrotation results indicate that loblolly pine is capable of maintaining higher basal areas and of producing more total and merchantable volume and green weight of wood on all sites within the study region. This gain in production exists despite the increased incidence of cronartium infection. In fact it is possible that the increased cronartium rates are a direct result of the increased growth exhibited by loblolly pine (Zutter et al., 1987). Another explanation is that loblolly pine is better capable of surviving cronartium infection. Therefore infected stems remain in the stand and contribute to stand volume, basal area, and weight. This theory correlates well with the superior survival of loblolly pine across all soil types observed in this study (Table 9 and 10). This study indicates that loblolly pine is capable of establishing more volume than slash pine at age 11, and increasing the gains in volume at least to age 14. The results collected at this time indicate that loblolly pine, with higher volumes, superior survival, and decreased risk of ice damage when compared to slash

pine, would be the logical species choice on all of the soils and sites covered by this study.

Table 9. Mean species differences by UGA soil group for all installations in the species comparison study.

Variable		Soil Group 1	2	3	4	5	6	7	8
% Cronartium	Loblolly	16.9	12.5	18.3	17.1	16.6	25.9	26.4	22.8
	Slash	14.2	11.8	19.2	9.2	15.7	22.4	26.9	20.7
	P Value	0.0966	0.8555	0.7683	**0.0004**	0.7454	0.1788	0.8574	0.4561
% Survival	Loblolly	72.6	68.7	76.7	77.1	70.7	74.9	67.3	59.4
	Slash	68.4	67.2	69.3	70.5	60.6	69.8	63.1	58.8
	P Value	0.1758	0.8963	**0.0410**	0.0974	**0.0125**	0.1219	0.2994	0.6047
Basal Area/ac.	Loblolly	89.6	94.5	110.0	99.8	100.5	114.8	96.7	72.5
	Slash	89.8	83.0	91.9	90.9	77.0	90.9	76.5	51.3
	P Value	0.9749	0.4582	**0.0495**	0.3833	**0.0465**	**0.0064**	**0.0004**	**0.0091**
Trees/ac.	Loblolly	525	499	557	560	513	544	488	431
	Slash	496	488	503	512	440	507	458	427
	P Value	0.1746	0.8955	**0.0407**	0.0975	**0.0124**	0.1216	0.2990	0.6047
Total Volume (ft^3/ac.)	Loblolly	1719	1870	2189	1959	1683	2369	1732	1315
	Slash	1980	1736	1985	1938	1600	1978	1549	1002
	P Value	0.0621	0.7695	0.3761	0.9349	0.4963	0.0698	0.0912	0.0722
Merch. Vol. (ft^3/ac.)	Loblolly	1285	1513	1769	1518	1382	1976	1383	1101
	Slash	1526	1299	1547	1481	1223	1526	1154	687
	P Value	0.0562	0.5077	0.2939	0.8695	0.5147	**0.0265**	**0.0342**	**0.0333**
Total Green Weight (tons/ac.)	Loblolly	48.6	52.9	62.0	55.4	47.5	67.1	48.9	37.2
	Slash	53.7	46.8	53.7	52.4	43.1	53.4	41.6	26.9
	P Value	0.1787	0.5608	0.2129	0.6656	0.2626	**0.0337**	**0.0245**	**0.0445**
Merch. Green Weight (tons/ac.)	Loblolly	35.8	42.3	49.4	42.4	38.5	55.4	38.5	30.9
	Slash	41.1	34.7	41.5	39.6	32.7	41.0	30.7	18.4
	P Value	0.1263	0.3798	0.1846	0.6594	0.3237	**0.0164**	**0.0138**	**0.0263**
# of Observations		17	14	17	19	18	19	17	16

Table 10. Mean species differences for each CRIFF soil group for all installations in the species comparison study.

