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Predicting Stand and Stock Tables from a Spacing Study in Naturally Regenerated Longleaf Pine

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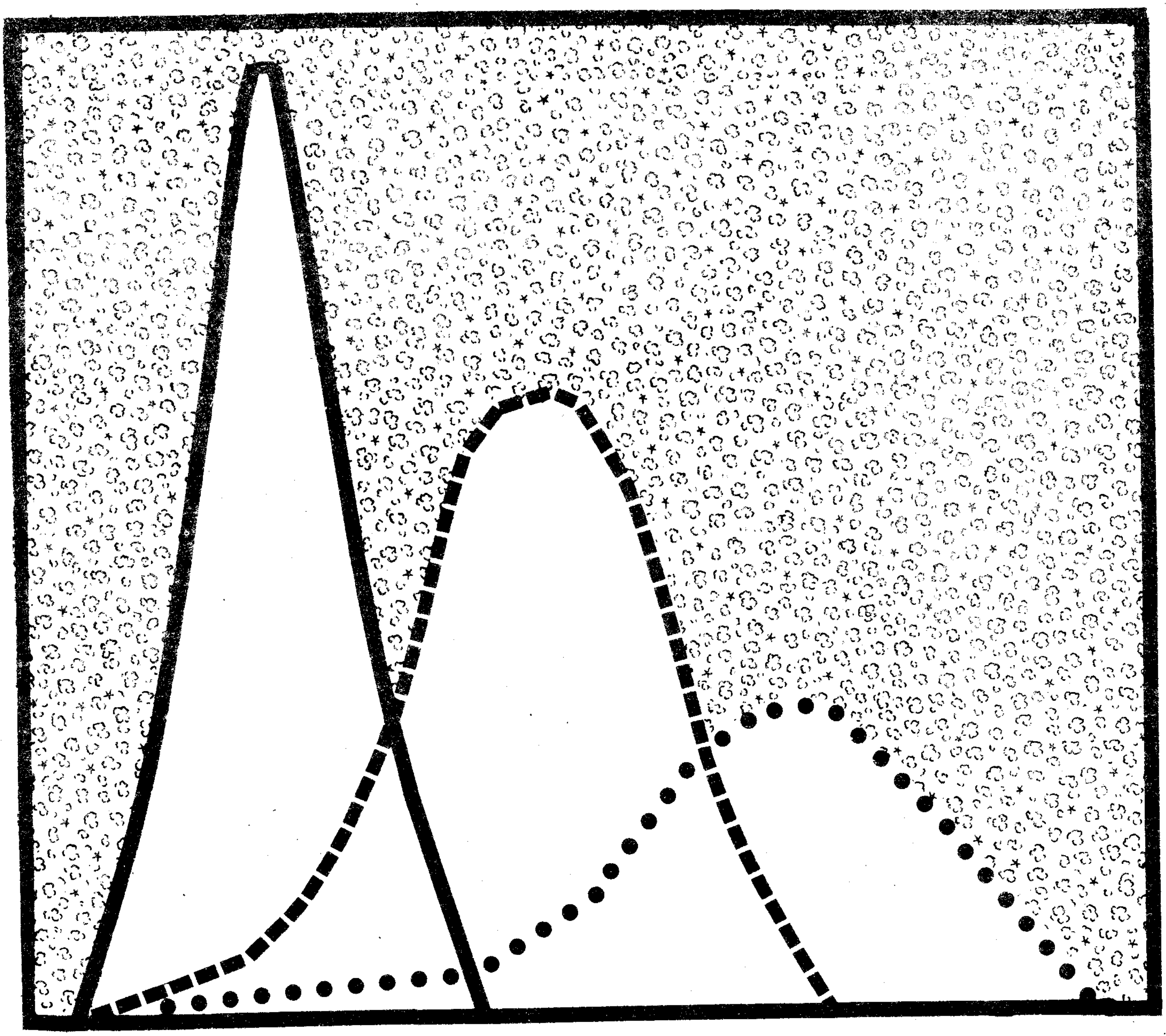

SUMMARY

A prediction system is presented whereby stand and stock tables are calculated for young natural longleaf pine stands of varying initial density. Tables can be output for stand conditions of 10 to 20 years of age, 300 to 1,500 initial trees per acre (at age 10), and 70 to 80 feet in site index (index age 50). The system also allows one to translate from density expressed as trees per acre at an age between 10 and 20 years to basal area at age 20 and thereby gain entry to another stand volume prediction and projection system for thinned natural longleaf pine that is operable for stand ages of 20 years and older.

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INTRODUCTION

Stand volume and volume growth prediction systems for natural, even-aged stands of southern pines usually use basal area as the stand density variable, and predictions usually are not feasible before about 20 years of age. Basal area is a very practical density measure for stands about this age or older but not very informative or useful if stands are younger, especially if many of the trees are less than 4-1/2 feet tall. Since intensive management calls for volume and growth information at these younger ages, methods are needed to translate from one density measure at an early age (such as trees per acre) to basal area at a later age. The following paper outlines a system developed to do this for young stands of natural longleaf pine (*Pinus palustris* Mill.) by predicting stand and stock tables.

METHODS

Study Area

The data were gathered from a natural stand spacing study initiated in the winter of 1967-68 on the Escambia Experimental Forest in south Alabama. The study area was a 40-acre stand of dense, even-aged young longleaf pines, resulting principally from seed-tree regeneration in 1957 and 1958. Seed-trees were removed in 1961. In 1963, stand density ranged from about 3,000 to 8,000 trees per acre and averaged about 6,000. In 1967, when the study was installed, the stand was 9 to 10 years old from seed. Tree sizes then ranged from grass-stage seedlings to trees about 3 inches in d.b.h. and 20 feet tall. Dominant and codominant trees averaged 6 to 10 feet in height. The soil of the area is Alaga loamy sand, which is common on ridges and upper slopes in the rolling middle Gulf Coastal Plain. At about age 20, the site index (Farrar 1973) estimated on study plots ranged from 71 to 86 feet at 50 years and averaged 79 feet.

Treatments

Five tree-frequency densities *were* replicated three times on 1/5-acre permanent plots with 1/2-chain isolation strips in a completely randomized design. Residual densities of exactly 300, 600, 900, 1,200, and 1,500 trees per acre were initially established by manually cutting the trees that appeared poorest in vigor. No record was kept of the numbers of trees removed. All hardwoods with d.b.h. ≥ 1 inch were killed during the summer of 1968, and the study area was prescription burned in the winters of 1973-74, 1975-76, and 1977-78. No subsequent thinnings have been made.

Inventory

All trees on the 1/5-acre net plot were positively and permanently identified. Their d.b.h. was measured to the nearest one-tenth inch on all trees taller than breast height, and a systematic sample was made of total heights and heights to the live crown base by measuring these heights on every sixth tree in each l-inch d.b.h. class (including the zero class) to the nearest foot. At least 2 trees were measured per d.b.h. class, if available, and at least 10 were measured per plot. Inventories were repeated at 2-year intervals and occurred in the dormant season. In the winter of 1973-74, at about stand age 15 years, all dominant and codominant sample trees were bored at 4 feet to determine age (age = ring count + 7 years). At least five trees were aged per plot. The mean age determined in this fashion agreed closely with the historical records of reproduction on the area. The last inventory reported on herein was made in the winter of 1977-78.

Analysis

Rather than analyze the stand characteristics and volume production data to simply detect any significant discrete differences among treatments, it was decided to employ techniques used to generate pre-

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dicted stand and stock tables for unthinned pine plantations in relation to stand age, site index, and density. This would allow predictions for a range of stand conditions (bounded by the limits of the data) rather than simple treatment means. This approach necessitated the development of the following six groups of prediction system components by site index and age at the stand level and/or at the d.b.h. class level.

1. ***A stand-level predictor (eq. 3a)*** [1] ***for mean dominant height (dominant and codominant trees) that uses a published site-index function to widen its utility.*** The published site-index function chosen (Farrar 1973) was the one for natural longleaf from USDA Miscellaneous Publication 50 (U.S. Forest Service 1976), hereafter called MP50, because the trends of dominant height observed in the study followed this MP50 function better than other available site-index functions. A given MP50 site-index value at index age 50 for a stand is translated to MP50 site index at index age 20 (eq. 1). This latter value is used with the dominant height function (eq. 3d) developed from study data to extend the dominant height estimates from age 20 down to age 10 (eq. 3a). The MP50 function could not be used alone because it does not allow predictions below about age 15, and the study function could not be used alone because its limited data base does not allow it to be a generally suitable site-index function.

2. ***A stand-level function that predicts the survival of all trees (eq. 4) and one that predicts the number of surviving trees 1 inch d.b.h. and larger from age 10 into the future by 1-year increments up to age 20 (eq. 5).*** For other species, a predictor for trees 1 inch d.b.h. and larger would be the only one needed. But, since longleaf has a grass-stage and trees can remain in this stage for many years, the first predictor is also necessary here. These functions are similar to a model presented by Hamilton (1974).

3. ***A mean total height predictor for each 1-inch d.b.h. class (eq. 6a).*** This function essentially predicts a proportion for each d.b.h. class that modifies stand mean dominant height. This function is similar to the model presented by Clutter and Belcher (1978).

4. ***A mean crown ratio predictor for each 1-inch d. b. h. class (eq. 7a).*** The underlying model is identical in form to the one in eq. 6a, but employs stem length (or height to the live crown base) as the dependent variable.

5. ***A function that predicts the number of trees in each 1-inch d.b.h. class (eq. 8a).*** This predictor utilizes the Weibull cumlative density function and estimates of the "b" and "c" parameters that are predicted by the stand variables age, dominant height, and trees per acre (eq. 8b, 8c). The "a" parameter was fixed at 0.55 because it is possible for any natural longleaf stand aged 10 through 20 years to have a tree in the first l-inch d.b.h. class. The "b" and "c" parameter predictors were developed using the fitted values of "b" and "c" from a maximum-likelihood program developed for this purpose at the Southern Forest Experiment Station (Bailey 1974).

