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Growth and Yield of Shortleaf Pine In the West Gulf Region

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SUMMARY

An equation system is developed to estimate current volume, projected basal area, and projected volume for merchantable even-aged stands of shortleaf pine in the West Gulf region. The estimates indicate the expected volumes from the woods-run conditions encountered in practice.

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INTRODUCTION

Shortleaf pine (*Pinus echinata* Mill.) with the widest range of any of the major southern pines, occurs in 22 states and is distributed over more than 440,000 square miles (U.S. Forest Service 1965). Nearly half of the entire shortleaf resource is located west of the Mississippi River (Sternitzke and Nelson 1970).

The most recent state-by-state field inventories conducted by the Forest Service during the nationwide survey report the standing volume of southern pine on commercial forest land[1] west of the Mississippi at 24 billion cubic feet (table 1), designating some 9 billion as shortleaf pine (table 2). With heaviest concentration in the Ouachita Mountains, shortleaf pine is the only conifer, except scattered juniper, found naturally above 700 feet elevation in Arkansas, Missouri, and Oklahoma (Mattoon 1915).

Although recognized as a valuable resource well-adapted to intensive management, natural even-aged stands of shortleaf pine in its western range are not adequately documented concerning growth and yield. Yields for normally stocked stands were reported (U.S. Forest Service 1976, Rev. 1929 ed.) based upon 188 plots located in the 12 southern states, and Turner (1937) later used the results to determine timber growth of severa1 Arkansas soils. Schumacher and Coile (1960) reported yields for well stocked stands from 74 plots in the Piedmont of North Carolina. Brinkman, Rogers, and Gingrich (1965) investigated the 10-year growth and yield of a 30-year old natural shortleaf pine stand, thinned to different densities, in southeastern Missouri. Sander and Rogers (1979) later offered 21-year results from the same study.

Existing information has several limitations in application to the West Gulf. Misc. Publ. 50 (U.S. Forest Service 1976, Rev. 1929 ed.) was based on temporary plots and the volumes are for normally stocked stands. Schumacher and Coile (1960), based on temporary plot data from another region, give yields for only well stocked conditions. The Missouri study, though based on remeasurement plots, is limited geographically and to one site and initial age.

The relationships presented here have been observed on inventor-y plots located throughout the main commercial range of shortleaf in the West Gulf. Inventory data have much more unexplained variation than do data from controlled studies, and variables tend to be clustered rather than dispersed throughout their range of possible values. This type of information, however, has the advantage of depicting actual conditions confronting forest managers.

DATA

The data cited here are from statewide surveys conducted about every 10 years by the Forest Service. Sample plots are located at the intersections of a 3-mile-square grid. At forested plots, information was collected according to standardized procedures[2] on 10-point samples systematically spaced 66 feet apart over about 1 acre.

Plots within the West Gulf Region were screened according to the following criteria: (1) at least half of the basal area in trees 5 inches and larger in the initial survey to be shortleaf pine; (2) al1 ten points recovered in the remeasurement tally; (3) site index information gathered from shortleaf sample trees; (4) the plots free of catastrophic mortality ; (5) the stands even-aged and natural in origin; and (6) plots undisturbed by logging or other activity between measurements. Dates of the surveys are Arkansas, 1969 and 1978; Louisiana,

Table 1. — *Volume of southernpine growing stock on commercial forest land west of the Mississippi River, by state*

State	Date of survey	Growing stock
		million cubic feet
Arkansas	1978	8,168.0
Louisiana1	1974	6,779.4
Missouri	1972	305.0
Oklahoma	1976	1,002.4
Texas	1975	8,075.2
All states		24,330.0

[1]Excludes southeast Louisiana parishes.

[1]Forest land that is producing or capable of producing crops of industrial wood and not withdrawn from timber utilization.

[2]Renewable Resources Evaluation Staff. Forest resources inventory work plan. Suppl., For. Serv. Handb. 4809.11, 83 p. U.S. Dep. Agric. For. Serv., South. For. Exp. Stn., New Orleans, La.

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1964 and 1974; east Oklahoma, 1966 and 1976; and east Texas, 1965 and 1975.

The 153 plots meeting the screening criteria are geographically charted in figure 1. As expected, their locations tend to follow the distribution of the resource. The numbers of plots by age, site, and density at the first measurement are shown in table 3. Average basal area at initial measurement was 51 square feet per acre; average stand age, 39 years; and site index, 67 feet (base age 50 years). Basal area ranged from ll to 127 square feet, site index varied from 44 to 101 feet, and stand age went from 14 to 81 years. Average basal area of softwood species other than shortleaf pine was 1 square foot. Hardwood basal area averaged 14 square feet per acre for the study plots. The breakdown by classes is shown in table 4.

The 4-state West Gulf region can be divided into two broad physiographic regions — the Coastal Plain and the Interior Highlands (figure 1). Louisiana and east Texas lie in the Coastal Plain, while east Oklahoma is in the Highlands. Arkansas is bisected diagonally by the line that divides the State into the two regions.

Table — *Volume of shortleafpine growing stock on commercial forest land west of the Mississippi River, by state*

State	Date of survey	Growing stock
		million cubic feet
Arkansas	1978	4,089.7
Louisiana[1]	1974	1,138.0
Missouri	1972	305.0
Oklahoma	1976	938.7
Texas	1975	2,539.1
All states		9,010.5

[1]Excludes southeast Louisiana parishes.

