Site Index Curves for Direct-Seeded Loblolly and Longleaf Pines in Louisiana

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ABSTRACT. *Site index equations were developedfor direct-seeded loblolly pine (*Pinus taeda *L.) and longleaf pine* (Pinus palustris *Mill.) based on data from 148 and 75 permanent plots, respectively. These plots varied from 0.053 to 0.119 ac in size, and were established in broadcast, row, and spot seeded stands throughout Louisiana. The Bailey and Clutter (1974) model was selectedfor stand height prediction. Site index curves are presentedfor both species based on these equations. These site indexmodels shouldprovide satisfactory short-term height projection for direct-seeded loblolly and longleaf pine stands in Louisiana. South. J. Appl. For. 21(3):134–138.*

Nearly one million ac of southern pines were established by direct seeding during the 1960s as an alternative to natural regeneration and planting (Derr and Mann 197 1) and of that more than 150,000 ac was in Louisiana (Mann and Derr 1966). This artificial stand establishment practice has continued strongly since that time because of lower establishment costs (Haywood and Barnett 1994). However, planting has become more popular likely because some bird and rodent repellents used earlier to coat the seeds were banned, planting provides for better control of genetic quality, and planting gives one better control of early stand density. The usual direct seeding procedure was to broadcast the seed over the area to be regenerated (on the ground or from the air without site preparation) at specified application rates, and often follow with precommercial thinning (Mann and Lohrey 1974). Other direct seeding methods included row seeding variations (furrow sowing, broadcast sowing on flat or mounded strips, swath sowing on flat or mounded strips) or spot seeding-seeding in small or less well defined clumps with no site preparation (Campbell 1985).

Since it was not known how these techniques would affect the growth and yield of pines on various sites, several long-term direct-seeding studies were established using these techniques to provide data to model pine response to the various treatment and stand density combinations. This paper provides site index prediction equations for direct-seeded loblolly and longleaf pines developed from data provided by studies established by the USDA Forest Service in cooperation with several forest industries.

Site index is utilized as a means to evaluate the potential of an area to produce timber. Equations for site index can also be used to project stand height into the future in the effort to predict growth and yield of forest stands. Site index equations and/or curves have been published for longleaf pine natural stands (USDA Forest Service 1929, Schumacher and Coile 1960, Farrar 1981, Farrar and Matney 1994) and young plantations (Boyer 1983). Numerous site index equations have been prepared for loblolly pine natural stands (USDA Forest Service 1929, Schumacher and Coile 1960, Burkhart et al. 1972) and plantations (Coile and Schumacher 1964, Clutter and Lenhart 1968, Smalley and Bower 197 1, Trousdell et al. 1974, Golden et al. 1981, Amateis and Burkhart 1985).

Data

Data were collected from 148 and 7.5 permanent plots in loblolly and longleaf pine stands, respectively. The majority of the loblolly pine plots were in central Louisiana (107 plots in Rapides parish and 27 plots in Natchitoches parish), with 14 plots in north Louisiana (Union parish). These plots varied from 0.053 to 0.119 ac, and were measured 3 to 6 times at ages ranging from 8 to 34 yr. All 75 longleaf pine plots were located in Rapides parish in central Louisiana. They were measured 2 to 6 times at ages from 11 to 27 yr and were about 0.1 ac in size. Studies for each of the species were established on relatively poor, medium, and good sites. Table 1 shows distribution of plots by measurement age.

Note: Some studies providing data for this publication were established on lands owned and managed by Olinkraft, Inc. and T.L. James and Co. We thank them for their cooperation in this work. Manuscript received November 22, 1995, accepted August 9, 1996.

A total of 74 loblolly pine plots were precommercially thinned once at age 3 or 5 yr. Precommercial thinning was also applied to 39 longleaf pine plots at age 7. Stand densities at all measurements ranged from 340 to 9720 trees per acre for loblolly pine and 76 to 2798 trees per acre for longleaf pine. Stand height for each plot at each measurement age was computed as average height of the dominant and codominant trees in the plot. Distribution of height-age observations for loblolly and longleaf pines is shown by age and site index in Table 2. There was a total of 69 1 height-age observations and 542 growth periods for loblolly pine, as compared to 287 observations and 212 growth periods for longleaf pine.

Development of Site Index Curves

Several site index models were evaluated to determine the most appropriate model(s) for the two data sets, using the method outlined in Cao et al. (1995). All of the models considered were base-age invariant, which means that the base age or index age can be changed without refitting the equations. Results of the evaluation showed that the site index model developed by Bailey and Clutter (1974) performed well overall for both data sets. This model produced polymorphic site index curves, i.e., they have different shapes and are not proportional to one another.

The final site index equations are as follows.

