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Validation of the Unthinned Loblolly Pine Plantation Yield Model-USLYCOWG

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SUMMARY

Yield and stand structure predictions from an unthinned loblolly pine plantation yield prediction system (USLY-COWG computer program) were compared with observations from 80 unthinned loblolly pine plots. Overall, the predicted estimates were reasonable when compared to observed values, but predictions based on input data at or near the system's limits may be in error by as much as 14 percent. Correlations between observed and predicted values for the variables selected ranged from 0.72 to 0.96.

Additional keywords: *Pinus taeda,* validation, volume prediction, unthinned plantation yields.

INTRODUCTION

A system of equations presented by Dell et al. (1979) and Feduccia et al. (1979) made detailed forecasts for unthinned slash pine (*Pinus elliottii* var. *elliottii* Englem.) and loblolly pine (*P. taeda* L.) plantation development using diameter distributions and stem taper functions. A FORTRAN computer program to predict yields with this system, USLY-COWG (unthinned slash and loblolly yields for cutover sites in the West Gulf), is available from the Southern Forest Experiment Station.[1]

For the unthinned slash pine, 68 plots were remeasured after the system was developed and the new data were used in validation (Dell et al. 1979). However, the equations presented for loblolly pine were only evaluated by summarizing trends in deviations between predicted and observed values for the observations upon which they were based (Feduccia et al. 1979). A comprehensive validation of the loblolly pine model was lacking. After the system was developed and results published, some of the unthinned loblolly pine plots used in model development were remeasured. This paper presents a partial validation of the loblolly pine model using data collected from these plots. Validation with an appropriate, independent data set has not yet been accomplished.

METHODS

Eighty of the study plots that had been used in model development were remeasured after 6 years. These were located in unthinned loblolly pine plantations established on cutover forest sites. Plots were within plantations having good planting survival, and also free of heavy insect, disease, or other damage ("ideal" survival conditions). Site indices at base age 50 ranged from 54 to 129 feet (35 to 84 for base age 25), initial planting densities were 109 to 1,390 stems per acre, survival was from 35 to 85 percent, and ages ranged from 11 to 31 years. Summaries of the distributions of the plots are given in tables 1 through 3.

For each plot, all tree diameters were measured at breast height (dbh) to the nearest 0.1 inch.[2] Trees were allocated to l-inch dbh classes and sample trees for volume determinations were selected in proportion to the diameter distribution. Data obtained included total height (TH), height to succeed-

[1] Statistical Methods for Research and Application, Room T-10210, 701 Loyola Ave., New Orleans, LA 70113.

[2] Measurement plot sizes varied from 0.1 to 0.7 acre.

ing 2-inch diameter taper steps, outside bark (o.b.), height to base of living crown (HBLC), and crown class. The average height of a minimum of 10 dominant and/or codominant sample trees was used for site index estimates.

Cubic-foot volume of each sample tree was calculated by height accumulation (Lohrey and Dell 1969). Total and merchantable per acre volumes on individual plots were then computed by multiplying plot basal area by the volume to basal area ratio of the sample trees.[3]

An estimate of site index (base age 50) on each plot was determined from loblolly pine site curves by Popham et al. (1979). Mean plot crown ratio percent (CR) was computed using the formula $CR = (100/m) \Sigma (TH - HBLC)/TH$, where m was the number of sample trees measured on each plot.

RESULTS AND DISCUSSION

Results are presented separately for the two survival situations described in Feduccia et al. (1979): (1) known surviving trees and (2) a knowledge of trees planted and "ideal" survival. Predictions from the USLYCOWG system were compared with observed values from the 80 remeasured plots (n). The correlation coefficient (r) of observed and predicted values was computed along with mean percent difference ($\%d = (100/n) \Sigma (\text{Pred.} - \text{Obs.})/\text{Obs.}$), observed

[3]Total volume-was for all trees 0.6 inch dbh and larger, from the stump to O-inch top. Merchantable volume was for trees in the 5-inch dbh class and larger, from the stump to 4-inch top diameter outside bark.

Table 1 .-*Distribution of plots by plantation age and planting density*

	Planting density range (trees per acre)						
Age class	≤250	251-500	501-750	751-1000	1001-1250	≥1251	Total
years				*number*			
8-12	8	4	4	. . . . .	. . . .	. . . .	16
13-17	.	.		4	. . .	. . . .	4
18-22		11	.	9			20
23-27	.		4	5	5	3	17
28-32	. . .	8	7	5	4	1	23
Total	8	21	15	23	9	4	80

Table 2.-*Distribution of plots by plantation age and site index*

	Site index class (age 50)						
Age class	≤65	66-75	76-85	86-95	96-I 05	≥106	Total
years				*number*			
8-12	.	·		1	5	10	16
13-17	.	.	.	2	2		4
18-22	5	1	2	9	2	3	0
23-27	. .	. 5		7	4	1	17
28-32	.	2	4	5	12	. .	23
Total	5	3	11	24	23	14	80