Site quality is lower in the Highland region. Three-fifths of the 153 plots fall in the Highland region, and their average site index is 62 feet. The average for the Coastal Plain plots is 81, a differential of 19 feet.

Merchantable cubic foot volumes of 3,861 shortleaf pine trees, 5 inches dbh and larger, were calculated from upper stem measurements taken during remeasurement surveys. The following volume equation was fitted to these data using weighted least squares.

$$Y=\beta_0+\beta_1 D^2H,$$

Table 3.-*Plot distribution by age, site index, and shortleaf pine basal urea at initial measurement*

Age	Site index	Basal area per acre					All basal areas
		≤20	21-40	41-60	61-80	80+	
years	*feet*	*square feet*					
≤30	≤60	3	5	1			9
	61-70	3	7		1		11
	71-80	1	3	4	2	2	12
	80+	1	5	8	3	1	18
Total		8	20	13	6	3	50
31-40	≤60	1	4	3		1	9
	61-70	1	4	7	6	2	20
	71-80		1	2	1		4
	80+		1	3	1	2	7
Total		2	10	15	8	5	40
41-50	≤60		1	3	5	1	10
	61-70		2	4	5	3	14
	71-80			2	1	1	4
	80+						
Total			3	9	11	5	28
50+	≤60	3	7	5	4		19
	61-70			7	3	3	13
	71-80			1		2	3
	80+						
Total		3	7	13	7	5	35
All ages	≤60	7	17	12	9	2	47
	61-70	4	13	18	15	8	58
	71-80	1	4	9	4	5	23
	80+	1	6	11	4	3	25
Total		13	40	50	32	18	153

Table 4.-Average hardwood basal area per-acre by shortleafpine basal area, site index, and age

Age	Site index	Basal area per acre <20	21-40	41-60	61-80	80+	All basal areas
years	*feet*	*square feet*					
≤30	≤60	10	15	11	6		13
	61-70	6	6	...	15		7
	71-80	11	5	14	4	4	8
	80+	0	8	11	0	38	9
All sites		8	8	12	4	15	9
31-40	≤60	4	11	10		4	9
	61-70	0	10	20	17	21	16
	71-80		17	17	4		12
	80+	.	8	24	8	8	14
All sites		2	10	i8	14	12	14
41-50	≤60	,	22	12	12	0	12
	61-70		26	6	22	21	18
	71-80	...		10	8	30	14
	80+		..				
All sites			25	9	16	19	15
50+	≤60	8	15	12	22	...	14
	61-70	.....		24	15	21	21
	71-80	.....		38	....	36	36
	80+	.....		.....			.
All sites		8	15	20	19	27	19
All ages	≤60	8	15	12	16	2	13
	61-70	5	10	18	18	21	16
	71-80	11	7	16	5	22	14
	80+	0	8	15	2	18	11
All sites		7	11	15	14	19	14

where:

Y = cubic foot volume, inside bark, from a 1-foot stump to a 4-inch diameter, outside bark,

D = diameter breast height, outside bark, in inches,

H = merchantable height in feet from the stump to a 4-inch top, outside bark,

B_i = coefficients to be estimated,

$1/D^2H$ = weighting factor.

The resulting equation was:

(1) $Y = .002701D^2H + .20438, R^2 = .976.$

The following variables were calculated for each plot: (1) shortleaf site index from equations developed b.y Farrar (1975); (2) stand age at first and second measurements; (3) basal area in square feet per acre of shortleaf pine trees 5 inches dbh and larger at the first measurement and the basal area of these same trees at remeasurement; and (4) solid wood volume from a 1-foot stump to a 4-inch top, outside bark, of trees included in the basal area calculations at both measurements. Individual tree volumes at both measurements were calculated using equation (1). The data were summarized according to procedures recommended by Beers and Miller (1964) for permanent point samples.

MODEL DEVELOPMENT

A system of three equations for predicting projected basal area, current volume, and projected volume-previously applied to loblolly pine (Murphy and Sternitzke 1979)—was used here. It is:

(2) $E[\ln(B_2)] = \ln(B_1)A_1/A_2 + \alpha_1(1 - A_1/A_2) + \alpha_2(1 - A_1/A_2)\ln(B_1) + \alpha_3(1 - A_1/A_2)(\ln(B_1))^2$

(3) $E[\ln(V_1)] = \beta_0 + \beta_1 S + \beta_2/A_1 + \beta_3 \ln(B_1),$

(4) $E[\ln(V_2)] = \beta_0 + \beta_1 S + \beta_2/A_2 + \beta_3 \ln(B_2),$

where:

A_i = stand age, in years at the ith occasion,

B_i = basal area in square feet per acre of shortleaf pine trees 5 inches dbh and larger, at the ith occasion,