Variable		Soil Group A	B	C	D	F	G
%Cronartium	Loblolly	25.8	19.1	16.1	15.9	30.2	19.9
	Slash	33.4	14.8	12.2	13.5	30.3	17.5
	P value	0.1704	0.0519	**0.0091**	0.1466	0.9582	0.3033
% Survival	Loblolly	81.7	74.7	75.7	70.6	63.9	63.7
	Slash	61.2	76.6	69.7	63.7	54.1	66.4
	P value	**0.0026**	0.4491	**0.0290**	**0.0147**	**0.0102**	0.9189
Basal Area/ac.	Loblolly	124.6	95.7	98.6	100.1	110.1	68.2
	Slash	85.5	91.9	90.8	81.6	81.2	50.9
	P value	**0.0370**	0.5776	0.2434	**0.0196**	**0.0001**	**0.0169**
Trees/ac.	Loblolly	593	542	550	512	464	463
	Slash	444	556	506	462	392	482
	P value	**0.0026**	0.4521	**0.0290**	**0.0147**	**0.0102**	0.9193
Total Volume (ft^3/ac.)	Loblolly	2573	1861	1964	1806	2131	1189
	Slash	1824	1966	1986	1706	1728	959
	P value	0.1233	0.5113	0.9001	0.4900	**0.0015**	0.1435
Merch. Vol. (ft^3/ac.)	Loblolly	2126	1474	1526	1461	1807	924
	Slash	1451	1457	1520	1311	1416	565
	P value	0.1335	0.8990	0.9663	0.4380	**0.0011**	**0.0487**
Total Green Weight (tons/ac.)	Loblolly	72.9	52.6	55.6	51.0	60.3	33.6
	Slash	49.3	53.2	53.8	46.0	46.6	25.6
	P value	0.0913	0.9070	0.7140	0.2060	**0.0003**	0.0890
Merch. Green Weight (tons/ac.)	Loblolly	59.5	41.2	42.7	40.7	50.5	25.9
	Slash	38.8	39.10	40.8	35.0	37.8	15.1
	P value	0.1053	0.5966	0.6805	0.2293	**0.0003**	**0.0403**
# of Observations		7	23	32	36	22	17

Figure 2. Merchantable green weight per acre to a 4" top (ob) for slash and loblolly pine by UGA soil group.