6. ***A set of tree volume-defining functions (Farrar 1981) for natural longleaf pines (eq. 10-15).***

All functions were fitted using ordinary least squares multiple linear regression.

RESULTS AND DISCUSSION

All of the above groups and component parts are presented in Appendix A, along with certain relative statistics for each critical component in Appendix B.

Also, the components have been inserted into a BASIC computer program (Appendix C) that allows generation of stand and stock tables for stands having the specifications and limits shown in table 1.

Appendix D shows example output from this program, stand and stock tables for ages 10, 15, 20; site index 70 and 80; and 300, 600, 900, 1,200, and 1,500 initial trees per acre (all trees, at age 10). By modifying a few program lines, the program can predict tables for other combinations of stand initial and final age, site index, and initial density within the above limits on minimum and maximum values given in table 1.

Several trends are evident upon inspection of these Appendices. Survival of all trees (TSO) is inversely related to initial density and is very good for the 10-year period studied. The poorest survival was 88 percent at age 20 for 1,500 initial trees per acre at age 10 and site index 70. Similarly, the poorest survival on site index 80 was 95 percent for otherwise similar conditions. These trends probably hold through age 20, but beyond that one would expect survival to become relatively poorer for site index 80 as competition becomes more intense on these better sites (Dell and others, 1979).

The modal d.b.h. class advances with age and the advance is most rapid for the lowest initial stand den-

Table *l.-Specifications and limits of stand and stock tables*

Stand variable	Minimum value	Maximum value
Age (years)	10	*20*
Site index (feet) (MP50, index age = 50)	66	85
Initial number of trees per acre at age 10	300	*1,500*

[1] Numbers and letters refer to equations presented in Appendix A.

sity. This effect is shown in figure 1 for initial densities of 300 and 1,500 trees on site index 70. Increasing site index accelerates the advance.

The number of trees per acre 1 inch d.b.h. and larger (TS1) is directly related to initial density, increases with age, and approaches and asymptote or declines slightly due to mortality in the higher densities (fig. 2). Increasing site index tends to increase the number of such trees at any age for any initial density.

The quadratic mean d.b.h. is negatively related to density, appears to approach an asymptote with density, and increases positively with age (fig. 3). The effect of site index is positive. The arithmetic mean d.b.h. response is similar but the values are, of course, smaller.

Total basal area per acre is positively related to initial density and age and appears to approach an asymptote with density (fig. 4). Over the lo-year period, the growth rate accelerated during the last 5 years for the lowest initial density and decelerated for the highest. The effect of site index is positive.

Mean crown ratio has a differential response to initial density and age (fig. 5). At the three lower densities it increases to a peak at middle ages and then declines with age, but at the two higher densities it generally declines slowly to the middle ages and then declines more rapidly. It appears to approach an

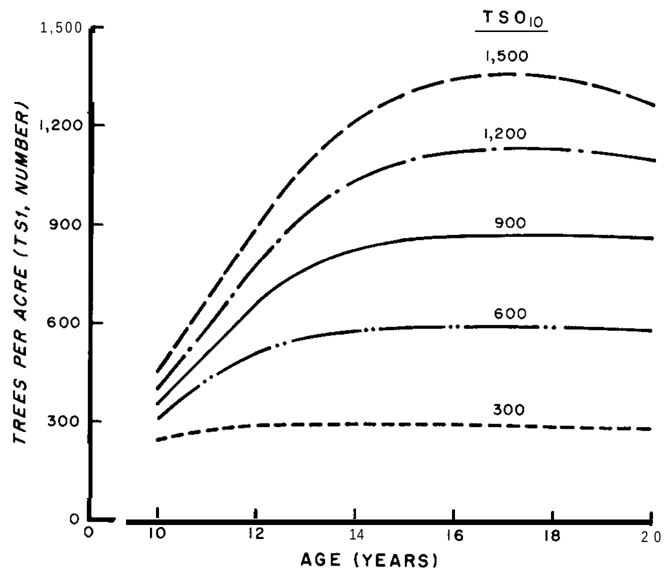

Figure *2.-Predicted number of trees per acre (d.b.h. ≥ 0.6") at ages 10 through 20 years by initial stand density at age 10, site index 70.*

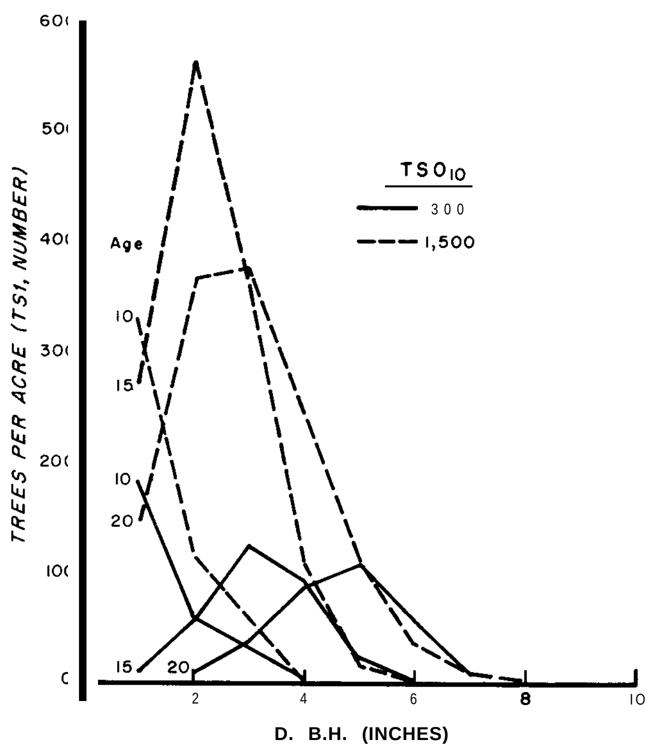

Figure *l.-Predicted d.b.h. distributions for 300 (solid line) and 1,500 (dashed line) initial trees per acre at ages 10, 15, and 20 years, site index 70.*

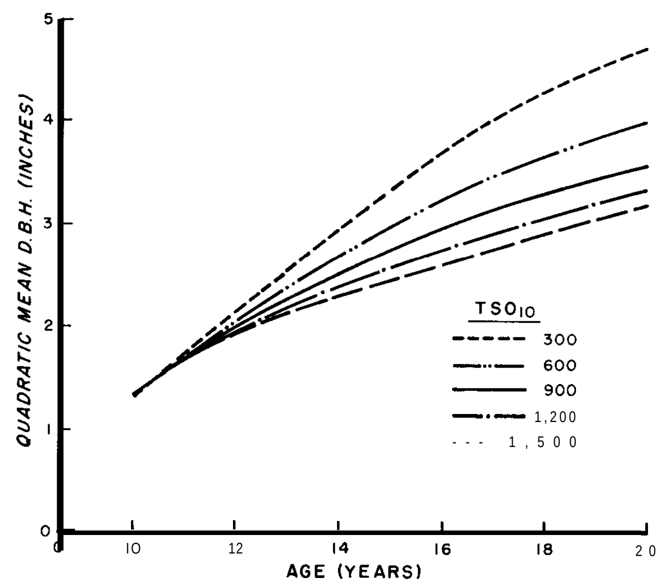

Figure *3.-Predicted quadratic mean stand d.b.h. at ages 10 through 20 years by initial stand density at age 10, site index 70.*

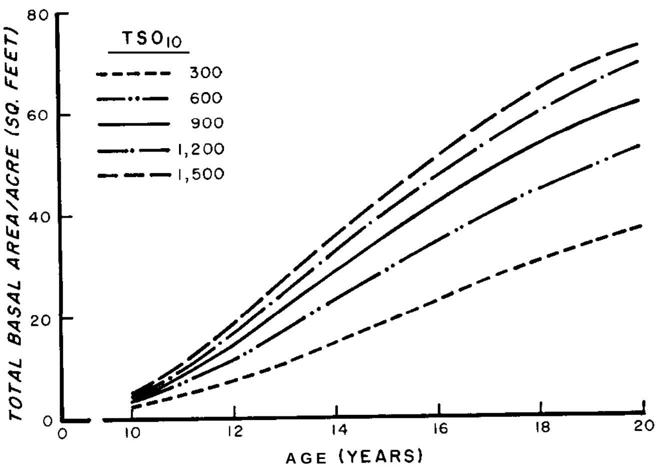

Figure *J.-Predicted total stand basal area per acre at ages 10 through 20 years by initial stand density at age 10, site index 70.*

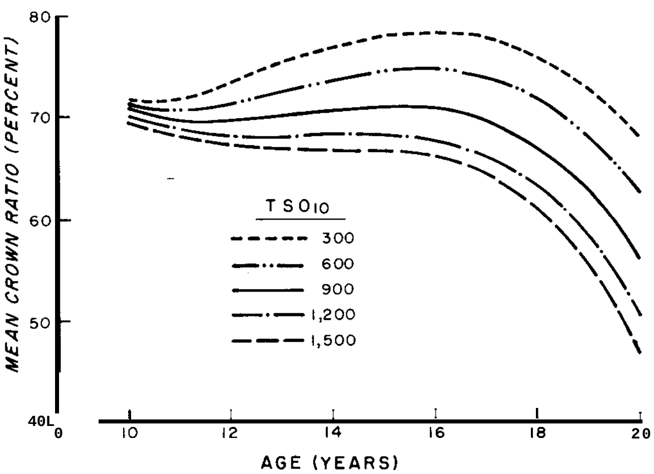

Figure *B.-Predicted stand mean crown ratio percentage at ages 10 through 20 years by initial stand density at age 10, site_ index 70.*

asymptote with density. The general effect of increasing site index is to lower the crown ratio about 5 to 10 percentage points.

The total cubic-foot volume, inside bark, per acre (TVI) response is similar to the response of total basal area to age and initial density except that the growth rate appears to be accelerating for all densities over the lo-year period (fig. 6); probably because height growth is overcoming any reduction in basal area growth. The effect of site index is positive. The greater the age, site index, and initial density; the greater the total volume.