S = site index in feet at base age 50,

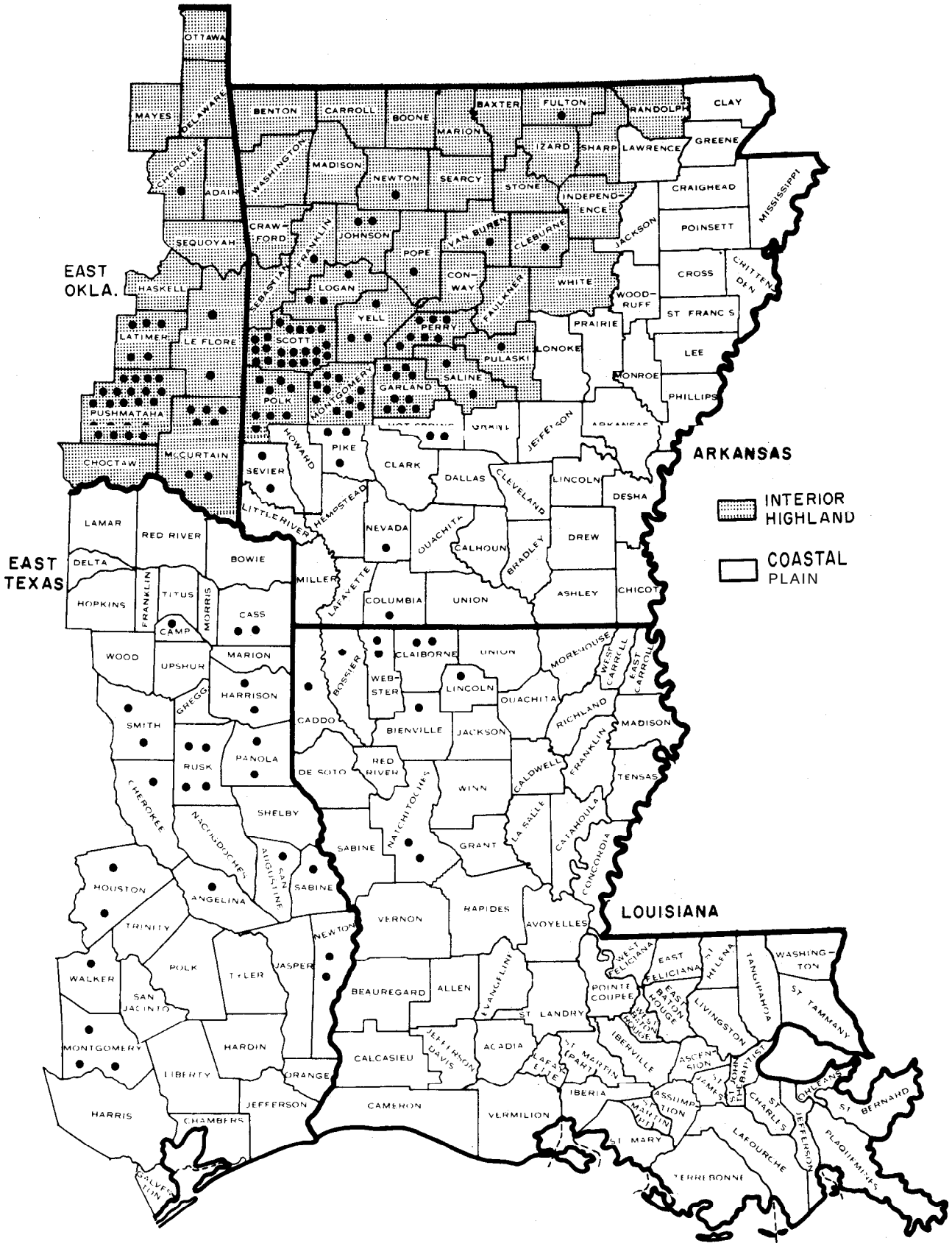

Figure 1.—*Geographical distribution of shortleaf pine sample plots in Arkansas, Louisiana, east Oklahoma, and east Texas.*

Table 5.-*Estimates of model coefficients and theirstandurd errors*

Parameter	Estimate	Standard error
α_1	1.16693	1.16740
α_2	1.64705	0.65080
α_3	-0.16381	0.08961
β_0	2.32977	0.10413
β_1	0.01242	0.00922
β_2	− 25.81221	1.10000
β_3	1.11906	0.02458

V_i = cubic foot volume (inside bark) per acre of shortleaf pine trees 5 inches dbh and larger from a 1-foot stump height to a 4-inch top diameter, outside bark, at the ith occasion,

α_i, β_i = parameters to be estimated.

The symbol E(. . .) denotes expected value of the quantity within the parentheses, and In is the logarithm to the base e. Equation (2) is used to determine ln(B_2), which then is used as an independent variable in equation (4). The equations were fitted using three-stage least squares (SAS Institute 1979). Details about using three-stage least squares for estimation of timber growth and yield equation systems may be found in Murphy and Sternitzke (1979).

The parameter estimates and their standard errors are shown in table 5. The stand volume equations accounted for 96 and 98 percent of the variation about mean cubic-foot volumes for current V_1 and projected V_2 stand volumes, respectively. The basal area equation explained 99 percent of the variation about mean projected basal area B_2. Table 6 provides additional information on the predictive performance of the equation system. The mean differences indicate that current volumes are overestimated and projected volumes and basal areas are slightly underestimated. The root mean square errors penalize large deviations from observed values. The percent mean difference and percent root mean square error depict deviations as a proportion of observed values.