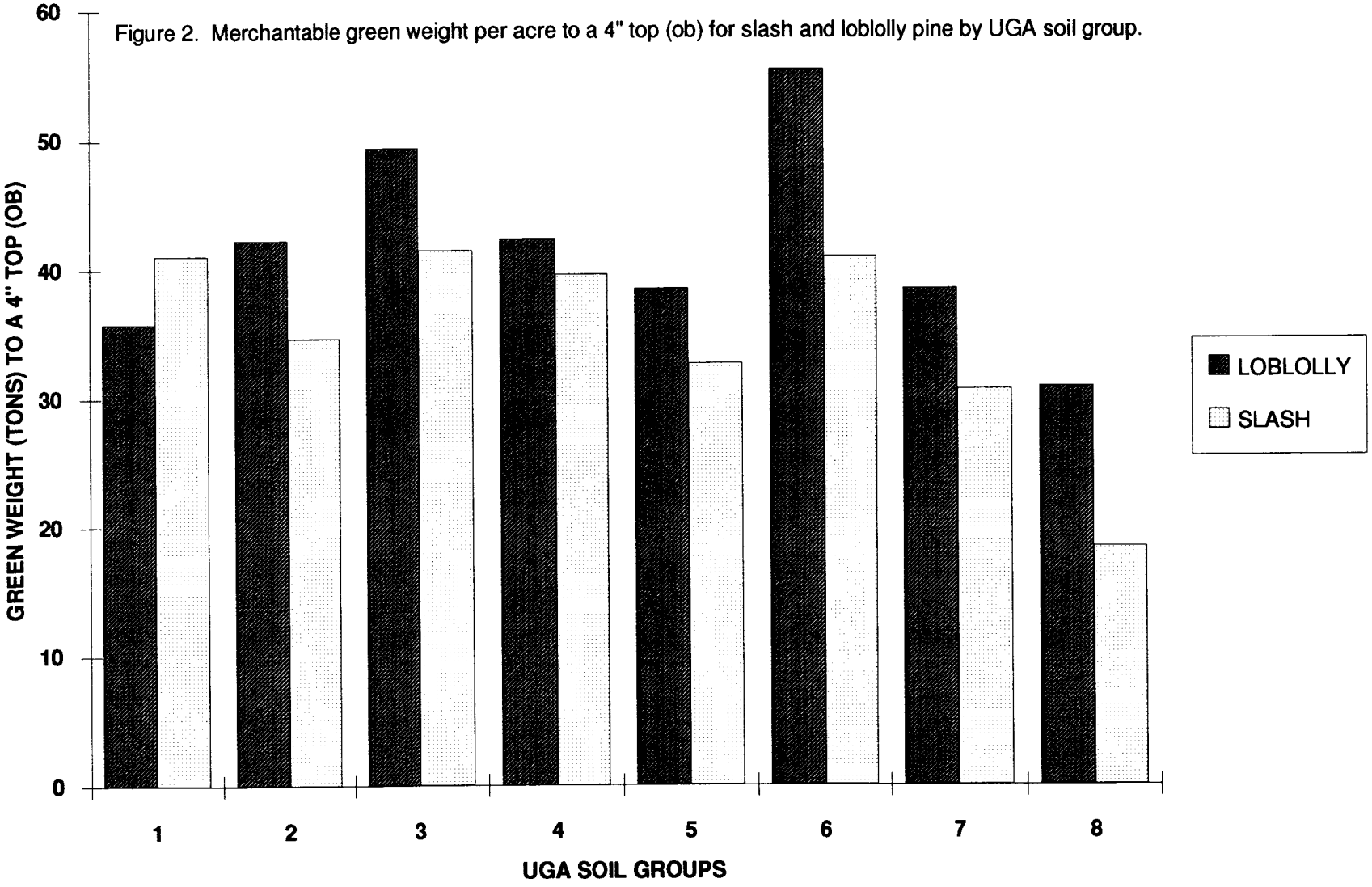


Figure 3. Merchantable green weight per acre to a 4" top for slash and loblolly pine by CRIFF soil group.

