Site Index Curves for Eastern Cottonwood Plantations in the Lower Mississippi Delta[1]

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*ABSTRACT. A site index equation was developed based on stem-analysis data collected from 30 sites of an eastern cottonwood (*Populus deltoides *Bartr.) plantation in the lower Mississippi Delta. The Bailey and Clutter (1974) equation form was selected for stand height prediction. Polymorphic site index curves (base age 10 years) were presented based on this equation. These curves should be applicable to cottonwood plantations up to 11 years old in and near the Mississippi River Delta.*

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Eastern cottonwood is the fastest growing tree native to North America (Capel and Coffman 1966, Carter and White 1970, Johnson and Burkhardt 1976). Cottonwood is usually restricted to river bottoms, but its range includes every state from the Great Plains eastward. It is important along the Mississippi River because this part of its range has alluvial soils where moisture is abundant year-round without long-term flooding (McKnight 1971). There is a continuing demand for cottonwood grown on short pulpwood rotations (10 years) in the South. However, escalating land use competition with agriculture requires a readily available method to evaluate which sites are best suited for cottonwood production.

Neebe and Boyce (1959) developed site index curves for eastern cottonwood grown in Kentucky, Missouri, Illinois, and Indiana, but no equations were presented. In addition, these curves are not suitable for short-rotation cottonwood because they are based on an index age of 25 years. The objective of this study was to develop a site index equation for eastern cottonwood plantations grown on short rotations (up to 11 years) in the lower Mississippi River Delta.

DATA

Stem-analysis data for this study were taken from 30 sites of a cottonwood plantation ranging in age from 3 to 11 years at Fitler Managed Forest, near Vicksburg, MS. At each site, three dominant or codominant trees were randomly selected; each tree was felled and cross-sectioned at 5-ft intervals starting from a 0.5-ft stump, and annual rings were counted at each cut. Heights corresponding to various ages were estimated using Lenhart's (1972) method. The stand height for each site at ages one to 11 was computed as the average of the three trees (Table 1). The 30 sites encompassed seven soil series which included Robinsonville (10 plots), Sharkey (5 plots), Bowdre (4 plots), Commerce (4 plots), Tunica (4 plots), Bruin (2 plots), and Commerce to Sharkey (1 plot). There were a total of 250 height-age pairs in the data set.

DEVELOPMENT OF SITE INDEX CURVES

Although short pulpwood rotations are predominant, site index equations for cottonwood should be flexible enough to conform to varying rotations. Base-age invariant site index curves fit this requirement because the base age can be changed without refitting the equations. After evaluating different models, we found the Bailey and Clutter (1974) equation form most appropriate for rapid-growing cottonwood plantations.

The height-age model used by Bailey and Clutter (1974) was

Table 1. Summary statistics for stand height of eastern cottonwood plantations.

Stand age	*N*	Minimum	Mean	Maximum	Standard deviation
		(ft)			
1	30	3.00	6.39	13.00	2.64
2	30	8.00	14.58	26.33	4.47
3	30	14.67	23.47	38.00	6.21
4	28	21.33	32.06	46.33	6.83
5	21	28.00	39.19	53.00	7.31
6	21	34.40	47.19	59.67	6.69
7	21	38.27	53.46	66.33	7.10
8	21	43.00	59.83	74.27	8.08
9	21	48.00	64.01	77.73	7.82
10	14	61.60	70.36	80.10	6.13
11	13	66.33	75.07	83.27	5.96

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based on a modified form of the Schumacher (1939) equation:

$$\ln(H) = b_1 + b_2(1/A)^{b_3} \qquad (1)$$

where

$\ln(x)$ = the natural logarithm of x,
H = average height in feet of the dominants and codominants,
A = stand age in years, and
b_i = regression coefficients to be estimated from the data.

If the slope b_2 from the above equation is assumed to vary with different sites, then b_2 can be expressed in terms of site index (S) and base age (I):

$$b_2 = I^{b_3}[\ln(S) - b_1]$$

Substituting b_2 into Equation (1) resulted in a polymorphic site index model:

$$\ln(H) = b_1 + [\ln(S) - b_1](I/A)^{b_3} \qquad (2)$$

Bailey and Clutter (1974) developed a method to compute the coefficients b_1 and b_3 (common for all sites) without having to estimate the slope b_2 for each site. Applying this method to the cottonwood data yield the final site index equation:

$$\ln(H) = 5.83564 + [\ln(S) - 5.83564](I/A)^{0.41576} \qquad (3)$$

Site index prediction for any base age up to 11 years can be determined with the following equation:

$$\ln(S) = 5.83564 + [\ln(H) - 5.83564](A/I)^{0.41576} \qquad (4)$$

Equation (3) was used to calculate height at a given age for each site. The stem-analysis data contained a series of stand height and age observations for each site. Since the oldest observation from each site occurred at an age ranging from 3 to 11 years, it was difficult to determine a consistent base age for site index (both needed as inputs for Equation 3). The age and height of the oldest observation for each site were arbitrarily considered as base age and site index, respectively. Table 2 shows the differences between observed and predicted height values. The site index equation yielded an average difference of 0.21 ft (different from zero at P = 0.39), an average absolute difference of 2.75 ft, and a fit index (similar to R^2) of 0.97. Plots of residuals versus age as well as predicted height for the height-age equation revealed no noticeable trends.