APPLICATION

The use of the equations to determine volumes is straight-forward. Projected basal area can be determined by:

$$B_2 = \exp[\ln(B_1)A_1/A_2 + 1.16693(1 - A_1/A_2) + 1.64705(1 - A_1/A_2)\ln(B_1) - 0.16381(1 - A_1/A_2)(\ln(B_1))^2], \quad (5)$$

where exp [. . .] denotes that e is raised to the power within the brackets.

Current and projected volumes may be calculated by:

$$V_i = \exp(2.32977 + 0.01242S - 25.81221/A_i + 1.11906\ln(B_i)). \quad (6)$$

As an example, suppose estimates of current volume and projected volume and basal area in 10 years are wanted for a natural shortleaf pine stand 30 years old, having a site index of 65 feet and a basal area of 70 square feet per acre. The current yield is:

$$V_1 = \exp(2.32977 + 0.01242(65) - 25.81221/30 + 1.11906\ln(70)),$$
$$= 1131 \text{ cubic feet.}$$

Projected basal area is:

$$B_2 = \exp[\ln(70)30/40 + 1.16693(1 - 30/40) + 1.64705(1 - 30/40)\ln(70) - 0.16381(1 - 30/40)(\ln(70))^2],$$
$$= 89 \text{ square feet.}$$

Projected cubic foot volume is:

$$V_2 = \exp(2.32977 + 0.01242(65) - 25.81221/40 + 1.11906\ln(89)),$$
$$= 1835 \text{ cubic feet.}$$

The periodic annual increment for basal area in this example is 1.9 square feet, and the periodic annual

Table 6.—*Evaluation of model predictions*

Equation	Observed mean value	Criterion			
		$\bar{D}$[1]	RMSE[2]	$\bar{D}$%[3]	RMSE%[4]
	cubic feet			*percent*	
Current volume, V_1	923	59	213	8	24
Projected volume, V_2	1,507	-13	222	1	15
	square feet				
Basal area, B_2	66.3	-1.1	6.3	-1	10

[1]Mean difference $\bar{D} = \frac{1}{n}\sum(\hat{Y}_i - Y_i)$,

[2]Root mean squareerror $RSME = \sqrt{\frac{1}{n}\sum(\hat{Y}_i - Y_i)^2}$,

[3]Percent mean difference $\bar{D}\% = \frac{1}{n}\sum\left(\frac{\hat{Y}_i - Y_i}{Y_{i_1}}\right) \times 100$,

[4]Percent root mean square error $RMSE\% = \sqrt{\frac{1}{n}\sum\left(\frac{Y_i - Y_i^2}{Y_i}\right)}$ x100,

where n = number of observations, Y_i = actual value, and $\hat{Y}_i$ = predicted value.

volume increment is 70 feet.

Solutions for current volumes, given basal areas 60, 70, and 80 square feet per acre and site index 70, are in figure 2. Projected basal areas for these starting basal area levels at age 30 are shown in figure 3, and the associated cubic volume development for the same stands is depicted in figure 4.

Equations (5) and (6) or tables 7-14 in the appendix can be used to indicate expected yields under different thinning regimes. Suppose a 20-year-old shortleaf stand with 100 square feet of basal area occurs on land with a site index of 80 feet. Two management alternatives are being considered— (1) thin to 80 square feet at age 20 and every 10 years thereafter until age 50, when the stand is clearcut, or (2) thin back to 80 square feet at age 20 and make no further intermediate cuts during the 50-year rotation. What might be the yields under these two alternatives?

The current volume of a 20-year old stand with 100 square feet of basal area and site index 80 is reported in appendix table 14. The volume of this stand is 1,321 cubic feet. To find the volume of the stand after being cut back to 80 square feet, consult table 12, which gives volumes and basal areas for stands with a current density of 80 square feet. That volume is 1,029 cubic feet. The cut is 1,321−1,029 or 292 cubic feet. Still using table 12, the projected volume at age 30 of a residual stand of 80 square feet at age 20 is 2,178 cubic feet. The volume after cut at age 30 with basal area of 80 square feet is 1,582 cubic feet, and the cut is 2,178−1,582 or 596 cubic feet. The before- and after-cut volumes and the harvest volumes for ages 40 and 50 can be found in like manner. The standing volume at age 50 is 2,704 cubic feet according to table 12. At this time the entire stand is harvested.

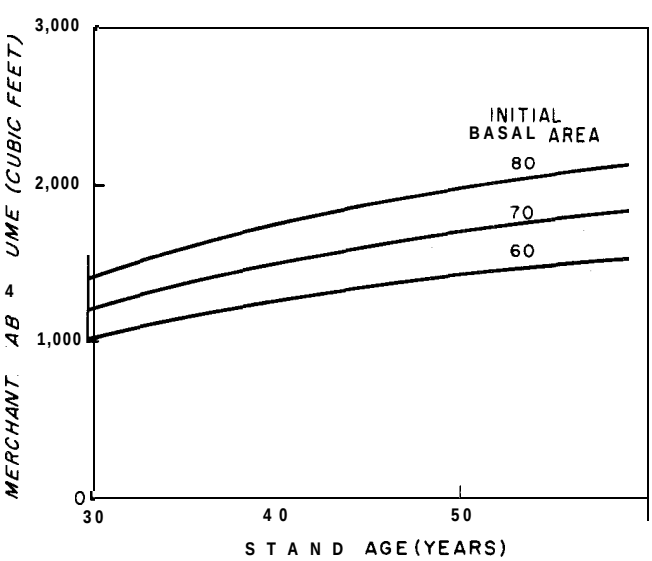

Figure 2.— *Relationship of current yield to basal urea and age for natural even-aged shortleaf pine stands in the West Gulf, site index 70.*