Table 3.-*Distribution of plots by planting density and site index*

Planting density range	Site index class (age 50)						
	≤65	66-75	76-85	86-95	96-I 05	≥106	Total
no. of trees				*number*			
≤250	....	....	....	1	5	2	8
251600	5	1	3	....	5	7	21
501-750	....	....	2	5	4	4	15
751-1000	....	1	3	12	6	1	23
1001-I 250	....	1	1	5	2	....	9
≥1251	....	....	2	1	1	....	4
Total	5	3	11	24	23	14	80

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Table 4.— *Closeness of fit statistics for which the number of surviving loblolly pine trees is known*

Variable	Statistics[1] r	$\overline{\%d}$	$\overline{Obs.}$	$\overline{Pred.}$	$\overline{d}$
Quadratic mean dbh (in)	0.84	3.5	8.0	8.1	0.1
Basal area (ft²/acre)	.91	9.4	132	138	8
Total volume (ft³ o.b./acre)	.96	10.8	3,726	3,921	195
Merchantable volume (ft³ o.b. to 4 in top/acre)	.95	6.5	3,491	3,462	-29
Percent mean crown – ratio (All trees)	.96	11.6	40	44	4

[1] r = correlation coefficient
$\overline{\%d}$ = mean percent difference = $(100/n)\ \Sigma$ (Pred. – Obs.)/Obs.
$\overline{Obs.}$ = observed mean
$\overline{Pred.}$ = predicted mean
$\overline{d}$ = mean difference = $1/n\Sigma$(Pred. – Obs.)
where n = sample size

Table 5.— Closeness *of fit statistics based on loblolly pine trees planted and the 'ideal" survival model*

Variable	Statistics[1] r	$\overline{\%d}$	$\overline{Obs.}$	$\overline{Pred.}$	a
Quadratic mean dbh (in)	0.72	3.1	8.0	8.0	0.0
Basal area (ft²/acre)	.87	11.7	132	136	4
Total volume (ft³, o.b./acre)	.93	13.6	3,726	3,842	116
Merchantable volume, (ft³, o.b./acre)	.93	8.7	3,491	3,396	-95
Surviving trees (No./acre)	.88	7.0	408	398	-10
Percent mean crown-ratio (All trees)	.96	12.0	40	44	4

[1] r = correlation coefficient
$\overline{\%d}$ = mean percent difference = $(100/n)\Sigma$(Pred. – Obs.)/Obs.
$\overline{Obs.}$ = observed mean
$\overline{Pred.}$ = predicted mean
$\overline{d}$ = mean difference = $1/n\Sigma$(Pred. – Obs.)
where n = sample size

Table 6—*Closeness of fit statistics within three age classes for the two survival models*

			Known survival		Trees planted and "ideal" survival	
Variable	Age class	Plots	Mean percent diff.[2]	Plots overpredicting	Mean percent diff.	Plots overpredicting
	yrs	*no.*	*percent*			
Quadratic mean dbh (in)	≤18	28	-4.5	32	-8.0	25
	19-25	27	10.9 (1.4)[1]	56	11.3 (2.1)[1]	59
	≥26	25	4.7	72	8.8	64
Basal area (ft²/acre)	≤18	28	-7.9	29	3.9	46
	19-25	27	28.7 (3.6)	59	28.3 (2.2)	52
	≥26	25	10.0	76	4.7	40
Total volume (ft³ o.b./acre)	≤18	28	-4.0	36	9.1	54
	19-25	27	25.7 (3.2)	63	25.3 (2.0)	59
	≥26	25	11.2	72	6.0	52
Merchantable volume (ft³ o.b./acre)	c18	28	-11.5	14	-0.9	39
	19-25	27	25.1 (-3.1)	52	24.8 (-4.0)	44
	≥26	25	6.5	68	2.0	44
Surviving trees (no./acre)	≤18	28			28.2	68
	19-25	27			-0.9 (-12.1)	44
	≥26	25			-8.2	40

[1]Values in parentheses obtained by exclusion of six plots.
[2]Mean percent difference = $\overline{\%d}$ = $(100/n)\ \Sigma$ (Pred. Obs.)/Obs.