Site index curves can be easily generated from Equation (3), as illustrated in Figure 1. These curves are polymorphic because they possess a variety of shapes and a constant proportional relationship does not necessarily exist among them.

The ability of Equation (3) to extrapolate past the maximum age (11 years) of the data was then explored. Table 3 illustrates long-term height projection from ages 10 and 12 to ages 15, 20, and 25, respectively, using Equation (3) and using site index curves published by Neebe and Boyce (1959). The latter were derived from measured cottonwood trees which ranged from 11 to 53 years old.

Table 2. Differences between observed and predicted stand heights by age classes.

Plantation age (yr)	Average difference (ft)	Difference in feet (Observed-Predicted Height)									
		≤ -10	-8	-6	-4	-2	0	2	4	6	All
		(no. of observations)									
1	0.94					5	12	10	2	1	30
2	−0.67			2	6	5	7	7	2	1	30
3	−1.24	2	3		4	1	9	5	4		28
4	−1.45	1	2	2	3	3	3	2	3	2	21
5	−0.33	1	2	1	2	3	3	2	2	5	21
6	0.95		1		3	2	6	2	3	4	21
7	1.13			1	2	2	4	5	6	1	21
8	1.93				1	2	3	8	5	2	21
9	1.50					2	4	4	4		14
10	0.30					1	10	2			13
All	0.21	4	8	6	21	26	61	47	31	16	220

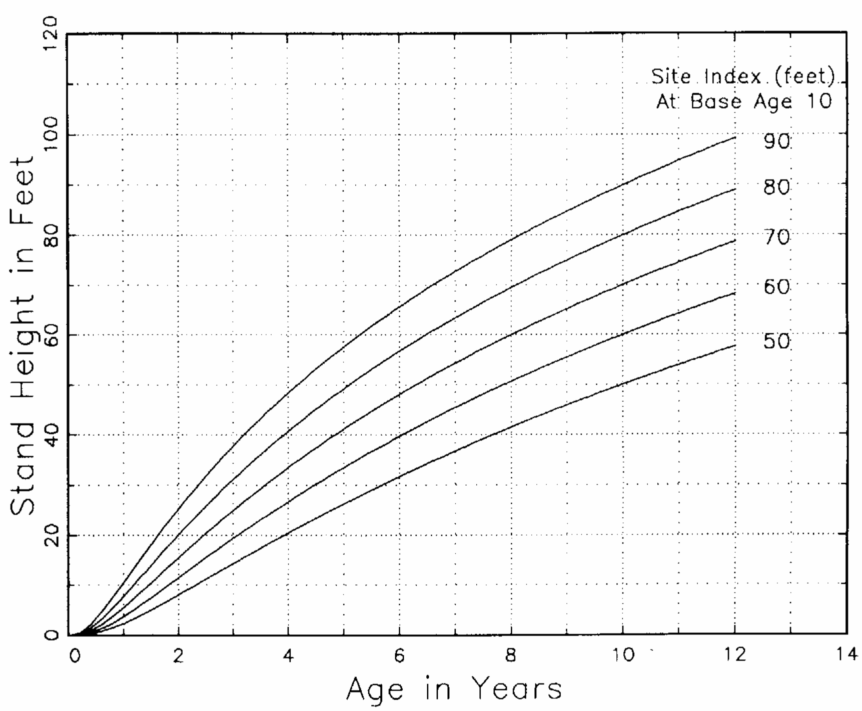

Figure 1. Site index curves for eastern cottonwood plantations grown in the lower Mississippi River Delta near Vicksburg, Mississippi. The equation is: $\ln(H) = 5.83564 + [\ln(S) - 5.83564](I/A)^{0.41576}$

Table 3. Extrapolation of Equation (3)—long-term height projection as compared with that from Neebe and Boyce's (1959) curves.

Starting age	Projected age	Starting height	Projected height Eq. (3)	Projected height Neebe and Boyce
.... (yr)	....	....	(ft)	....
10	15	50	68	70
		55	73	77
		60	79	83
		65	85	91
		70	90	97
	20	50	82	83
		55	88	92
		60	94	99
		65	100	108
		70	105	115
	25	50	93	92
		55	99	102
		60	105	110
		65	111	120
		70	117	128
12	15	50	59	59
		55	65	65
		60	70	71
		65	76	77
		70	81	82
		75	86	88
		80	91	94
	20	50	73	71
		55	79	77
		60	84	84
		65	90	91
		70	96	98
		75	101	105
		80	107	112
	25	50	84	78
		55	90	85
		60	96	93
		65	102	102
		70	107	109
		75	113	117
		80	119	124

Equation (3) appeared to extrapolate well and provided height projections compatible with Neebe and Boyce's site index curves, even though the range in age of the two data sets barely overlaped at age 11. Table 3 also implies that it might be acceptable to use Equation (3) for younger ages and then switch to Neebe and Boyce's system for older trees.

The site index equation presented here has many desirable properties. The resulting site index curves are base-age invariant, polymorphic, and start at zero when age is zero. They should perform well in height or site index prediction for eastern cottonwood plantations grown on short rotations in the lower Mississippi River Delta. □

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