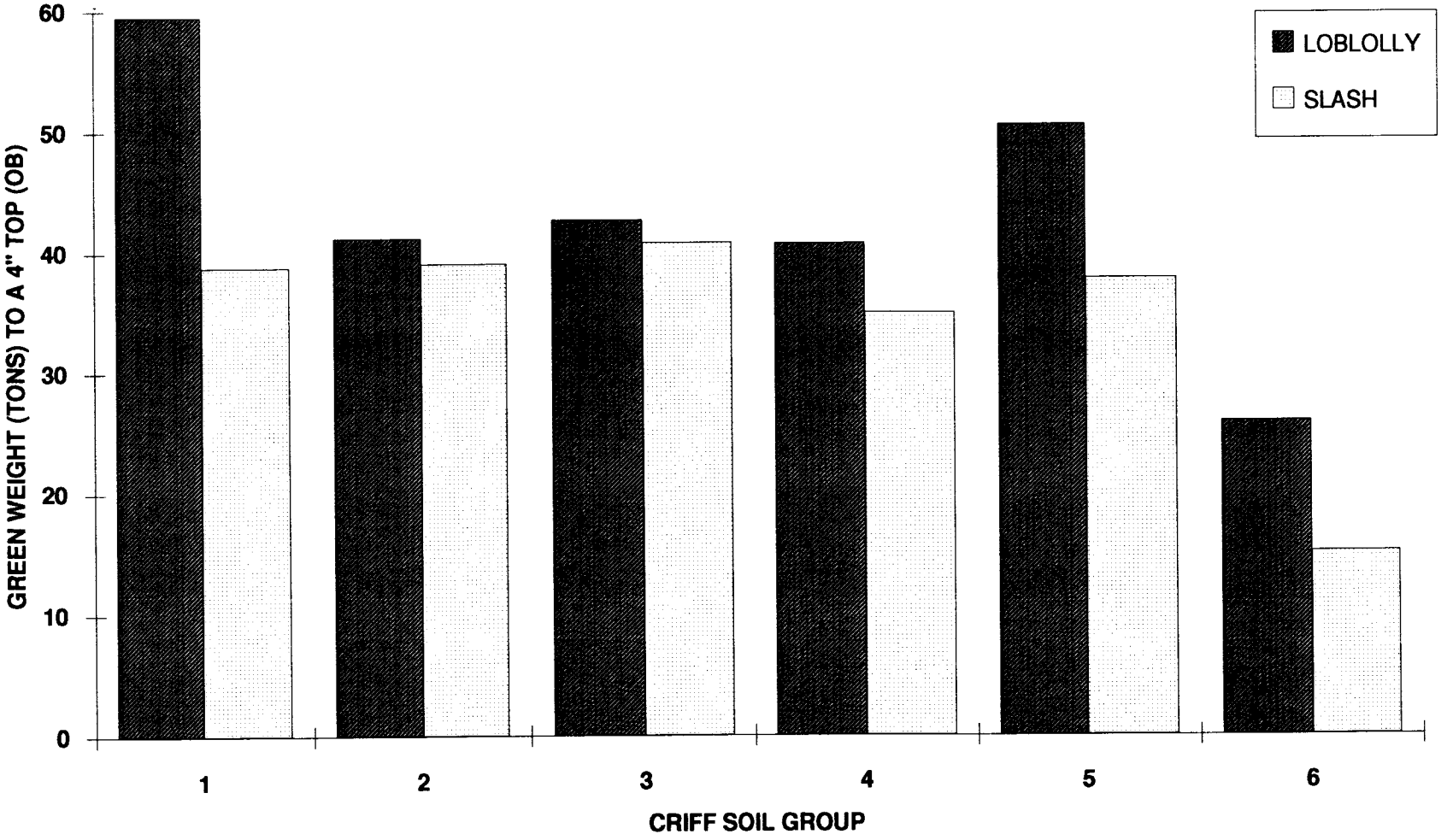


Figure 4. Basal area per acre vs age for loblolly and slash pine across all soil types.