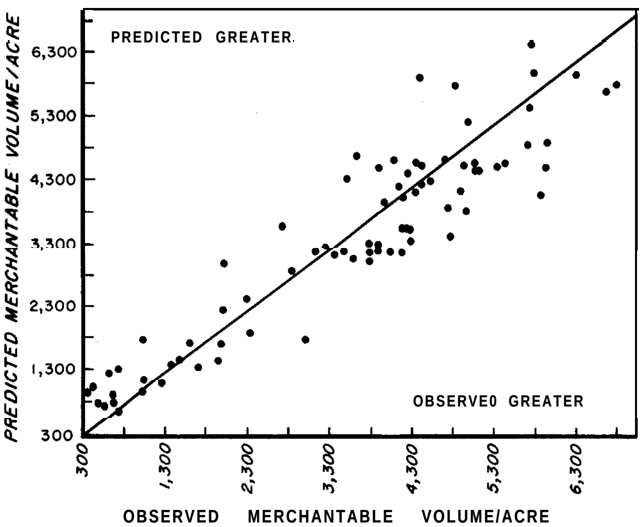

Figure 1.—Comparison *of observed versus predicted merchantable* ***volume*** *(outside bark) per acre for* ***loblolly*** *pine* ***trees*** *planted and "'ideal" survival.*

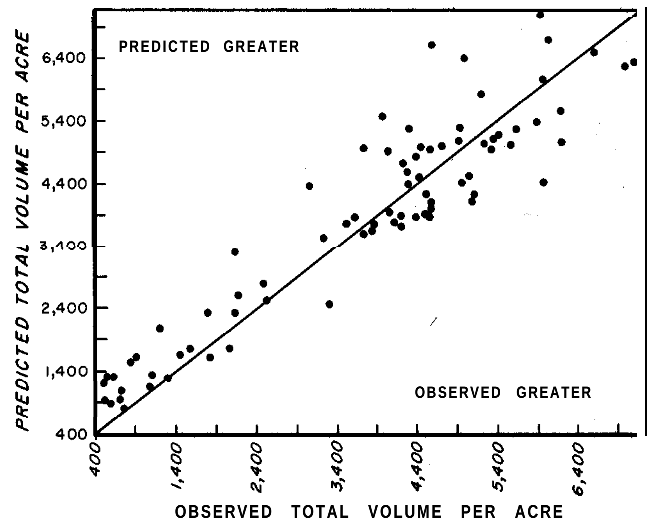

Figure **2.—Comparison** *of observed versus predicted total volume (outside bark.) per acre* ***for loblolly*** *pine* ***trees planted*** *and "ideal"* ***survival.***

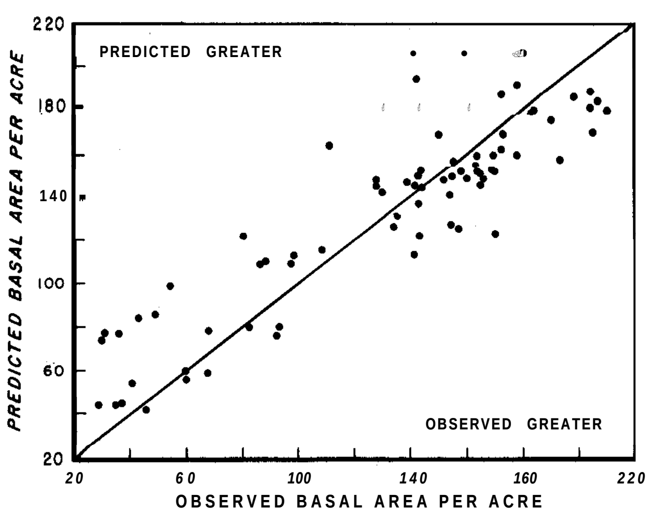

Figure **3.—Comparison** *of observed versus predicted basal area per acre for* ***loblolly pine*** *frees planted and "'ideal" survival.*

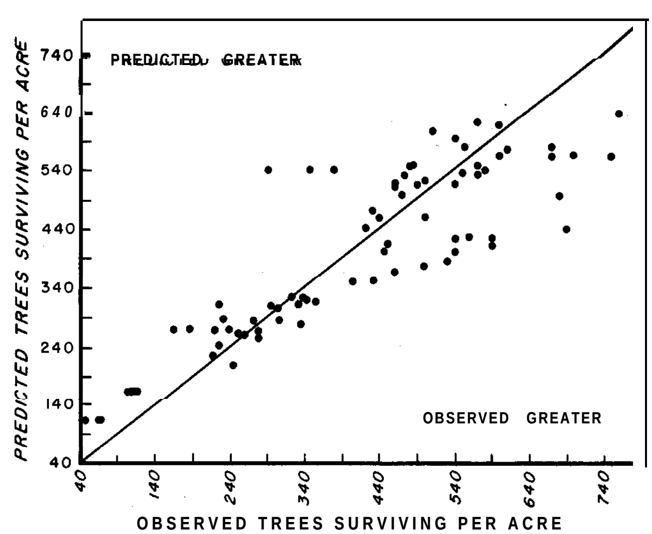

Figure **4.—Comparison** *of observed versus* ***predicted trees surviving*** *per acre for* ***loblolly*** *pine* ***trees*** *planted and "ideal"* ***survival.***

mean (Obs.), predicted mean (Pred.), and mean difference ($\bar{d}$ = (l/n) Σ (Pred. $-$ Obs.)) statistics.