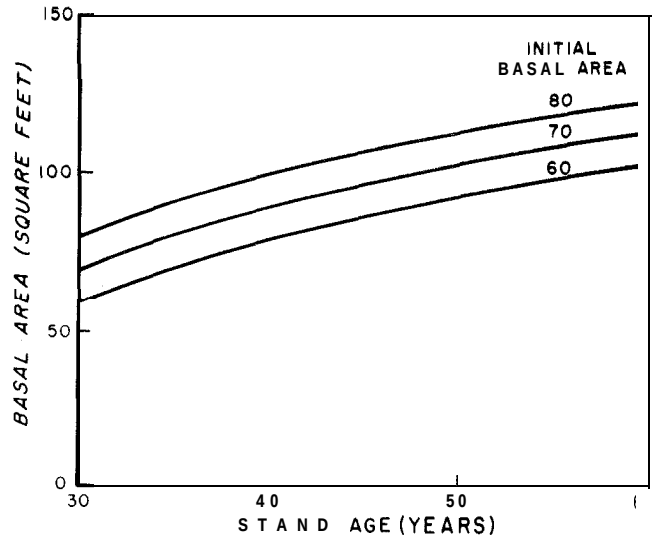

Figure 3.—*Relationship of projected basal urea to age* and *initial basal urea at age 30 for natural even-aged shortleaf pine stands in the West Gulf.*

Given these stand volumes and cuts, the following tabulation can be constructed.

Age	Before cut	After cut	Yield
years	cubic feet		
20	1,321	1,029	292
30	2,178	1,582	596
40	2,494	1,962	532
50	2,704	0	2,704
Total			4,124

The total yield production for this alternative is 4,124 cubic feet.

The after-cut basal area for the second alternative is the same at age 20, 80 square feet with the identical cut volume. Only one additional item of information is required to find the total yield- the projected volume of the stand at age 50 years, given a basal area of 80 square feet at age 20. In table 12, that volume is listed as 3,969 cubic feet. The total yield would be 3,969+292 or 4,261 cubic feet. Hence, the management alternative of thinning every 10 years yields slightly less merchantable cubic foot volume than no thinning beyond age 20. No inferences should be made from this example regarding either cubic volume production for other merchantability standards or board foot yields. The underlying assumption in calculating all these yields is that a stand of a given age and site cut back to a residual density will have the same volume and behave in a manner similar to an unthinned stand of the same density.

Another potential application of the equations is to find volume differentials existing between different areas. For example, it was previously stated that the site index for the Coastal Plain plots used in this study was 81 feet versus 62 feet for those in the Interior

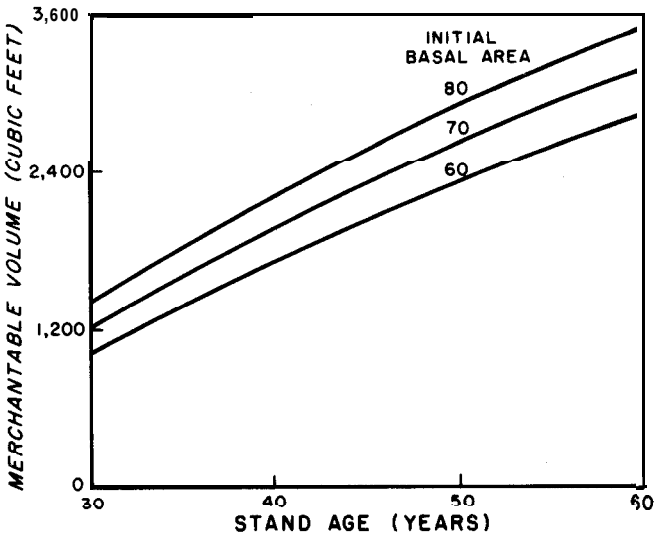

Figure 4.—*Relationship of projected volume to age and initial basal area at age 30 for natural even-aged shortleaf pine stands in the West Gulf, site index 70.*

Highlands. If these averages are indicative of the site differences between these regions, the stand volume equation can be used to calculate the difference in volume production expected for stands of similar ages and densities on average sites for the two regions. The difference can be calculated as a ratio V_C/V_H, where V_C is the volume for the average site on the Coastal Plain and V_H is the volume for the average site in the Highlands.

It is:

$$V_C/V_H = \exp[2.32977 + 0.01242(81) - 25.81221/A + 1.11906\ln(B) - 2.32977 - 0.01242(62) + 25.81221/A - 1.11906\ln(B)],$$
$$= \exp[0.01242(81-62)],$$
$$= 1.27.$$

The expected yield for an average site in the Coastal Plain is 27 percent greater than the average site in the Highlands for stands identicalin age and density.