Merchantable cubic-foot volume, inside bark (VI43), is zero for all densities and both sites at age 10. By age 15, the **900-trees-per-acre** density has the most volume on site index 70 (fig. 7) and 80. By age 20, volume has increased at an increasing rate such that the **1,200-trees/acre** density has the most volume on site index 70 and the **1,500-trees/acre** density on site index 80.

The merchantable mean annual volume (VI43) increments to age 20 are not striking, but the responses between age 10 and 20 are impressive, particularly for the last 5 years. For the period age 10 to age 20, the maximum predicted growth rates are 61.2 cubic feet/acre/year for site index 70 and 1,200 initial trees. For site index 80, the maximum is 101.5 cubic feet for 1,500 initial trees. Assuming 80 cubic feet/cord, these figures translate to 0.77 and 1.27 cords/acre/year. For the last 5 years (age 15 to 20), the maximum rates are 99.7 and 170.5 cubic feet/acre/year for site indices 70 and 80, respectively, and both for initial densities of 1,500 trees. These figures translate to 1.25 and 2.13 cords/acre/year.

If maximum stand merchantable cubic-foot volume production is desired, the results through age 20 do not suggest any practical benefit from having more than about 900 to 1,200 trees per acre at age 10 since these densities produced maximum or near-maximum volumes. However, if maximum total cubic-foot volume is desired, the highest initial density (1,500 TSO_{10}) is indicated. This information supports earlier conclusions (Farrar 1974) that to maximize early merchantable cubic-foot yields a density range of 500 to 1,000 established trees per acre appeared optimal and that, for this purpose, precommercial thinning should be considered only if stand density exceeded 1,000 crop seedlings at age 5 to 10 years. As the study continues, it may develop that a medium initial TSO density will maximize early sawtimber volumes also.

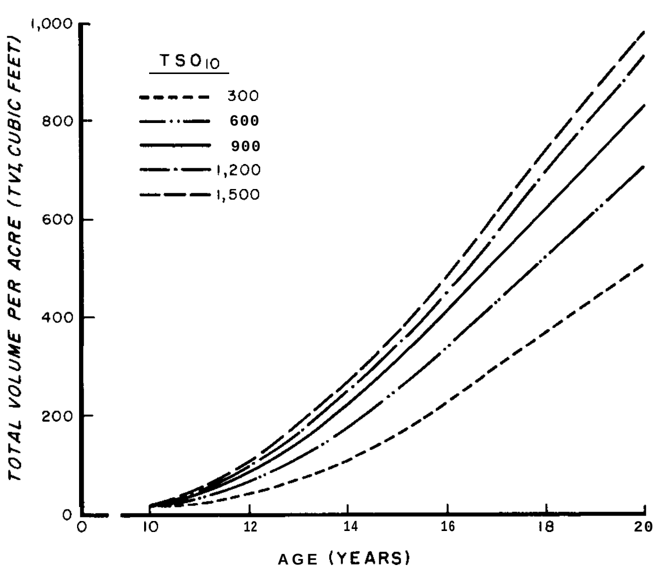

Figure *B.-Predicted stand total cubic-foot volume, inside bark, per acre at ages 10 through 20 years by initial stand density at age 10, site index 70.*

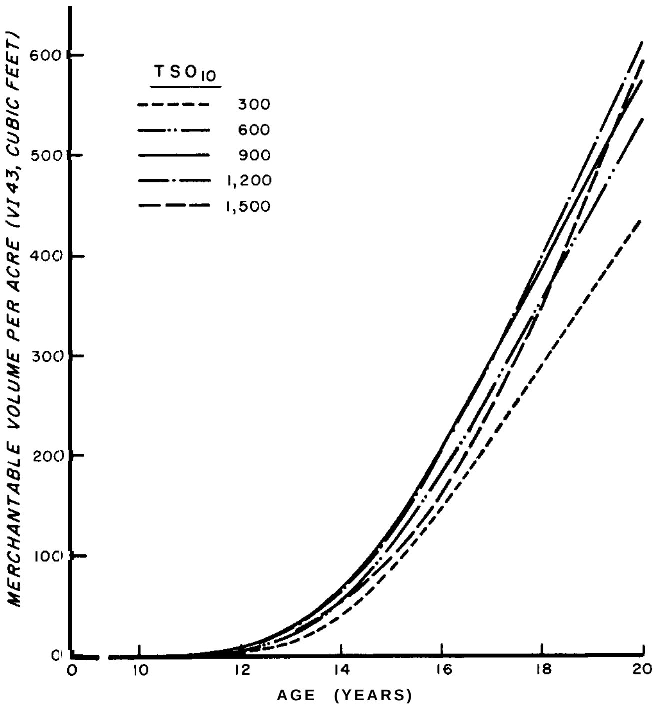

Figure *T.-Predicted stand merchantable cubic-foot volume, inside bark, per acre at ages 10 through 20 years by initial stand density at age 10, site index 70.*

Preliminary results from this spacing study have been reported in two previous publications (Farrar 1974, 1979a). At the time of the first (Farrar 1974), neither the ages from seed (from increment borings) nor the site index were determinable. Age, although not specifically stated, was age from seed-tree removal which is 2 to 3 years younger than age from seed. Average site index was estimated in surrounding 60-year-old stands on similar soils to be about 70 feet. If the data in Farrar (1974) are updated to reflect the average age from seed (15 to 16 years) and the average site index (MP50) of about 80, the results are comparable to those presented herein.

In the second publication (Farrar 1979a) the ages are from seed but the average site index was estimated to be in the 70 class (about 75) by the site-index function in Farrar (1979b). If this site index is translated to MP50 site index, the value is about 80. Then, with due allowance for a different survival function in Farrar (1979a), the results are comparable. Since the results reported in these two previous publications were preliminary, they can be regarded to be superseded by the results reported herein.

To see, on the average, how well the prediction system reproduces certain observed stand values for the 15 plots at nominal ages 10, 15, and 20 years, the mean difference ($\bar{d}$), percent mean difference (%d), root mean square difference (RMSd), and root mean square percent difference (RMS%d) were calculated and are presented in table 2. The latter two measures are comparable to absolute (algebraic sign ignored) values. The "observed" values for each plot at each age were determined by the procedures given by Farrar (1979b) for plot inventory summary. Briefly, observed volumes were obtained by fitting a total height function in terms of d.b.h. for each plot, using this function in conjunction with the tree volume formulae presented herein to estimate a volume for every tree on the plot, and summing tree volumes to obtain plot volumes. Observed trees per acre and basal area were the actual values per plot. Observed ages were the actual mean age at nominal ages 10, 15, and 20 years for each plot.

Predicted plot values were obtained by using the following inputs to the appended program:

a. Site index (MP50) observed at nominal age 20 on each plot.

b. The actual plot age at nominal age 20 and backdated 5 and 10 years to obtain estimates at nominal ages 15 and 10.

c. The number of trees at the age in b., above, were obtained via the survival function (eq. 4) by starting with the treatment densities at the backdated age at nominal age 10 and projecting forward 5 and 10 years.

The results of this exercise (table 2) suggest that the predictions improve with time and that all are within usable limits. At ages 15 and 20, they are comparable to results from other studies of natural even-aged southern pine growth and production (Farrar 1979b, Murphy and Sternitzke 1979, Murphy and Beltz 1981). At age 10, the percentage differences are comparatively large but small in real terms. This is not surprising because at this young age there is considerable variability in the stand taller than breast height. Later, as more of the stand passes the breast-height threshold, stand traits become more predictable.

If stand and stock tables are desired for conditions other than those shown in the Appendix, but within the study limits, the program (Appendix B) can be modified to provide output for any integer age between 10 and 20 years, any site index in the 70 and 80 classes, and any initial integer number of trees per acre between 300 and 1,500. The desired input values are specified in line 80, and lines 120,130, and 140 are modified as needed. For example, if annual output is desired for site index 75 at ages 13 through 17 for 750 initial trees per acre at age 13, the input would be 75, *75, 13, 17,* 750, 750 and line 140 would be altered to read: ***FOR A =A1 to A2 STEP 1.***

If for some reason the MP50 site-index function is not deemed appropriate, but the rest of the process is considered suitable, some other site-index function thought to be more appropriate can be solved as a dominant-height function at age 20 and substituted in line 280.

Table *2.-Goodness of fit" statistics for the stand and stock table prediction system'*

Predicted value	n	Obs	$\bar{d}$	$\overline{\%d}$	RMSd	RMS%d
			Age *10*			
TS1 (no.)	15	349.7	*-5.07*	5.2	*63.73*	*24.4*
B (ft^2)	15	3.2	*0.08*	6.4	*0.76*	*26.1*
TVO (ft^3)	15	28.6	*0.05*	5.4	*7.00*	*27.1*
TVI (ft^3)	15	14.8	*0.15*	5.9	*3.93*	*28.7*
vo43 (ft^3)	.	......	......	.....		
VI43 (ft^3)	..	......	......	.....	......	....
			Age 15			
TS1	15	830.7	30.13	0.04	*74.66*	*7.4*
B	15	43.1	-0.49	-0.8	*4.31*	*10.3*
TVO	15	690.7	-23.85	-4.3	*83.09*	*12.3*
TVI	15	453.3	- 15.66	-3.2	*55.73*	*12.6*
vo43	15	347.3	- 12.55	-3.0	*54.05*	*16.2*
VI43	15	233.3	-6.7	-2.3	*36.72*	*16.5*
			Age 20			
TS1	15	832.0	*30.20*	*3.8*	61.26	6.4
B	15	68.0	*-0.71*	*-0.6*	4.51	6.9
TVO	15	1454.8	*-4.13*	0.1	115.09	8.6
TVI	15	1012.0	*-4.43*	-0.01	81.71	8.8
vo43	15	1088.1	*-23.26*	-1.4	102.84	9.8
VI43	15	767.6	*-16.4*	-0.4	72.97	9.8