Overall, the prediction system produced close estimates of selected variables for both survival conditions (tables 4 and 5). For example, the results support the validity of the taper curve volume defining component used in the prediction system since the observed total and merchantable volume yields were determined by the height accumulation method.

However, the mean percent difference statistics suggested a possible general overprediction trend for the variables tested. Therefore, scattergram comparisons of observed and predicted plot values were made for both survival models and all variables. Since the results using both survival models were similar, only the graphs using known trees planted and "ideal" survival are shown in figures 1-4.

The graphs indicated that the yield system predicted high for low values of all the variables and underpredicted for high values of some of the variables. The most accurate predictions occurred within the mid-range of the data. Also, there was some tendency towards greater variability in the larger predicted values of the variables being considered.

The overall positive mean percent difference statistics could have been due to a greater frequency of overpredictions than underpredictions and/or a larger average magnitude of positive over negative errors. The frequency analysis revealed that observed plot values for merchantable and total volume were greater than the corresponding predicted values on 55 and 44 percent of the plots, respectively (figures 1 and 2). Observed basal area exceeded predicted basal area in 51 percent of the cases and observed trees surviving were greater than predicted living stems on 46 percent of the plots (figures 3 and 4). These results indicated no strong positive error trend due to frequency. Therefore, it was surmised that the greater magnitude of the positive errors, particularly for low variable values, was the dominant contributing factor.

Some further comparisons were made by separating the observed and predicted values of the volume, basal area, and trees surviving into three or four classes based on the system input variables of age, site index, and density (table 6). The analysis using the age class separations provided the most enlightening additional information.

For stands in the age 18 and younger category, the greater part of the magnitude of the prediction errors was caused by the preponderance of young-aged and high-site plantations. Stands represented by 16 out of 28 plots were only 11 years old when remeasured and were all on excellent sites. They represented both the lower-age and upper-site limits for prediction reliability with the Feduccia et al. (1979) system: and 70 percent of the highest site plots in the validation data set as compared to only 33 percent of the highest site plots in the model data set. Thus, since models represent average conditions within the data used to build them, it is understandable that the model predictions were lower, on the average, than the observed values for these plots.

Two values of the mean percent difference statistic were determined for each variable in the 19 to 25 age class. The smaller, or more negative, values (table 6, in parentheses) were obtained when six unusual plots were intentionally excluded from the analysis. The extent of possible overall prediction error by the system within this age class was dramatically reduced by 9.2 to 28.8 percent.

The six plots that were excluded (age 20 years) were located on low density, poor sites ($251 \leqslant$ planting density $\leqslant 500$, $54 \leqslant SI_{50} \leqslant 72$) from one geographical area. As with the 16 plots mentioned previously, they were at the lower end of the prediction system's capability and represent an extreme in the spectrum of the validation data. For example, predicted yields on these plots were about double observed yields. As the mean percent difference statistics for that age class indicated, the influence of the data from these plots for low values of basal area and volume was considerable.

The effect on the overall analyses was also noticeable. By omitting data from those six low-site plots, the mean percent difference statistics for the quadratic mean dbh, basal area, total volume, and merchantable volume presented in tables 4 and 5 under known survival conditions became 0.25, 1.44, 3.19, and -3.06, respectively; and – 0.15, 3.69, 6.04, and – 0.84, respectively, for the "ideal" survival model.

Thus, the main cause of the apparent yield overprediction tendency in the 19 to 25 year-old class was likely the inclusion of validation data from those low-density, low-site stands. From this it was concluded that the system may significantly overpredict yields in similar stands.

The mean percent difference statistics in the oldest age class also indicated a small overprediction possibility averaging 6.5 percent for all variables considered, except for surviving trees (table 6).

CONCLUSIONS

This validation analysis found that, overall, the Feduccia et al. (1979) unthinned loblolly pine plantation yield prediction system produced reasonably close estimates of volume yields and other parameters. Yield trends for volume and basal area from the system were towards underprediction in young high-site or older stands, and overprediction in low-density, low-site stands. Errors up to 14 percent were found to occur at or near the extremes of some of the input data ranges suggested in Feduccia et al. (1979), so the following slightly more restrictive limits for the use of the system are proposed: (1) stand ages 15 to 30; (2) sites (base age 50) of 70 to 100 (45-65 for base age 25), and (3) planting densities of 250 to 1,500 stems per acre. Predictions will be best when input data lie within the middle of the above ranges.

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