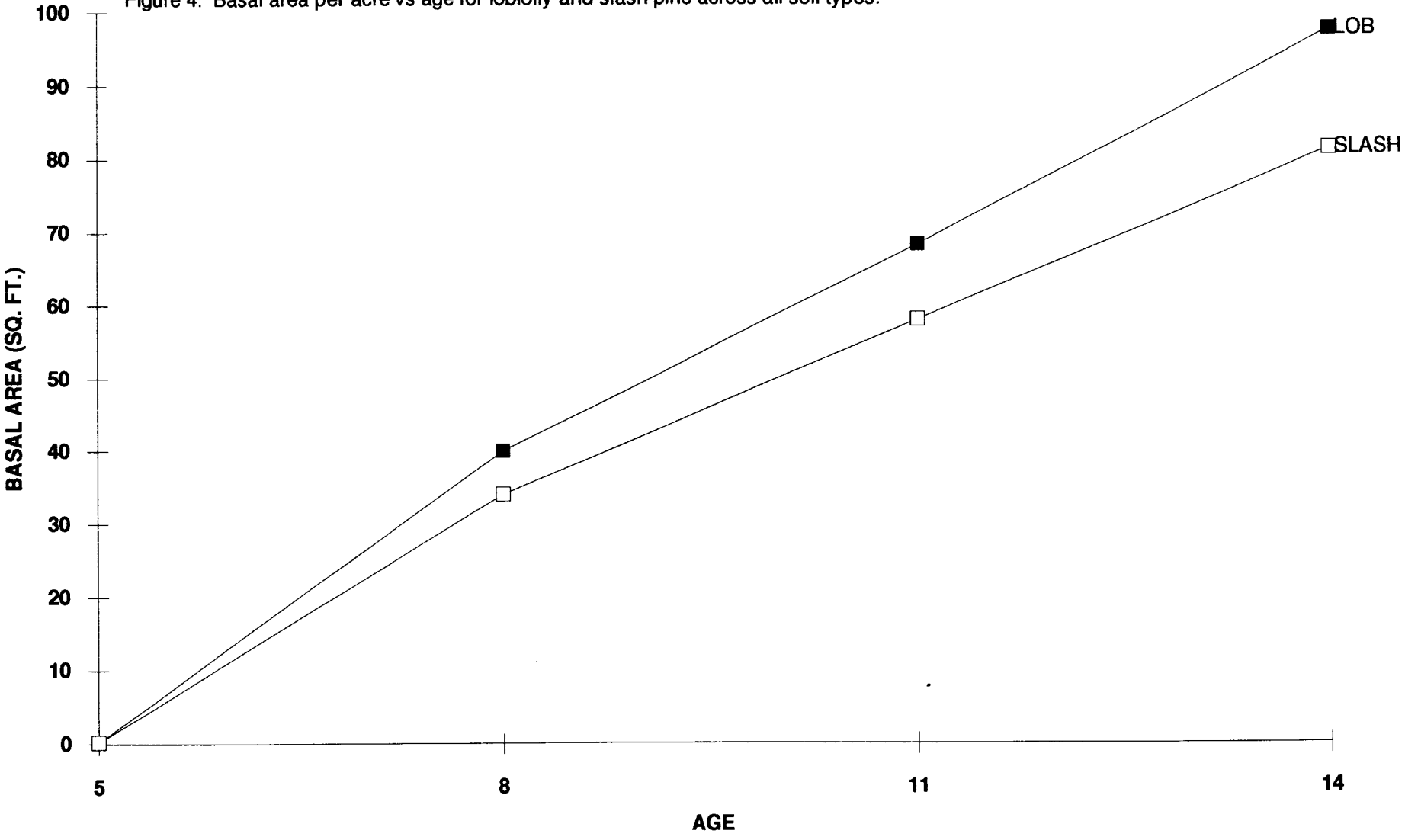


Figure 5. Average stand total volume per acre vs age for loblolly and slash pine across all soil types.

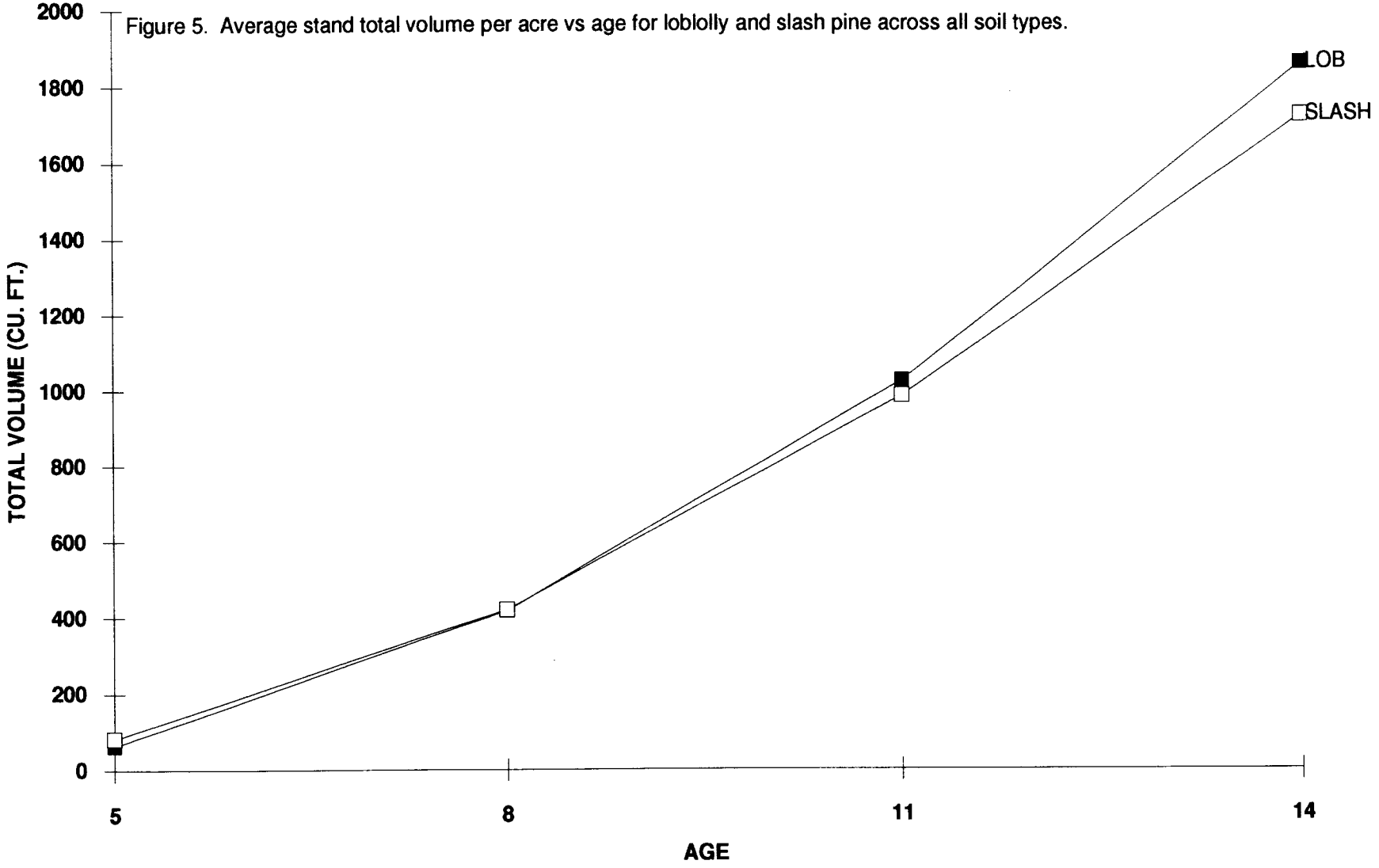


Figure 6. Average stand total green weight per acre vs age for loblolly and slash pine across all soil types.