in = number of observations
y_i = ith observed value
$\hat{y}_i$ = ith predicted value

$$\overline{Obs} = \left(\sum_{i=1}^{n}(y_i)\right)/n$$

$$\bar{d} = \left(\sum_{i=1}^{n}(\hat{y}_i - y_i)\right)/n$$

$$\overline{\%d} = \left(\sum_{i=1}^{n}((\hat{y}_i - y_i)/y_i)/n \; *(100)\right)$$

$$RMSd = \sqrt{\left(\sum_{i=1}^{n}(\hat{y}_i - y_i)^2\right)/n}$$

$$RMS\%d = \sqrt{\left(\sum_{i=1}^{n}((\hat{y}_i - y_i)/y_i)^2\right)/n*(100)}$$

. . = no data observed or predicted

Besides providing estimates of the production in 10- to 20-year-old longleaf stands, this system can provide entry to other growth and production prediction systems that usually start at about age 20. For example, assume that we have a longleaf stand at age 10 that has 1,200 trees per acre and a site index of 70 feet (MP50) and we would like to estimate its volume at age 25. At age 20, Appendix C shows this stand should have a dominant height of 36.4 feet, 68.9 square feet of basal area (B), and the following cubic-foot volumes per acre: total, inside bark (TVI) = 930; merchantable, inside bark (VI43) = 612. The indicated merchantable periodic annual increment from age 15 to 20 is 97.8 cubic feet. Using the functions in a recently published system for volume growth and production prediction for thinned natural longleaf (Farrar 1979b) that uses some of the same tree volume-defining functions but a different site-index function, the following values are obtained at age 20. The 36.4-foot dominant height translates to a site index (Farrar 1979b) of 65.6 feet and the cubic-fool volume estimates are TVI = 914 and VI43 = 661. These are within ±2 to 8 percent of the above values. At age 25, the predictions from the functions in Farrar (1979b) are B = 99 square feet/acre, TVI = 1,639, and VI43 = 1,390.

The estimated average annual growth from age 20 to 25 is 6 square feet of basal area and 145.8 cubic feet of merchantable volume or 1.82 cords. The merchantable mean annual increments at ages 20 and 25 (33.1 and 55.6 cubic feet) suggest that the periodic annual cubic-foot volume increment has not peaked for this stand by age 20.

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Appendix A-System Predictor Groups and Components

(1) $H_{20} = (S_{50})(10)^{\{g(20)-g(50)\}}$

(2) $S_{20} = (H_{20})[\exp\{f(20) - f(20)\}] = H_{20}$

(3a) $HD1_A = (S_{20})[\exp\{f(A) - f(20)\}]$

where: H_20 = mean height of dominant stand at age 20, predicted from MP50 dominant-height function (Farrar 1973), feet

S_{50} = site index, index age 50 years, feet ($65 < S_{50} \leq 85$)

(3b) $g(A) = -11.870(1/A) + 1263.79(1/A)^3 - 12409.5(1/A)^4$ (Farrar 1973)

S_{20} = site index, index age 20 years, feet

(3c) $f(A) = 51.5672(1/A) - 976.490(1/A)^2 + 3836.84(1/A)^3$ [1]

[1] From the fitted function:

(3d) $\ln(HD1_A) = 3.08908 + 51.5672(1/A) - 976.490(1/A)^2 + 3836.84(1/A)^3$

A = given age, years

$HD1_A$ = predicted mean height of dominant stand at age A, feet (A, here, = 10, 11, ... 19, or 20).

Total tree frequencies per stand at age A

The number of surviving trees per acre is predicted in an iterative fashion by a modified form of a function presented by Hamilton (1974).

(4) $TSO_{A+1} = TSO_A/[0.99999 + \exp\{-20.964 + 1.1808(A) - 0.25569(HD1_A) + 0.0031657(TSO_A)\}]$

where: TSO_A = number of surviving trees per acre (all) at age A years

TSO_{A+1} = number of surviving trees per acre (all) at age (A + 1) years. Note that $TSO_A + 1$ becomes TSO_A for each new iteration of this function. Minimum A = 10, maximum (A + 1) = 20, minimum TSO_{10} = 300, maximum TSO_{10} = 1,500.

The number of surviving trees in the l-inch class and larger is predicted by:

(5) $$TS1_A = TSO_A/[0.99999 + \exp\{3.7052 - 2.5068(HD1_A/A) - 94.772(HD1_A/TSO_A)\}]$$

where: $TS1_A$ = number of surviving trees per acre (d.b.h. > = 0.6 inches) at age A years.

Mean height for a given d.b.h. class at age A

(6a) $$H1_{iA} = (HD1_A)[\exp\{b_{0A} + b_{1A}(1/D_i)\}]$$

where: $H1_{iA}$ = predicted mean tree total height for the ith l-inch d.b.h. class at age A, feet

(6b) $$b_{0A} = 0.23727 + 5.9139/HD1_A$$

(6c) $$b_{1A} = -0.19070 - 0.012645(TS1_A/A) - 0.11953(HD1_A) + 0.0010798(TS1_A) + 0.0016258(HD1_A)^2$$

. D_i = midpoint of the ith 1 inch d.b.h. class, inches.

Mean crown ratio for a given d.b.h. class at age A

(7a) $$CR_{iA} = \{(H1_{iA} - SL_{iA})/H1_{iA}\}(100)$$

where: CR_{iA} = mean crown ratio for the ith l-inch d.b.h. class at age A, percent

(7b) $$SL_{iA} = (HD1_A)[\exp\{c_{0A} + c_{1A}(1/D_i)\}]$$

where: SL_{iA} = predicted mean tree height to the live crown base for the ith l-inch d.b.h. class at age A, feet

(7c) $$c_{0A} = 3.4392 - 0.54950(A) + 0.045001(HD1) + 0.00057003(A^3) + 0.000000048139(A^3)(TS1_A)$$

(7d) $$c_{1A} = -0.53734 - 0.0025185(A^2) + 0.000018202(A)(TS1_A).$$

Tree frequencies by d.b.h. class at age A

(8a) $$TS1_{iA} = N2_A - N1_A$$

where: $N1_A = (TS1_A)[1 - \exp\{-((D_i - a)/b_A)^{c_A}\}]$

$N2_A = (TS1_A)[1 - \exp\{-((D_i + 1 - a)/b_A)^{c_A}\}]$

and

$TS1_{iA}$ = number of surviving trees per acre (d.b.h. > = 0.6 inch) in the ith l-inch d.b.h. class at age A years.

a = 0.55

(8b) $$b_A = -0.78012 - 0.000084899(HD1_A)(TS1_A) + 0.17355(HD1_A) + 0.00087836(TS1_A) - 0.0000013083(HD1_A)^2(TS1_A) + 0.0000000010321(HD1_A)^2(TS1_A)^2$$

(8c) $$c_A = 0.80699 - 0.00025619(HD1_A)(TS1_A) + 0.00000010200(HD1_A)(TS1_A)^2 + 0.16045(HD1_A) + 0.00096973(TS1_A).$$

Basal area per acre by d.b.h. class at age A

(9) $$B_{iA} = (TS1_{iA})(\pi/576)(D_i)^2$$

where: B_{iA} = basal area per acre in the ith l-inch d.b.h. class at age A, square feet.

Mean tree volume for a given d.b.h. class at age A

(10) $$TVI_{iA} = 0.00535 + 0.0021971(D_i)^2(H1_{iA})$$

where: TVI_{iA} = tree volume in cubic feet, inside bark, from a 0.2-foot stump to a zero-inch top d.o.b., d.b.h. > = 0.6 inch

(11) $$TVO_{iA} = (TVI_{iA})\{1 + (10^{b_0})(TVI_{iA})^{b_1}\}$$

where: TVO_{iA} = same specifications as TVI_{iA} except outside bark

b_0 = -0.30925

b_1 = -0.21895

(12) $$VI42_{iA} = (TVI_{iA})/\{1 + (10^{b_{02}})(TVI_{iA})^{b_{12}}\}$$

where: $VI42_{iA}$ = tree merchantable volume in cubic feet, inside bark, from a 0.2-foot stump to a 2-inch top d.o.b., d.b.h. > = 3.6 inches

b_{02} = -1.2415

b_{12} = -1.2107

(13) $$VO42_{iA} = (VI42_{iA})\{1 + (10^{b_0})(VI42_{iA})^{b_1}\}$$

where: $VO42_{iA}$ = same specifications as $VI42_{iA}$ except outside bark

(14) $$VI43_{iA} = (TVI_{iA})/\{1 + (10^{b_{03}})(TVI_{iA})^{b_{13}}\}$$

where: $VI43_{iA}$ = tree merchantable volume in cubic feet, inside bark, from a 0.2-foot stump to a 3-inch top d.o.b., d.b.h. > = 3.6 inches

b_{03} = -0.54930

b_{13} = -1.3024

(15) $VO43_{iA} = (VI43_{iA})\{1 + (10^{b_0})(VI43_{iA})^{b_1}\}$

where: $VO43_{iA}$ = same specifications as $VI43_{iA}$ except outside bark.

Per acre tabular values

(16) $$TS1_A = \sum_{i=1}^{n} (TS1_{iA})$$

(17) $$B_A = \sum_{i=1}^{n} (B_{iA})$$

(18) $$Volume_A = \sum_{i=1}^{n} \{(Volume_{iA})(TS1_{iA})\}$$

where $Volume_A$ = a total volume and $Volume_{iA}$ = volume per tree in the ith l-inch d.b.h. class, for any volume function

(19) $$\overline{D}_A = \{\sum_{i=1}^{n} (D_i)(TS1_{iA})\}/TS1_A$$

where $\overline{D}_A$ = arithmetic mean d.b.h.

(20) $$\overline{D}_Q = \sqrt{B_A/\{(\pi/576)(TS1_A)\}}$$

where $\overline{D}_Q$ = quadratic mean d.b.h.