The user should be aware that predictions are better for stands that fall within the range of the sample data (table 3). Predictions outside this range can be made, provided that the estimates are treated with caution and judged by the experience of the user. Projections of 10 years can be approached with the greatest confidence, since this was the average remeasurement period for the plots used in this study. Although projected basal areas and volumes look realistic and reasonable for long-term projections, they should be used with the awareness that the estimates will be less reliable as the length of the projection period increases.

The volume and density increases measured in this study involve only shortleaf trees that were 5 inches and greater at the first measurement. That ingrowth is not included should be considered when using these models, particularly for younger age classes where ingrowth can be significant.

The examples of potential applications are not exhaustive. The tables and equations should provide helpful guides to forest managers who are faced with making decisions for forests paralleling woods-run stands represented by this study.

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Appendix

Table 7.—Current and projected merchantable cubic-foot volumes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area— 30 square feet.

Xnitial age (Years)	Final age	Site index 50	60	70	80	90	100	Pro jectcd basal area (sq. ft.)
		(Cubic feet)						
20	20	237	268	303	343	389	440	30
	30	630	713	808	915	1036	1172	49
	40	1028	1164	1318	1493	1690	1913	63
	50	1380	1562	1769	2002	2267	2567	73
	60	1678	1900	2151	2436	2758	3123	80
	70	1930	2185	2474	2802	3172	3592	86
	80	2144	2427	2748	3112	3523	3989	91
30	30	364	412	466	528	598	677	30
	40	681	771	873	989	1119	1267	43
	50	992	1123	1272	1440	1631	1846	54
	60	1275	1444	1635	1851	2095	2373	63
	70	1525	1727	1955	2214	2507	2838	70
	80	1745	1975	2237	2532	2867	3246	75
40	40	451	511	578	655	741	839	30
	50	714	808	915	1036	1173	1328	40
	60	969	1097	1242	1406	1592	1803	49
	70	1205	1365	1545	1749	1981	2243	56
	80	1420	1608	1820	2061	2333	2642	63
50	50	513	581	658	745	843	955	30
	60	736	833	944	1068	1210	1370	38
	70	952	1078	1221	1382	1565	1772	46
	80	1155	1308	1481	1677	1899	2150	52
60	60	559	633	717	812	919	1041	30
	70	753	852	965	5092	1237	1401	37
	80	940	1065	1206	1365	5.545	1750	43
70	70	595	673	762	863	977	1107	30
	80	765	867	981	1111	1258	1424	36
80	80	623	705	798	904	1024	1159	30

Table 8.--Current and projected nerchantable cubic-foot volunes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area-- 40 square feet.

Initial age (Years)	Final age	Site index so	60	70	80	90	100	Pro iected basal apea (sq. ft.)
		(Cubic feet)						
20	20	326	370	418	474	536	607	40
	30	823	931	1055	1 194	1352	1531	62
	40	1306	1479	1674	1896	2146	2430	78
	50	1723	1951	2209	2502	2832	3207	89
	60	2073	2348	2658	3010	3408	3858	97
	70	2366	2679	3033	3434	3889	4403	ío3
	80	2612	2958	3349	3792	4293	4861	108
30	30	502	568	643	729	825	934	40
	40	902	1021	1156	1309	1482	1678	56
	50	1281	1451	í643	1860	2106	2384	68
	60	1619	1834	2076	2351	2662	3054	78
	70	1914	2568	2454	2779	3146	3562	85
	80	2171	2458	2783	3151	3567	4039	92
40	40	622	705	798	903	1023	1158	40
	SO	953	1078	1221	1383	1565	1772	52
	60	1265	1432	5.622	1836	2079	2354	62
	70	1549	1754	1986	2249	2546	2883	71
	80	í803	2042	2312	2618	2944	33136	78
50	50	708	802	908	1028	íi64	13i8	40
	60	988	1119	1267	1434	1624	1839	50
	70	1253	1419	1607	1819	2060	2332	58
	80	í498	í696	1921	2175	2462	2788	66
40	60	772	874	989	íj.20	1268	í436	40
	70	1014	1148	í300	1472	1667	1887	48
	RO	1245	1410	1596	1807	2046	2316	56
70	70	821	929	5052	1191	1349	íS27	40
	80	1034	1171	1326	1501	1700	1925	47
80	80	859	973	1102	1247	1412	1599	40

Table 9.--Current and projected merchantable cubic-foot volumes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area-- 50 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	100	Projected basal area (sq. ft.)
		(Cubic feet)						
2n	20	419	474	537	608	689	780	50
	30	1005	1138	1288	1458	1651	1870	74
	40	1556	1762	1995	2258	2557	2895	91
	50	2023	2290	2593	2936	3324	3764	102
	60	2409	2728	3089	3497	3960	4483	111
	70	2730	3095	3500	3962	4486	5080	117
	80	2998	3395	3843	4352	4927	5579	122
30	30	644	729	826	935	1059	1199	50
	40	1115	1262	1429	1618	1832	2075	67
	50	1549	1754	1986	2249	2546	2883	81
	60	1929	2184	2473	2800	3171	3590	91
	70	2257	2555	2893	3275	3707	4199	99
	80	2538	2874	3254	3684	4171	4723	105
40	40	799	905	1024	1160	1313	1487	50
	50	1187	1344	1521	1723	1950	2208	63
	60	1545	1749	1981	2242	2539	2875	74
	70	1865	2112	2391	2707	3065	3475	83
	80	2148	2432	2754	3118	3531	3998	91
50	50	909	1029	1165	1319	1494	1691	50
	60	1237	1401	1586	1796	2033	2302	61
	70	1542	1746	1977	2238	2534	2869	70
	80	1819	2059	2331	2640	2989	3384	78
60	60	991	1122	1270	1438	1628	1843	50
	70	1274	1443	1634	1850	2094	2371	59
	80	1539	1743	1974	2235	2530	2865	67
70	70	1053	1193	1350	1529	1731	1960	50
	80	1303	1475	1671	1892	2142	2425	58
80	80	1103	1.249	1414	1601	1813	2053	50