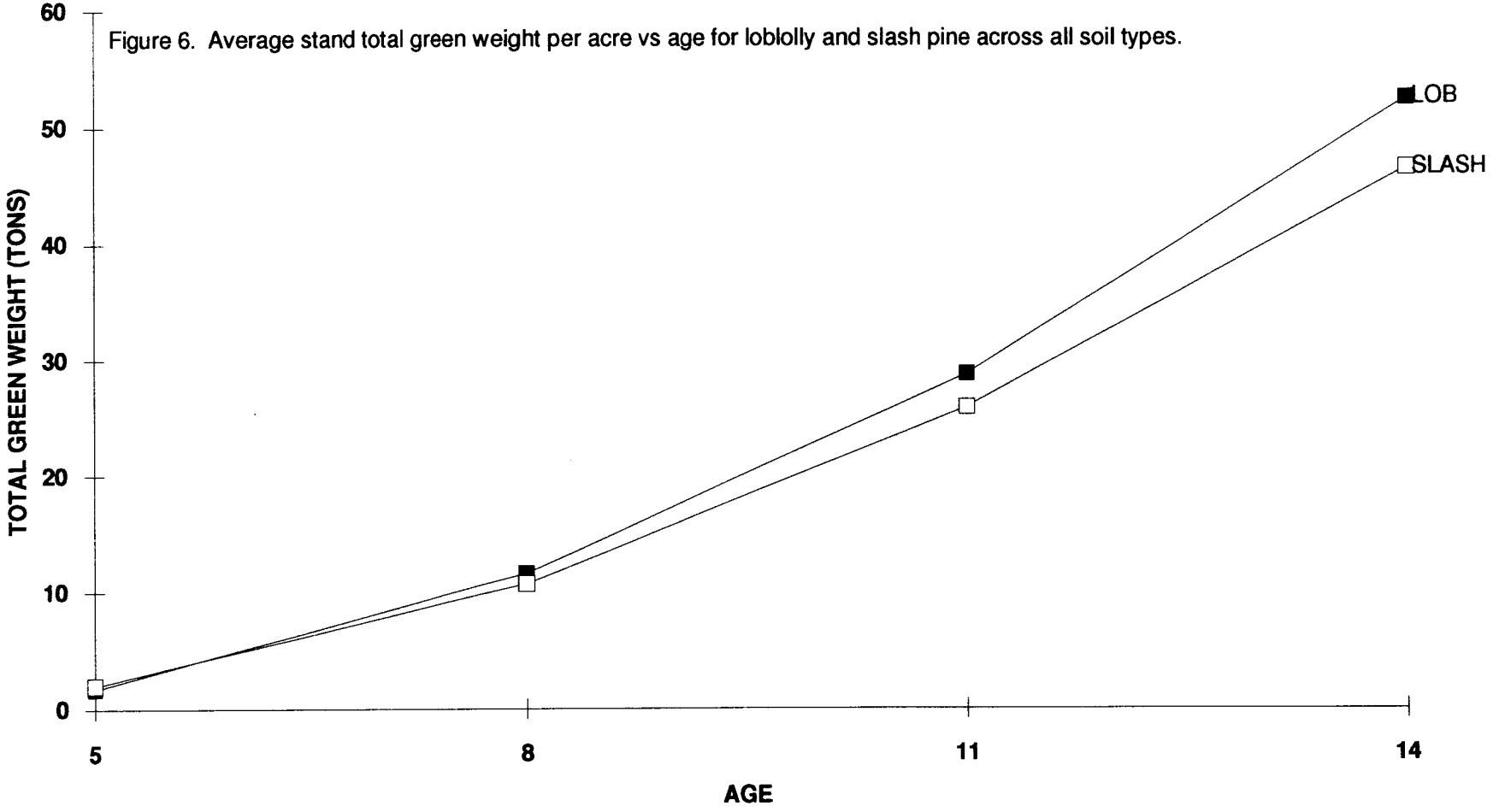


Figure 7. Average merchantable volume per acre to a 4" top vs age for loblolly and slash pine across all soil types.