(21) % Survival $= TS0_A/TS0_{10}$

(22) $$\overline{CR}_A = \{\sum_{i=1}^{n} (CR_{iA})(TS1_{iA})\}/TS1_A$$

where $\overline{CR}_A$ = arithmetic mean crown ratio percentage.

Appendix B-Coefficient of Determination and Standard Error of Regression for Fitted Functions

Equation no.	n	R^2 or r^2	$s_{y \cdot x}$
(3d)	90	0.987*	0.063*
(4)	150	0.315*	2.653*
(5)	90	0.735*	2.211*
(6b)	90	0.811	0.094
(6c)	90	0.727	0.214
(7c)	90	0.482	0.280
(7d)	90	0.204	0.397
(8b)	90	0.984	0.148
(8c)	90	0.846	0.327

*In logarithmic form, from regression where y was transformed to ln (y).

Appendix C-BASIC Program to Generate Predicted Stand and Stock Tables for Young Natural Longleaf Pine

```
10   REM THIS PROGRAM "LLS&SO" GENERATES STAND AND STOCK TABLES FOR YOUNG
     NATURAL LONGLEAF PINE STANDS HAVING INITIAL AND FINAL AGES BETWEEN 10 AND
20   REM 20 YEARS, SITE INDEX (INDEX AGE 50 YEARS, MISC. PUBL. 50) OF 66 TO 85
     FEET, ANDINITIAL DENSITIES OF 300 TO 1500 TREES PER ACREAT INITIAL AGE.
30   OPTIONBASE1
40   PRINTER IS 0
60   INTEGER A,S,D
70   REAL N1,N2,H1(30),T0(30)
80   INPUT "S1,S2,A1,A2,T1,T2 ?",S1,S2,A1,A2,T1,T2
81   PRINTLIN(5)
90   IMAGE "YIELDS GIVEN TSO (  #  OF TREES PER ACRE AT DESIRED INITIALAGE) WITH T
YPICAL  SURV  I  VAL--"
100  PRINT USING 90
101  PRINT LIN(3)
110  N99=1
120  FOR S=S1 TO S2 STEP  1 0
130  FORT0=T1 TO T2 STEP 300
140  FOR A=A1 TO A2 STEP 1
150  IF N99>=3 THEN 180
160  IF A1>10 THEN 270
170  GOTO 200
171  WHIT 500
172  PRINT LIN(12)
180  IMAGE 40X,"CU. F T . VOL.ABOVE 0.2 F T . STUMP"
190  PRINT USING 180
191  GOTO 220
132  PRINT LIN( 121
200  IMAGE 40X,"CU. F T . VOL. ABOVE 0.2 F T . STUMP"
210  PRINT USING 200
211  IMAGE 40X, "HLL TREES *  4- INCH CLASS & UP"
212  PRINT USING 211
220  IMAGE 13X,"AV.",4X," STEMS",14X,9("*"),"FOR O.B.  TOPS OF----",9("*")
230  PRINT USING 220
240  IMAGE 1X,"TSO SI AGE  D+C DBH PER  BASAL CR  AV. 0   INCHES   *   2 INCHES
  *   3 INCHES"
250  PRINT USING 240
260  IMAGE13X," "HT. ",5X,"ACREAREA",6X, "HT. o.b.   i.b.  *  o.b.   i.b. *   o.b.
 i.b."
261  PRINTUSING260
262  IMAGE 80("_")
263  FRINTUSING262
270  N99=N93+1
271  IFN99= 4 THEN N99=2
280  H20=S*.520219437307
281  T0(A1)=T0
290  FOR I=A1 TO A2 STEP 1
300  H1(I)=H20*EXP(51.5672/I-976.49/I^2+3836.84/  I^3-.61674)
310  T0(I+1)=T0(I)/(.99999+EXP(-20.964+1.1808*I-.25569*H1(I)+.0031657*T0(I)))
320  NEXT I
330  I=A
340  T11=T0(I)/(.99999+EXP(3.7052-2.5068*(H1(I)/I)-94.772*(H1(I)/T0(I))))
350  A4=.55
360  B=-.78012-8.4899E-5*H1(I)*T11+.17355*H1(I)+8,7836E-4*T11-1,3083E-6*H1(I)^2*
T11+1,0321E-9*H1(I)^2*T11^2
```

```
370  C=.80699-2.5619E-4*H1(I)*T11+1.02E-7*H1(I)*T11^2+.16045*H1(I)+9.6973E-4*T11
380  S11=0
390  D13=0
400  T111=0
410  T121=0
420  T123=0
430  V111=0
440  V121=0
450  V123=0
460  V124=0
461  Crpp=0
470  PRINT USING "DDDD,1X,DD,1X,DD,2X,DD.D";T0,S,A,H1(A)
471  PRINT LIN(1)
480  D=1
448  D11=1.5
500  IF D=2 THEN D11=1.5
510  N1=T11*(1-EXP(-((D11-A4)/B)^C))
520  N2=T11*(1-EXP(-((D11+1-A4)/B)^C))
530  T112=N2-N1
540  IF D=1 THEN T112=N1
550  T112=PROUND(T112,0)
568  B0=.23727+5.9139/H1(A)
570  B1=-.19070-.012645*T11/A-.11953*H1(A)+.0010798*T11+.0016258*H1(A)^2
580  H10=H1(A)*EXP(B0+B1/D)
581  C0=3.7392-,54950*I+.045001*H1(I)+5.7003E-4*I^3+4.8139E-8*I^3*T11
582  C1=-.53734-.00251857*I^2+1.8202E-5*I*T11
583  S1=H1(I)*EXP(C0+C1/D)
584  Cr=(H10-S1)/H10*100
586  IF Cr<=5 THEN Cr=10
590  B00=D^2*(3.14159254/576)*T112
600  T00=.00535+.0021971*D^2*H10
610  T012=T00*T112
620  T01=T00*(1+10^(-.30925)*T00^(-.21895))
630  T013=T01*T112
640  T121=T121+T012
658  T123=T123+T013
660  S11=S11+B00
670  D12=D*T112
680  D13=D13+D12
681  Crpc=Cr*T112
682  Crpp=Crpp+Crpc
683  Cr=PROUND(Cr,-1)
690  T111=T111+T112
700  IF D=1 THEN 890
710  IF T112<.50000000001THEN910
720  IF D<4 THEN 890
730  V14=T00/(1+10^(-1,2415)*T00^(-1.2107))
740  V112=V14*T112
741  V112=PROUND(V112,-1)
758  V15=V14*(1+10^(-.30925)*V14^(-.21895))
768  V113=V15*T112
761  V113=PROUND(V113,-1)
770  V16=T00/(1+10^(-.5493)*T00^(-1.3024))
780  V114=V16*T112
781  V114=PROUND(V114,-1)
790  V17=V16*(1+10^(-.30925)*V16^(-.21895))
800  V115=V17*T112
801  V115=PROUND(V115,-1)
818  V111=V111+V112
820  V121=V121+V113
```

```
830  V123=V123+V114
840  V124=V124+V115
850  PRINT USING "17X,DD,2X,DDD,1X,DD.D,2(2X,DD),2X,DDD.D,2X,DDD.D,2(2X,DDD.D,2X
,DDD.D)";D,T112,B00,Cr,H10,T013,T012,V113,V112,V115,V114
860  D=D+1
861  D11=D11+1
870  IF D<11 THEN 500
880  GOTO 910
890  PRINT USING "17X,DD,2X,DDD,1X,DD.D,2(2X,DD),2X,DDD.D,2X,DDD.D";D,T112,B00,C
r,H10,T013,T012
900  GOTO 860
910  D33=D13/T11
920  D44=SQR(S11/(.005454*T11))
930  R1=T0(I)
940  R2=T0(A1)
950  S55=R1/R2*100
951  Barcr=Cpp/T11
960  IMAGE 20X,"----------------------------------------"
970  PRINT USING 960
972  IF D<5 THEN 1000
980  PRINT USING "[illegible]";T111,S11,T123,T121,V121,V111,V124,V123,1X,DDDD.D,1X,DDD.D,1X,DD
981  PRINT LIN(1)
990  GOTO 1030
1000 PRINT USING "20X,DDDD,2X,DD.D,9X,DDD.D,1X,DDD.D";T111,S11,T123,T121
1001 PRINT LIN(1)
1030 PRINT USING "17A,D.DD,1X,18A,D.DD";"ARITH. MEAN DBH =",D33,"QUADR.MEAN DB
H =",D44
1035 PRINT USING "17A,D.DD,2(1X,3A,D.DD)";"WEIBULL PARAM:A=",A,"B=",B,"C=",C
1040 PRINT USING "12A,1X,DDD.D,5X,19A,1X,DDD.D";"SURVIVAL%=",S55,"MEAN CROWN RA
TIO %=",Barcr
1041 PRINT LIN(6)
1050 NEXT A
1051 PAUSE
1060 NEXT T0
1070 NEXT S
1090 END
```

Appendix D-Predicted Stand and Stock Tables for Young Natural Longleaf Pine at Various Initial Densities, Site Indices, and Ages

YIELDS GIVEN TSO (# OF TREES PER ACRE AT DESIRED INITIAL AGE) WITH TYPICAL SURVIVAL--

TSO(10)	SI	AGE	Au. D+C HT.	DBH	STEMS PER ACRE	BASK AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES: 0 INCHES O.B.	0 INCHES I.B.	4-INCH CLASS AND GREATER: 2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B.	3 INCHES I.E.
300	70	10	9.1											
				1	183	1.0	70.2	6.7	7.9	3.7				
				2	59	1.3	76.1	12.2	11.9	6.6				
				3	1	.0	77.0	14.9	.5	.3				
					243	2.3			20.3	10.6				