Table 10.--Current and projected nerchantoble cubic-foot volumes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area-- 60 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	100	Projected basal area (sq. ft.)
		(Cubic feet)						
20	20	514	582	659	746	845	956	60
	30	1178	1333	1510	1710	1936	2192	86
	40	1783	2019	2286	2588	2930	3318	102
	50	2287	2589	2931	3319	3758	4255	114
	60	2699	3056	3460	3918	4436	5023	122
	70	3039	3441	3896	4411	4994	5655	129
	80	3321	3760	4258	4821	5458	6180	134
30	30	790	895	1013	1147	1299	1470	60
	40	1322	1496	1694	1918	23172	2459	78
	50	1800	2038	2307	2612	2958	3349	92
	60	2211	2503	2834	3209	3633	4114	102
	70	2561	2900	3283	3717	4209	4765	111
	80	2859	3238	3666	4151	4699	5321	117
40	40	980	1109	1256	1422	1610	1823	60
	50	1416	1604	1816	2056	2328	2636	74
	60	1811	2050	2321	2628	2976	3370	86
	70	2158	2444	2767	3133	3547	4016	95
	80	2462	2787	3156	3573	4046	4581	102
50	50	1115	1262	1429	1618	1832	2074	60
	60	1483	1679	1901	2153	2438	2760	72
	70	1819	2059	2332	2640	2989	3385	81
	80	2120	2400	2717	3077	3484	3944	90
60	60	1215	1376	1557	1763	1997	2261	60
	70	1533	1736	5.965	2225	2519	2852	70
	80	1825	2066	2340	2649	2999	3396	78
70	70	1292	1463	1656	1875	2123	2404	60
	80	1571	1779	2014	2281	2582	2924	69
80	80	1353	1532	1734	5964	2223	2517	60

Table 11.--Current and projected merchantable cubic-foot volumes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area-- 70 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	100	Projected basal area (sq. ft.)
		(Cubic feet)						
20	20	611	691	783	886	1004	1136	70
	30	1343	1520	1721	1949	2207	2499	96
	40	1991	2255	2553	2890	3272	3705	113
	50	2522	2856	3233	3661	4145	4693	124
	60	2953	3343	3785	4286	4853	5494	133
	70	3305	3742	4236	4797	5431	6149	139
	80	3596	4071	4610	5219	5909	6691	144
30	30	939	1063	1204	1363	1543	1747	70
	40	1523	1724	1952	2210	2502	2833	89
	50	2035	2304	2609	2954	3344	3787	103
	60	2469	2796	3165	3584	4058	4594	113
	70	2835	3210	3634	4115	4659	5275	121
	80	3144	3560	4031	4564	5167	5851.	127
40	40	1164	1318	1492	1690	1913	2166	70
	50	1642	1859	2105	2383	2698	3055	85
	60	2065	2338	2647	2997	3393	3842	96
	70	2432	2753	3117	3530	3996	4525	106
	80	2749	3113	3525	3991	4519	5116	113
50	50	1325	1500	1698	5.923	2177	2465	70
	60	1726	1955	2213	2506	2837	3212	82
	70	2086	2362	2674	3028	3428	3882	92
	80	2404	2722	3082	3490	3951	4474	100
60	60	1444	1634	1851	2 0 %	2372	2686	70
	70	1789	2026	2294	2597	2941	3330	80
	80	2102	2380	2695	3051	3455	3912	89
70	70	1535	1738	1968	2228	2523	2856	70
	80	1838	2081	2357	2668	3021	3421	79
80	80	1608	1820	2061	2333	2642	2991.	70

Table 12.--Current and projected merchantable cubic-foot volumes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area-- 80 square feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	100	Projected basal area (sq. ft.)
		(Cubic feet)						
20	20	709	803	909	5029	1165	1319	80
	30	1501	1699	1924	2178	2466	2793	106
	40	2183	2472	2799	3169	3588	4063	123
	50	2734	3096	3505	3969	4493	5088	134
	60	3177	3597	4072	4611	5220	5911	142
	70	3536	4003	4533	5532	5811	6579	148
	80	3831	4338	4912	5561	6297	7129	152
30	30	1090	1234	1398	1582	1792	2029	80
	40	1718	1945	2202	2494	2823	3197	99
	50	2257	2555	2893	3276	3709	4200	113
	60	2707	3065	3471	3930	4449	5038	123
	70	3083	3491	3952	4475	5067	5737	131
	80	3399	3848	4357	4933	5586	6324	137
40	40	1352	1531	1733	1.962	2222	2515	80
	50	1863	2110	2389	2704	3062	3467	95
	60	2308	2613	2958	3349	3792	4294	106
	70	2688	3044	3446	3902	4418	5003	115
	80	3015	3413	3865	4376	4955	5610	123
50	50	1538	1741	1972	2232	2528	2862	80
	60	1967	2227	2521	2855	3232	3660	92
	70	2344	2654	3005	3403	3853	4362	102
	80	2674	3028	3428	3882	4395	4976	110
60	60	1676	1898	2149	2433	2755	3119	80
	70	2044	2315	2621	2967	3360	3804	90
	80	2372	2686	3045	3443	3899	4414	99
70	70	1783	2018	2285	2587	2929	3317	80
	80	2104	2383	2698	3054	3458	3916	89
80	80	1867	2113	2393	2709	3068	3473	80