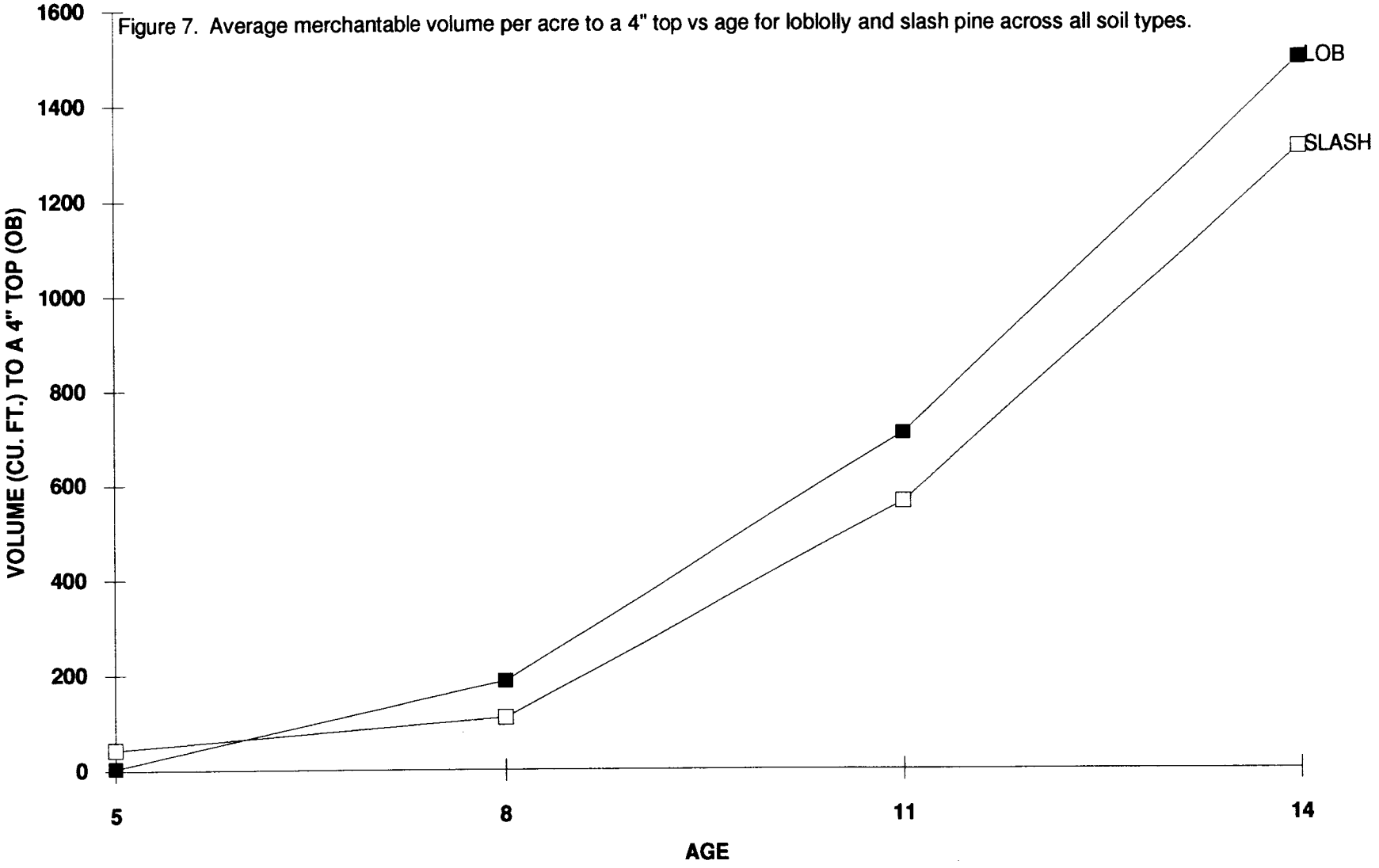
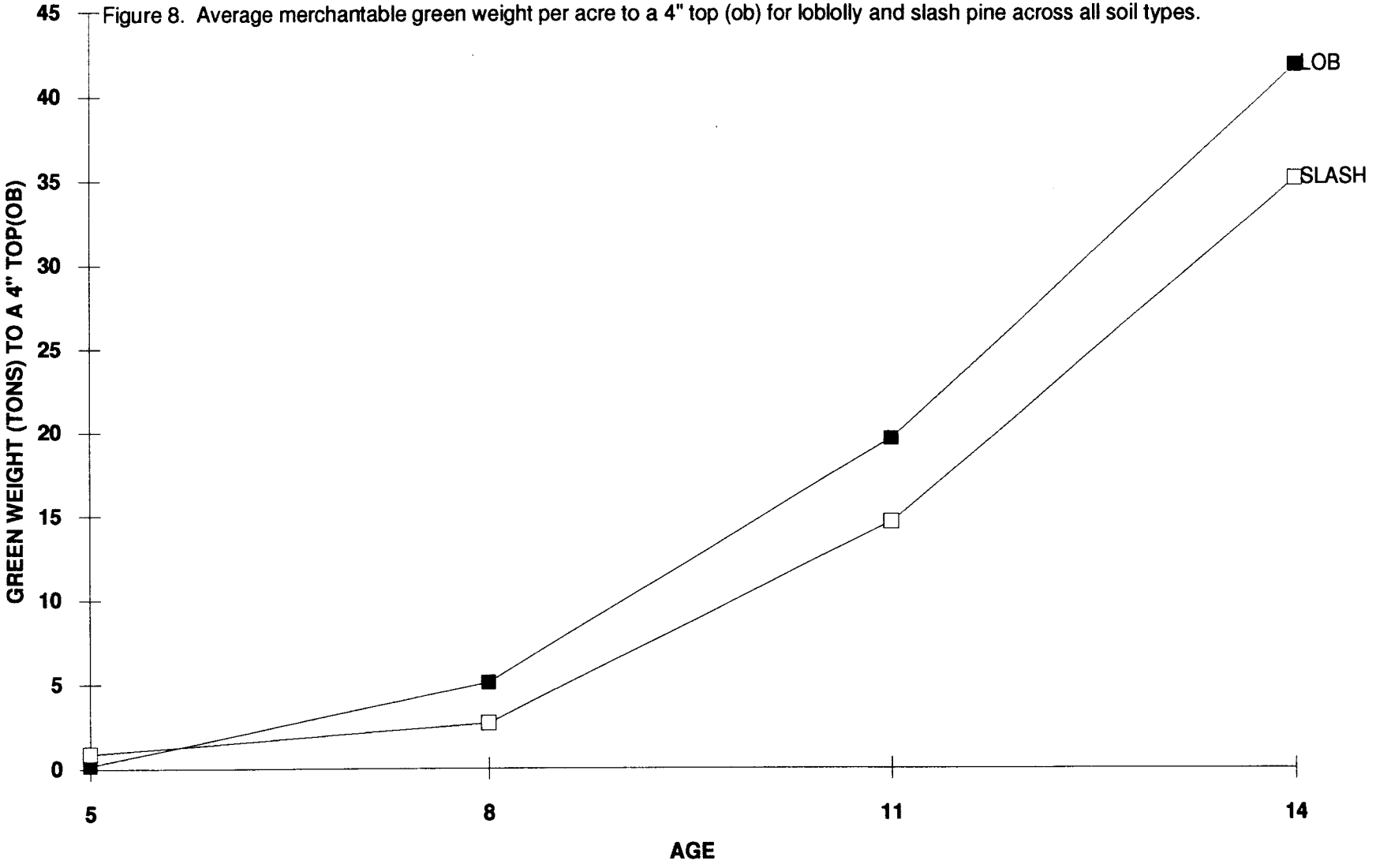


Figure 8. Average merchantable green weight per acre to a 4" top (ob) for loblolly and slash pine across all soil types.



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Appendix A

Analysis of variance (ANOVA) table for the loblolly-slash pine species comparison study.

Source of Variation	UGA Soil Groups DF	CRIFF Soil Groups DF
Soil	7	5
Error A[1]	133	135
Species	1	1
Soil*Species	7	5
Error B[2]	130	132
Total	278	278

[1] Error A is the variation of installations within a soil drainage class and is used to test for differences among soil drainage classes.

[2] Error B is used to test for differences between species and for soil*species interaction.