ARITH. MEAN DBH = 1.3　QUADRATIC MEAN DBH =1.33　UEIBULL PARAMETERS A = .55　B = .80　C =1.99

% SURVIVAL= 100.0　MEAN CROWN RATIO = 71.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES: 0 INCHES O.B.	0 INCHES I.E.	4-INCH CLASS AND GREATER: 2 INCHES O.B.	2 INCHES I.E.	3 INCHES O.B.	3 INCHES I.E.
300	70	15	24.9											
				1	b	.l	56.1	5.0	.2	.l				
				2	57	1.2	74.2	14.1	13.0	7.4				
				3	123	6.0	78.4	i9.9	78.6	49.2				
				4				23.7	fib.6	77.2	109.4	72.1	88.1	57.0
				5	92 21	8.0 2.9	80.2 81.3	26.3	44.3	30.5	42.8	29.4	38.1	26.0
				b	1	.2	81.9	28.2	3.2	2.2	3.i	2.2	2.9	2.0
					300	18.4			255.9	166.6	155.3	103.7	129.1	85.0

ARITH. MEAN DBH = 3.2　QUADRATIC MEAN DBH =3.35　YEIBULL PARAMETERS A =.55　B =2.98　c -3.40

% SURVIVAL= 100.0　MEAN CROWN RATIO = 78.0

TSO(10)	SI	ACE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- **************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B. *	2 INCHES * O.B.	I.B. *	3 INCHES O.B.	I.B.
300	79	20	36.4											
				2	0	0.0	40.5	5.7	0.0	0.0				
				3	3s 7	1.7	60.4	17.6	1.9	1.1				
						7.6	65.5 67.8	30.9 25.6	28.1	17.9				
				4	87				140.7	95.0	i34.3	90.4	ii4.3	75.9
				S	107	i4.6	69.1	34.6	290.8	293.9	283.9	198.7	261.2	181.8
				b	54	10.6	69.9	37.3	22i.4	iS9.6	2i8.2	157.2	208.0	149.3
				7	8	2.1	70.5	39.4	46.1	33.9	45.6	33.6	44.3	32.5
					298	36.8			729.1	511.5	682.0	479.9	627.8	439.5

ARITH. MEAN DBH = 4.6 QUADRATIC MEAN DBH =4.75 WEIBULL PARAMETERS A = .55 B =4.48 c =4.48

% SURVIVAL= 99.6 MEAN CROUN RATIO = 68.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * **************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B. *	4-INCH CLASS AND GREATER 2 INCHES * O.B.	I.B. *	3 INCHES O.B.	I.B.
600	70	10	9.1											
				1	226	i.2	69.5	6.7	9.7	4.5				
				2	75	1.6	75.8	12.1	15.1	8.4				
				3	1	.0	77.6	14.8	.S	.3				
					302	2.9			25.3	i3.2				

WITH. MEAN DBH = i.3 QUADRATIC MEAN DBH =1.33 WEIBULL PARAMETERS A = .SS B = .80 c =1.94

% SURVIVAL= 100.0 MEAN CROUN RATIO = 7i.2

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT UOLUHE ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	2 INCHES O.B.	I.B.	3 INCHES O.B.	I.E.
600	70	15	24.9											
				1	49	.3	53.5	5.3	1.8	.8				
				2	189	4.1	72.8	14.6	44.5	25.2				
				3	214	10.5	77.3	20.4	i39.7	87.5				
				4	110	9.6	79.2	24.1	141.7	93.9	133.1	87 8	107.6	69.8
				5	27	3.7	80.3	26.7	57.7	39.7	55.8	38.4	49.8	34.0
				6	3	.6	81.0	28.6	9.6	6.8	9.4	6.7	8.8	6.2
					592	28.8			394.9	254.0	-198.3	132.9	166.2	110.0

ARITH. MEAN DBH = 2.8 QUADRATIC MEAN DBH =2.98 WEIBULL PARMETERS A = .55 B =2.55 c =2.49

% SURVIVAL= 99.9 MEAN CROUN RATIO = 74.4

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT UOLUHE ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.E.	2 INCHES O.B.	I.B.	3 INCHES O.B.	I.E.
600	70	20	36.4											
				1	10	.1	34.9	6.5	.4	.2				
				2	72	1.6	56.2	i8.8	2i.2	52.3				
				3	157	7.7	61.7	26.8	131.2	84.0				
				4	182	15.9	64.1	32.0	303.5	205.4	290.2	195.7	248.4	165.5
				5	120	16.4	65.5	35.5	334.3	234.8	32b.S	229.0	301.3	210.1
				6	43	8.4		38.1	180.0	i29.9	177.5	128.0	ib9.3	121.8
				7	8	2.1	66.4 67.0	40.1	46.9	34.6	4b.S	34.3	45.1	33.2
				8	1	.3	67.5	41.7	7.8	5.9	7.8	5.8	7.6	5.7
					593	52.5			1025.3	707.0	848.5	592.8	771.7	536.3

ARITH. MEAN DBH = 3.8 QUADRATIC HEM DBH =4.03 UEIBULL PARAMETERS A = .55 B =3.68 c =3.00

% SURVIVAL= 99.1 MEAN CROUN RATIO = 62.4

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- A ALL TREES * ******************FOR O.B. TOPS OF---- 0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER ****** 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
900	70	10	9.1											
				1		1.4	....							
				2	258 87	1.9	68 75.5 9	6.6	11.1	5.1				
								12.1	17.4	9.7				
				3	2	.1	77.4	14.8	1.0	.b				
					347	3 . 4			29.4	If.4				

ARITH. MEAN DBH * 1.3 QUADRATIC MEAN DBH =1.34 UEIBULL PARAMETERS A = .55 B = .81 c =1.91

% SURVIVAL= 108.0 MEAN CROUN RATIO = 71.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT UOLUHE ABOVE 0.2 FOOT STUMP---- ALL TREES * ******************FOR O.B. TOPS OF---- 0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER ****** 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
900	70	15	24.9											
				1	137	.7	51.0	5.7	S.3	2.4				
				2	315	6.9	71.5	15.0	76.2	43.3				
				3	255	12.5	76.2	20.8	169.7	106.4				
				4	115	10.0	78.3	24.5	150.3	99.8	141.4	93.4	114.6	74.5
				5	31	4.2	79.4	27.0	67.0	46.2	64.9	44.6	58.0	39.6
				6				28.9	lb.1	11.4	15.8	11.2	14.8	10.4
				7	51	1.0 .3	80.i 80.6	30.2	4.5	3.3	4.4	3.2	4.3	3.1
					859	35.6			489.0	312.9	226.5	152.4	191.7	127.6

ARITH. MEAN DBH = 2.5 QUADRATIC MEAN DBH =2.76 YEIBULL PARAMETERS A = .55 B =2.25 C =2.03

% SURVIVAL= 99.8 MEAN CROUN RATIO = 70.9

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	*	2 INCHES O.B.	I.B.	*	3 INCHES O.B.	I.B.
900	70	20	36.4													
				1												
				2	198 62	4.3.3	29.2	7.4	2.9	1.3						
							51.8	20.0	61.5	35.9						
				3	248	12.2	57.6	27.9	2i5.2	138.2						
				4			60.3	33.0	338.2	229.3		323.6	218.9		278.7	i86.2
				5	197 109	i7.2 i4.9	61.8	36.4	310.8	2i8.7		303.8	213.4		280.9	196.3
				6	43	8.4	62.7	38.9	183.5	132.6		i8i.0	130.7		172.9	124.5
				7	12	3.2	63.4	40.8	71.5	52.8		70.9	SE.3		68.9	S0.7
				8	3	1.0	63.9	42.3	23.8	17.9		23.6	17.7		23.2	17.4
					872	61.6			1207.3	826.7		903.1	633.0		824.6	575.1

ARITH. MEAN DBH = 3.3 QUADRATIC MEAN DBH =3.60 UEIBULL PARAMETERS A = .55 B =3.14 C =2.18

% SURVIVAL= 97.7 BEAN CROYN RATIO = 55.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUHE ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	*	2 INCHES O.B.	I.B.	*	3 INCHES O.B.	I.E.
1200	70	10	9.1													
				1	293	i.6	68.2	6.5	12.5	5.8						
				I	101 2 2.2 .1		75.3 77.2	12.0 14.7	20.1 1.0 ii.2 .6							
					3 9 6 3 . 9										33.6	17.6

ARITH. MEAN DBH = i.3 QUADRATIC MEAN DBH =1.34 YEIBULL PARAMETERS A = .55 B = .81 C =1.87

% SURVIVAL= 100.0 MEAN CROWN RATIO = 70.1

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B. *	2 INCHES O.B.	I.B. 8	' 3 INCHES O.B.	I.B.
1200	79	if	24.9											
				2	221	9.3	48.6	6.1	6.9	4.1				
				3	428 297	14.6	75.2 70.2	21.2 15.5	201.0 106.1	126.3 60.5				
				4	116	10.1	77.4	24.9	153.5	102.0	144.6	9S.b	iii.6	76.5
				5	28	3.8	78.6	27.3	61.1	42.2	59.2	40.8	53.0	36.2
				6	5	1.0	79.3	29.1	ib.3	ii.5	16.0	ii .3	14.9	10.5
					1095	40.0			546.9	346.7	219.8	147.7	185.5	123.2

ARITH. MEAN DBH = 2.4 QUADRATIC MEAN DBH =2.59 YEIBULL PARAMETERS A = .55 B =2.06 C =1.92

% SURVIVAL= 99.4 MEAN CROWN RATIO = 68.2

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES 8 4-INCH CLASS AND GREATER ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B. 8	2 INCHES O.B.	I.B. 8	3 INCHES O.B.	I.B.
1200	70	20	36.4											
				1	124	.7	23.9	8.2	6.1	2.9				
				2	300	6.5	47.7	2i.i	97.6	57.3				
				3	308	15.1	53.9	28.9	276.2	177.8				
				4	213	18.6	56.7	33.9	374.0	254.6	359.4	243.4	310.7	2oe.i
				5	108	14.7	58.3	37.2	314.1	221.3	307.2	216.1	204.7	199.2
				6	42	8.2	59.3	39.6	iB2.2	131.9	i79.B	130.0	172.0	124.0
				7	13	3.5	60.0	41.5	78.6	58.1	77.9	57.6	75.8	55.8
				8	3	1.0	60.5	42.9	24.1	18.1	23.9	18.0	23.5	17.6
				9	1	.4	60.9	44.0	10.3	7.8	io.2	7.8	10.1	7.7
					1112	68.9			1364.1	929.0	958.4	672.9	876.8	612.4