Table 13. --Current and projected merchantable cubic-foot volumes and projected basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal area-- 90 square feet .

Initial age (Years)	Final age (Years)	Site index 50	60	70	80	90	100	Projected basal area (sq. ft.)
		(Cubic feet)						
20	20	809	916	1037	1174	1329	1505	90
	30	1652	1871	2118	2399	2716	3075	1 1 h
	40	2362	2674	3028	3428	3882	4395	132
	SO	2926	3313	3751	4248	4809	5445	142
	60	3376	3822	4328	4900	5548	6281	150
	70	3738	4233	4792	5426	6144	6956	155
	80	4036	4569	51.74	5858	6632	7510	159
30	30	1244	1408	1595	1805	2044	2314	90
	40	1909	2161	2447	2770	3137	3551	1 09
	50	2468	2794	3163	3582	4055	4592	122
	60	2929	3316	3754	4251	4813	5450	132
	70	3310	3747	4243	4804	5439	6159	139
	80	3628	4108	4651	5266	5962	6751	145
40	40	1542	1746	5.977	2239	2535	2870	90
	50	2081	2356	2668	3020	3420	3872	1 os
	60	2541	2877	3257	3688	4176	4728	1 ib
	70	2930	3318	3757	4253	4816	5453	125
	130	3261	3692	4181	4734	5360	6068	132
SO	50	1755	1987	2250	254'7	2884	3265	90
	60	2204	2496	2826	3200	3623	4102	1 02
	70	2594	2937	3326	3766	4264	4828	112
	80	2932	3319	3758	4255	4818	5455	120
60	60	1912	2165	2452	2776	Ji43	3559	YO
	70	2297	2601	2945	3334	3775	4274	1 0 0
	80	2635	2984	3378	3825	4331	4904	109
70	70	2034	2303	2607	2952	3342	3784	90
	B0	2369	2682	3037	3439	3893	4408	99
80	80	2130	2411	2730	3091	3500	3963	90

Table 14.--Current and projected merchantable cubic-foot volumes and projrcted basal area per acre for natural even-aged stands of shortleaf pine in the West Gulf, initial basal arca--i00 squara feet.

Initial age (Years)	Final age	Site index 50	60	70	80	90	5.00	Projected basal area (sq. ft.)
		(Cubic feet)						
20	20	910	1031	1167	1321	1496	1694	100
	30	1799	2036	2306	2611	2956	3347	125
	40	2528	2863	3241	3670	4155	4705	140
	50	3102	3512	3976	4502	S097	5771	íso
	60	3554	4024	4556	5159	584 1	665.4	ís7
	70	3917	4435	5022	5686	6438	7289	ib2
	80	4214	4771	5402	6117	6925	7841	166
30	30	1399	1585	1794	2031	2300	2604	100
	40	2095	2372	2685	3040	3442	3898	118
	S0	2668	3021	3420	3873	4385	4965	131
	60	3135	3550	4019	4551	5152	5834	140
	70	3518	3983	4510	5106	5782	6546	í47
	80	3836	4343	4917	5567	6304	7537	152
40	40	1735	1965	2225	2519	2852	3229	100
	S0	2295	2599	2942	3331	3772	4271	íí4
	60	2765	3131	3545	4014	4545	5146	125
	70	3159	3577	4050	4586	5192	S879	í33
	80	3491	3953	4475	5067	5737	6496	í40
S0	50	1974	2235	2531	2866	3245	3674	100
	60	2439	2762	3127	3541	4009	4539	íí2
	70	2837	3212	3637	4118	4663	5279	121
	80	3178	3598	4074	4612	5222	5913	129
60	60	2152	2436	2758	3123	3536	4004	100
	70	2548	2885	3266	3698	4187	4741	íío
	80	2892	327S	3708	4198	4753	5382	íí8
70	70	2288	2591	2933	3321	3760	4258	100
	80	2632	2981	3375	3821	4326	4898	ío9
80	80	2396	2713	3072	3478	3938	4459	100

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1981. Growth and yield of shortleaf pine in the West Gulf region. U.S. Dep. Agric. For. Serv. Res. Pap. SO-169, 15 p. South. For. Exp. Stn., New Orleans, La.

An equation system is developed to estimate current volume, projected basal area, and projected volume for merchantable even-aged stands of shortleaf pine in the West Gulf region.

Additional keywords: Volume prediction, basal area projection, stand volume, natural stand yields.