Direct-Seeded Loblolly Pine:

$$H = \exp\left\{5.43844 + [\ln(S) - 5.43844]\left(\frac{1}{A}\right)^{0.55033}\right\} \quad (1)$$

n = 542; Fit Index = 94.96%;

$\overline{H}$ = 41.88 ft; $s_{y.x}$ = 3.08 ft

Direct-seeded longleaf pine:

$$H = \exp\left\{5.68300 + [\ln(S) - 5.68300]\left(\frac{1}{A}\right)^{0.53408}\right\} \quad (2)$$

n = 212; Fit Index = 97.10%;

$\overline{H}$ = 47.43 ft; $s_{y.x}$ = 1.91 ft

Table 2. Distributionof height-ageobservationsof direct-seeded loblolly and longleaf pines by age and site index.

Age (yr) from seed	Site index in feet (base age 25 yr)'					
	26–35	36–45	46–55	56–65	66-75	All
	(no. of observations)					
Loblolly pine						
8-10	7	18	8	46	19	98
1 l-13	14	4	28	74	36	156
14–16	21	23	28	57	19	148
17–19	21	22	2	13	1	59
20–22	14	5	26	44	18	107
23-25	7	15	2	13	1	38
26-28		1	20	12		33
30		1	18	7		26
34		1	18	7		26
All	84	90	150	273	94	691
Longleaf pine						
1 l-13			1	38	3	42
14-16		10	8	15	3	36
17–19		17	16	39	3	75
20–22		10	9	38	3	60
23-25		7	7	16	3	33
26–28				38	3	41
All		44	41	184	18	287

[1] **Site index for each plot was interpolated from observed height values. If the last measurement of a plot was at an age below 25 yr, its site index was predicted from Equation (1) or (2).**

where

H = average height in feet of the dominant and codominant trees at age A,

A = stand age in years,

S = site index in feet at base age I,

I = base age or index age in years, and

Fit Index = $1 - \left\{\Sigma(H - \hat{H})^2 / \Sigma(H - \overline{H})^2\right\}$.

Figures 1 and 2 present site index curves for direct-seeded loblolly and longleaf pine stands, respectively, from the above two equations.

Comparison with Existing Site Index Curves

Site index curves from direct-seeded loblolly pine were compared to site index curves of natural stands (Farrar 1973, Schumacher and Coile 1960) and plantations (Golden et al. 198 1, Amateis and Burkhart 1985). For different site indices

Table 1. Distribution of 148 loblolly pine plots and 75 longleaf pine plots by measurement age.

Loblolly pine		Longleaf pine	
No. of plots	Measurement ages	No. of plots	Measurement ages
56	8, 11, 13, 16, 21	18	11, 14, 17, 20, 23, 26
14	9, 14, 18, 23	1	12, 17, 22
3	10, 14, 19	23	12, 17, 22, 27
24	10, 14, 19, 24	18	14, 17, 22
18	11, 14, 17, 22	15	18, 23
7	11, 16, 21		
20	11, 16, 21, 26, 30, 34		
6	16, 21, 26, 30, 34		

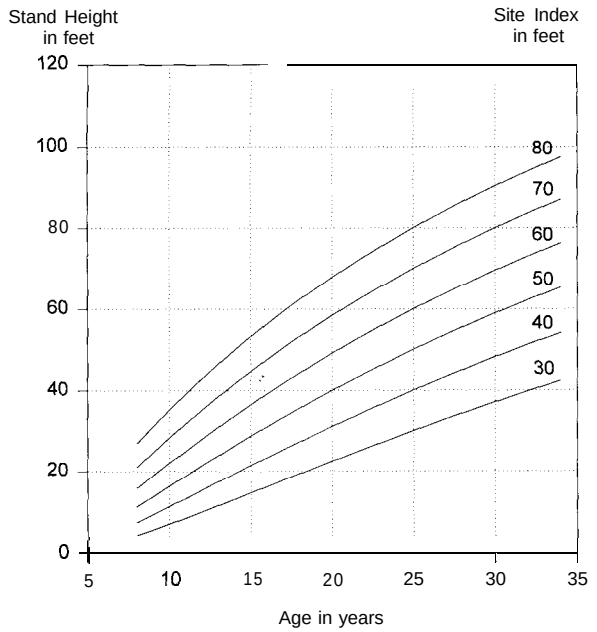

Figure 1. Site index curves (base age 25 yr) for direct-seeded loblolly pine stands.

at base age 25 yr, the curves were very similar at ages below 25, but formed two distinct groups for ages above 25 yr. Direct-seeded curves joined those from Farrar (1973) and Amateis and Burkhart (198.5) to form the upper group, whereas lower curves included those from Schumacher and Coile (1960) and Golden et al. (198 1). There did not seem to be a clear distinction between site index curves from natural stands, plantations, and direct-seeded stands.