ARITH. MAN DBH = 3.i QUADRATIC MEAN DBH =3.37 WEIBULL PARAMETERS A = .55 B =2.84 c =1.95

% SURVIVAL= 94.5 MEAN CROYN RATIO = so.2

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	* 2 INCHES * O.B.	I.B.	* 3 INCHES * O.B.	I.E.
1500	70	10	9.1											
				1										
				2	330 115	2.5 i.8	75.0 67.5	6.5	14.0	6.5				
								12.0	22.8	12.7				
				3	3	.1	77.0	i4.7	1.5	.9				
					448	4.5			38.2	20.i				

ARITH. MEAN DBH = 1.3 QUADRATIC MEAN DBH =1.35 WEIBULL PARAMETERS A = .55 B = .81 C =1.84

% SURVIVAL= 100.0 MEAN CROUN RATIO = 69.5

TSO(10)	SI-	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * ***************FOR O.B. TOPS OF---- 0 INCHES O.B.	I.E.	* 4-INCH CLASS AND GREATER ************** 2 INCHES * O.B.	I.B.	* 3 INCHES * O.B.	I.B.
1500	70	15	24.9											
				1	263	i.4	46.4	6.3	10.9	5.0				
				2	562	12.3	69.1	15.9	i42.4	81.4				
				3	359	i7.b	74.3	21.6	246.7	i55.2				
				4	108	9.4	76.5	25.2	144.6	96.2	136.3	90.3	iii.2	72.4
				5	16	2.2	77.8	27.6	35.3	24.4	34.2	23.6	30.6	20.9
				b	1	.2	78.6	29.4	3.3	2.3	3.2	2.3	3.0	2.1
					1309	43.1			583.2	364.6	173.7	iib.2	144.8	95.4

ARITH. MEAN DBH = 2.3 QUADRATIC MEAN DBH =2.46 WEIBULL PARAMETERS A = .55 B =1.96 C =2.07

% SURVIVAL= 98.6 MEAN CROUN RATIO = 66.7

TSO(10)	SI	ACE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----*************** 0 INCHES O.B.	0 INCHES I.B.	2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B.	3 INCHES I.B.
1500	70	20	36.4											
				1	141	.8	19.9	8.9	7.4	3.5				
				2	367	8.0	44.6	2i.9	i23.S	72.7				
				3	378	18.6	51.0	29.7	346.9	223.8				
				4	244	21.3	53.9	34.5	437.0	297.3	419.4	204.5	363.8	244.i
				S	109	14.9	55.5	37.8	321.6	226.8	314.7	221.6	292.0	204.6
				6			56.6	40.1	is3.7	iii.3	151.7	109.8	145.2	104.8
				7	35 8	6.9 2.1	57.4	4i.9	48.9	3L.i	48.5	35.8	47.1	34.8
				8	1	.3	57.9	43.3	8.1	6.1	8.1	6.1	7.9	5.9
					1283	72.8			1447.2	977.7	942.4	657.8	856.0	594.2

ARITH.MEAN DBH = 3.0 QUADRATIC MEAN DBH =3.23 UEIBULL PARAMETERS A = .55 B =2.73 C =2.04

% SURVIVAL= 88.2 MEAN CROWN RATIO = 46.9

TSO(10)	SI	ACE	AV. D+C HT.	DBH	STEMS 'PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE Q.2 FOOT STUMP---- ALL TREES 8 4-INCH CLASS AND GREATER ##############FOR O.B. TOPS OF----88888888888888 QINCHES 0.B.	I.B.	8 2 INCHES 8 O.B.	I.B.	# 3 INCHES # O.B.	I.B.
300	80	10	10.4											
				1		.9								
				2	104 162	2.3	70.7 61.2	6.3	6.7	3.1				
								12.1	20.8	11.6				
				3	4	.2	73.4	15.1	2.1	i.2				
					270	3 . 3			29.6	15.9				

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 WEIBULL PARAMETERS A= .55 B= .99 C =2.09

% SURVIVAL= 100.0 MEAN CROWN RATIO = b5.i

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES 8 4-INCH CLASS AND GREATER ##############FOR O.B. TOPS OF----88888888888888 0 INCHES O.B.	I.B.	8 2 INCHES 8 O.B.	I.B.	8 3 INCHES 8 O.B.	I.B.
300	80	15	28.4											
				1		.0								
				2	3:	.7	67.0 40.4	14.7 4.9	7.4 .1	4.2 .Q				
				3	95	4.7	72.9	2i.3	b4.4	40.5				
				4							147.3	97.6	120.6	78.6
				5	115 51	10.1 7.0	75.4 76.8	25.6 28.5	1f6.i 115.9	104.0 80.2	ii2.4	77.7	101.2	69.4
				6	6	1.2	77.7	30.7	20.5	14.6	20.1	14.3	iB.9	13.4
					300	23.5			3b4.3	243.5	279.8	i89.b	240.7	ibi.4

ARITH. MEAN DBH = 3.7 QUADRATIC MEAN DBH =3.79 YEIBULL PARAMETERS A = .55 B =3.45 c =3.73

% SURVIVAL= 100.0 MEAN CROWN RATIO = 73.8

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.E.	2 INCHES O.B.	I.B.	3 INCHES O.B.	I.B
300	80	20	41.6											
				1	0	0.0	26.1	6.6	0.9	0.0				
				2	16 2	.8	56.0 49.9	20.1 29.1	14.4 .b	.4				
				3						9.3				
				4	53 98	13.4 4.6	58.8 60.4	35.0 39.1	298.2 9b.i	65.4	92.3	62.6	80.2	53.9
				5						210.7	292.0	206.1	271.8	190.9
				6	92	18.1	61.4	42.b	422.8	306.4	416.7	302.4	399.9	289.4
				7	34	9.1	62.1	44.3	219.0	162.4	2i7.2	161.0	211.6	156.6
				8	3	1.0	62.6	4b.i	25.8	i9.s	25.7	19.4	25.2	19.0
					298	47.0			1076.0	774.1	1043.9	751.5	988.7	709.8

ARITH. MEAN DBH = 5.2   QUADRATIC MEAN DBH =5.36   WEIBULL PARAMETERS A = .55   B =5.13   c =4.96

% SURVIVAL= 99.9   MEAN CROWN RATIO = 60.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	2 INCHES O.B.	I.B.	3 INCHES O.B.	I.B.
600	80	10	10.4											
				1	230	1.3	59.4	6.2	9.4	4.4				
				2	141	3.1	70.1	12.0	28.0	15.6				
				3	8	.4	72.9	is.0	3.9	2.4				
					379	4.7			41.4	22.4	-	-	-	-

ARITH. MEAN DBH = 1.4   QUADRATIC MEAN DBH =1.51   WEIBULL PARAMETERS A = .55   B = .98   C =1.98

% SURVIVAL= 100.0   MEAN CROUN RATIO = 63.6

----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP----
**************FOR O.B. TOPS OF----88888888888888

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEHS PER ACRE	BASAL AREA	CR	AV. HT.	0 INCHES O.B.	0 INCHES I.B.	* 2 INCHES O.B.	2 INCHES I.B.	* 3 INCHES O.B.	3 INCHES I.E.
600	SO	15	20.4											
				1	31	.2	36.7	5.3	1.2	.5				
				2	146	3.2	65.1	15.3	35.8	20.4				
				3	210	10.3	7i.4	21.8	145.5	91.6				
				4			74.1	26.0	202.8	i35.2	19i.b	127.2	157.4	102.9
				5	14753	i2.8 7.2	75.b	28.9	122.0	84.6	118.4	81.9	106.8	73.3
				b	9	1.8	7b.b	3i.i	31.1	22.2	30.6	21.8	28.8	20.4
				7	1	.3	77.2	32.7	4.8	3.5	4.8	3.5	4.6	3.3
					597	35.8			543.1	358.0	345.4	234.4	297.6	199.9

ARITH. MEAN DBH = 3.1 QUADRATIC MEAN DBH =3.31 MIBULL PARAMETERS A =.55 B =2.90 C =2.63

% SURVIVAL= 100.0 HEM CROWN RATIO = b9.2

----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP----
ALL TREES * 4-INCH CLASS AND GREATER
**************FOR O.B. TOPS OF----88888888888888

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEHS PER ACRE	BASAL AREA	CR	AV. HT.	0 INCHES O.B.	0 INCHES I.B.	8 2 INCHES O.B.	2 INCHES I.B.	8 3 INCHES O.B.	3 INCHES I.B.
600	SO	20	41.6											
				1	5	.0	i9.i	7.6	.2	.1				
				2	46	1.0	44.5	21.5	is.2	8.9				
				3	120	5.9	5i.i	30.4	112.6	72.7				
				4	174	15.2	54.i	36.1	325.3	222.0	3i2.9	2i2.9	273.4	i04.2
				5	151	20.6	55.8	40.i	471.0	333.5	461.5	326.3	430.6	303.0
				6	77	15.1	51.9	43.0	360.6	262.2	356.3	258.9	342.2	248.0
				7	21	5.6	57.6	45.2	137.7	io2.2	136.6	101.4	133.2	90.7
				8	3	1.0	58.2	46.9	26.2	19.8	2b.i	19.7	25.6	19.3
					597	64.5			i448.8	1021.5	i293.4	919.2	1205.0	853.2

ARITH. MEAN DBH = 4.2 QUADRATIC MEAN DBH =4.45 YEIBULL PARAHETERS A = .55 B =4.14 C =3.21

% SURVIVAL= 99.7 MEAN CROWN RATIO = 53.3

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES ***************FOR O.B. TOPS OF----0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER 2 INCHES O.B.	I.B.	3 INCHES O.B.	I.B.
900	80,	10	10.4											
				1	273	1.5	58.2	6.i	11.1	5.1				
				2	164	3.6	69.5	ii.9	32.4	18.0				
				3	10	.5	72.6	14.9	4.9	3.0				
					447	5.6			48.4	26.2				

ARITH. HEM DBH = 1.4 QUADRATIC MEAN DBH =1.51 UEIBULL PARAMETERS A = .55 B = .98 c =1.93

% SURVIVAL= 100.0 MEAN CROWN RATIO = 62.5

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEM PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES ***************FOR O.B. TOPS OF----0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER 2 INCHES O.B.	I.E.	3 INCHES O.B.	I.B.
900	80	15	28.4											
				1	112	.6	33.0	5.6	4.3	2.0				
				2	204	6.2	63.3	15.8	71.6	40.9				
				3	268	i3.2	70.0	22.3	189.5	119.5				
				4	150	13.1	72.8	26.5	2io.2	140.3	198.8	132.1	164.0	i07.3
				5	54	7.4	74.4	29.3	125.9	07.3	122.2	84.6	iio.4	75.9
				6	13	2.6	75.4	3i.4	45.4	32.4	44.6	3i.8	42.0	29.8
				7	2	.5	76.1	33.0	9.8	7.1	9.7	7.0	9.3	6.8
					883	43.5			656.7	429.6	375.3	255.5	325.7	219.8

ARITH. WEAN DBH = 2.8 QUADRATIC MEAN DBH =3.00 YEIBULL PARAMETERS A = .55 B =2.51 C =2.05

% SURVIVAL= 99.9 MEAN CROWN RATIO = 64.0

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	2 INCHES O.B.	I.B.	3 INCHES O.B.	I.B
900	80	20	41.6											
				1	49	.3	11.7	8.6	2.5	1.2				
				2	167	3.6	38.7	22.9	58.5	34.6				
				3	230	11.3	45.7	31.7	224.6	145.6				
				4	209	la.2	48.9	37.3	402.7	275.5	387.9	264.6	340.7	230.2
				5	137	18.7	50.7	41.2	437.9	310.6	429.4	304.1	401.5	283.0
				6	67	13.2	51.9	43.9	320.3	233.2	3ib.S	230.3	304.4	220.9
				7	25	6.7	52.8	46.0	166.9	124.0	165.6	123.0	161.5	119.8
				8	7	2.4	53.4	47.7	62.1	46.9	61.8	46.7	60.8	45.9
				9	1	.4	53.8	49.0	11.4	a.7	11.3	a.7	11.2	8.6
					892	74.8			1686.9	1180.3	1372.5	977.4	1280.1	908.4

ARITH. MEAN DBH = 3.6 QUADRATIC MEAN DBH =3.93 UEIBULL PARAHETERS A = .55 B =3.48 c =2.22

% SURVIVAL= 99.2 MEAN CROUN RATIO = 44.8

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT UOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES * 4-INCH CLASS AND GREATER ***************FOR 0 .B. TOPS OF----************** 0 INCHES O.B.	I.B.	2 INCHES O.B.	I.B.	3 INCHES O.B.	I.B
1200	80	IO	10.4											
				1	316	1.7	57.0	6.0	12.8	5.9				
				2	187	4.1	69.0	11.8	36.7	20.5				
				3	13	.b	72.2	i4.8	b.4	3.9				
					516	6.4			55.9	30.2	-	-	-	-

ARITH. MEAN DBH = 1.4 QUADRATIC MEAN DBH =1.51 UEIBULL PARAHETERS A = .55 B = .98 c =1.88

% SURVIVAL= 100.0 MEAN CROUN RATIO = 61.7

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B TOPS OF----************** 0 INCHES O.B.	0 INCHES I.B.	2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B	3 INCHES I B
1200	80	15	28.4											
				1	194	1.1	29.4	6.0	7.8	3.6				
				2	411	9.0	bi.5	ib.3	106.6	6i.i				
				3	330	ib.2	68.5	22 8	237.9	150.3				
				4	157	13.7	7i.5	26.9	223.3	149.2	211 4	140 7	174.9	114 7
				5	49	6.7	73.2	29.7	115.6	80.2	1'12.3	77 8	101 6	69.9
				6	10	2.0	74.3	31.8	35.3	25.2	34.7	24.7	32.7	23 2
				7	2	.5	75.0	33.3	9.8	7.2	9.7	7.1	9.4	6.8
					- z	49.1			-- 736.3	476.8	368.1	250.3	318 6	ii4 6

ARITH. MEAN DBH = 2.6 QUADRATIC MEAN DBH =2.79 WEIBULL PARMETERS A = .55 B =2.27 C =1 94

% SURVIVAL= 99.7 MEAN CROUN RATIO = 60 1

TSO(10)	SI	AGE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AV. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES ***************FOR O.B TOPS OF----************** 0 INCHES O.B.	0 INCHES I.B.	4-INCH CLASS AND GREATER 2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B	3 INCHES I.B
1200	80	20	41.6											
				1	108	.6	10 0	9.8	6.0	2.9				
				2	274	6.0	32.6	24.4	101.4	60.2				
				3	306	15.0	40.1	33.1	310.3	201.8				
				4	238	20.8	43.5	38.5	472.0	323.6	455.2	311.3	401.7	272 i
				5	141	19.2	45.4	42.2	4bi.3	327.6	452.5	32i.0	424.0	299 4
				6	66	13.0	46.7	44.9	321.7	234.5	318.0	23i.6	306.1	222 5
				7	25	6.7	47.6	46.8	i69.7	126.2	168.4	525.2	ib4.4	122 0
				8	8	2.8	48.3	48.4	72.1	54.5	7i.7	54 2	70 5	53.3
				9	2	.9	48.8	49.6	23.1	17.7	23.0	17 6	22.7	17 4
					1168	84.9			1937.4	1349.0	1488.8	I0b0.9	1389 4	986 7

ARITH. MEAN DBH = 3.3 QUADRATIC MEAN DBH =3.65 YEIBULL PARAMETERS A = .55 B =3.13 c =1.95

% SURVIVAL= 98.0 MEAN CROUN RATIO = 37.5

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	* 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
1500	80	10	10.4											
				1	360	2.0	55.7	5.9	14.4	6.6				
				2	210	4.6	68.5	ii.8	41.0	22.8				
				3	16	.8	7i.9	14.8	7.8	4.8				
					586	7.3			63.3	34.2	-	-	-	-

ARITH. MEAN DBH = 1.4 *QUADRATIC MEAN DBH =1.51* *UEIBULL PARAHETERS A = .55 B = .98 C =1.85*

% SURVIVAL= 100.0 *MEAN CROUN RATIO = 60.8*

TSO(10)	SI	AGE	AU. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ALL TREES ***************FOR O.B. TOPS OF----************** 0 INCHES O.B.	I.B.	* 4-INCH CLASS AND GREATER 2 INCHES O.B.	I.B.	* 3 INCHES O.B.	I.B.
1500	80	15	28.4											
				1	210	1.1	25.7	6.4	8.8	4.1				
				2	565	12.3	59.7	ib.8	150.4	86.5				
				3	444	21.8	67.1	23.2	325.9	206.2				
				4	158	i3.8	70.3	27.3	227.8	152.5	21S.9	143.8	i79.2	ii7.7
				5	20	3.8	72.0	30.1	66.8	46.4	64.9	45.0	58.8	40.5
				b	2	.4	73.i	32.1	7.1	5.1	7.0	5.0	6.6	4.7
					1407	53.5			-- 78b.9	500.7	-287.8	i93.8	244.6	162.9

ARITH. MEAN DBH = 2.5 *QUADRATIC MEAN DBH =2.63* *UEIBULL PARAMETERS A = .55 B =2.16 C =2.23*

% SURVIVAL= 99.2 *WEAN CROWN RATIO = 58.4*

TSO(10)	SI	ACE	AV. D+C HT.	DBH	STEMS PER ACRE	BASAL AREA	CR	AU. HT.	0 INCHES O.B.	0 INCHES I.B.	2 INCHES O.B.	2 INCHES I.B.	3 INCHES O.B.	3 INCHES I.B.
									----CUBIC FOOT VOLUME ABOVE 0.2 FOOT STUMP---- ***************FOR O.B. TOPS OF----**************					
1500	80	20	4i.b											
				1	97	.5	10.0	10.9	5.9	2.8				
				2	331	7.2	26.7	25.8	i28.S	76.7				
				3	421	20.7	34.6	34.3	441.3	287.8				
				4	324	28.3	38.3	39.6	bS8.9	452.5	b3b.3	435.9	563.7	382.6
				S	165	22.5	40.4	43.1	550.8	391.8	540.7	384. 1	507.5	358.9
				6			4i.7	45.7	282.6	206.2	279.4	203.8	269.2	195.9
				7	57 13	11.2 3.5	42.6	47.b	89.5	bb.7	88.9	66.1	86.8	64.5
				8	2	.7	43.3	49.i	18.2	13.8	18.2	13.7	17.9	13.5
					1410	94.6			2175.7	1498.4	1563.5	1103.6	i44s.i	1015.4

ARITH. MEAN DBH = 3.3 QUADRATIC MEAN DBH =3.51 UEIBULL PARAMETERS A = .55 B =3.06 C =2.26

% SURVIVAL= 95.3 MEAN CROUN RATIO = 33.0

Farrar, Robert M., Jr. 1985. Predicting stand and stock tables from a spacing study in naturally regenerated longleaf pine. U.S. Dep. Agric. For. Serv. Res. Pap. SO-219, 28 p. South. For. Exp. Stn., New Orleans, LA.

Paper outlines a prediction system developed to calculate stand and stock tables for stands of natural longleaf pine 10 to 20 years old. The system also provides entry to other stand volume prediction and projection systems that usually start at age 20.

Additional keywords: *Pinus palustrus;* volume prediction; volume yields; crown ratio, survival prediction.

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