We performed a similar comparison of longleaf pine site index curves for direct-seeded stands, natural stands (Farrar 1973, Schumacher and Coile 1960, Farrar and Matney 1994), and young plantations (Boyer 1983). At ages below 25 yr, the natural stand curves form a lower group, the plantation curves were the highest, and the

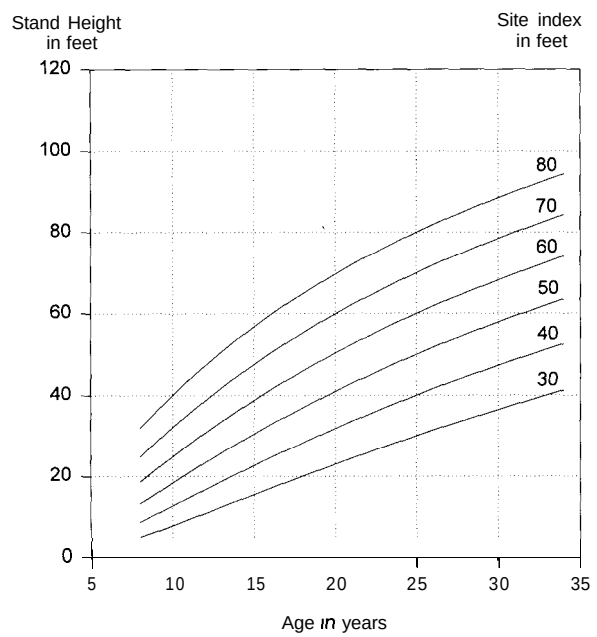

Figure 2. Site index curves (base age 25 yr) for direct-seeded longleaf pine stands.

direct-seeded curves were between these two groups. Above age 25, Boyer's (1983) plantation curves were distinctly lower than the rest of the site index curves which were very similar to one another. This trend showed that, for younger ages, height growth of direct-seeded longleaf pines could be expected to be between height growth of natural stands and plantations of the same site index.

Height Projections

The height projection capabilities of the site index models were evaluated by using all possible combinations of projection lengths from the data sets. Stand height H_2 at age A_2 was predicted from height H_1 at age A_1. This can be done by renaming variables S, *H, I,* and *A* in Equations (1) and (2) to H_1, H_2, A_1, and A_2, respectively. It means that the age at the beginning of the projection period was considered to be base age, and its corresponding height to be site index. This kind of flexibility was possible because both site index models are base-age invariant. The height projection equations are:

Direct-Seeded Loblolly Pine

$$H_2 = \exp\left\{5.43844 + [\ln(H_1) - 5.438441\left(\frac{A_1}{A_2}\right)^{0.55033}\right\} \quad (3)$$

Direct-Seeded Longleaf Pine

$$H_2 = \exp\left\{\mathbf{5.68300} + [\ln(H_1) - 5.68300]\left(\frac{A_1}{A_2}\right)^{0.53408}\right\} \quad (4)$$

Table 3 shows the differences between observed and predicted stand heights by projection length. The overall average difference was 0.24 ft (different from zero at $P = 0.07$) for loblolly pine and -0. 12 ft (different from zero at $P = 0.26$) for longleaf pine. The site index models provided better height projection for longleaf pine than for loblolly pine. Short-term height projections (less than 5 yr) were adequate for both species. The site index equation for loblolly pine, however, tended to underpredict for long-term projections (15 yr or more).

Numerical Examples

As an example, consider a direct-seeded loblolly pine stand of site index 60 ft at base age 25 yr. Average height of the dominant and codominant trees at age 17 is:

$$H = \exp\left\{5.43844 + [\ln(60) - 5.438441\left(\frac{25}{17}\right)^{0.55033}\right\}$$
$$= e^{3.77654} = 44 \text{ ft}$$

If stand height of a direct-seeded loblolly pine stand is 40 ft at age 20, then site index of this stand is:

Table 3. Differences between observed and predicted stand heights by projection length for direct-seeded loblolly pines.

Projection length (yr)	Average difference (ft)	Average absolute difference (ft)	Difference in feet (observed – predicted height) ≤–14	-12	–10	-8	–6	–4	–2	0	2	4	6	8	10	12	≥14	All
			(no. of observations)															
Loblolly pine																		
2	0.54	0.74								39	17							56
3	0.12	2.10					3	23	14	36	61	11						148
4	0.04	1.69						9	23	27	29	5						93
5	0.31	2.78	1			1	22	44	47	85	75	54	20	7			1	357
6	–8.04	8.04			2	15	1											18
8	1.32	4.12		2	10	6	1	2	16	19	36	33	20	8	3			156
9	-2.22	3.68			5	9	7	10	14	19	11	5				1		81
10	0.21	4.51		5	7	3	6	15	18	26	11	19	11	12	5	1		139
11	-13.64	13.64	12	5	1													18
13	3.79	4.42						3	8	11	18	13	12	5	4	5	3	82
14	–3.65	5.31	6	5	6	1	5	8	4	10	13	4	2					64
15	4.31	4.44								7	3	4	4	5	3			26
18	1.37	2.91						3	4	6	3	6	4					26
19	6.00	6.21							1	3	1	2	3	5	1	2	1	19
23	7.79	7.79								2	3		4	2	4	1	3	19
All	0.24	3.55	19	17	31	35	45	117	149	290	281	156	80	44	20	10	8	1,302
Longleaf pine																		
2	1.18	1.18									1							1
3	-0.65	1.36						8	35	49	13	2						107
5	0.37	1.73						9	17	31	42	5						104
6	–0.14	0.89						1	16	46	8	1						72
7	0.17	0.17								1								1
8	-5.12	5.12			1	3	5	5	2	1								17
9	-0.52	1.43					1	2	18	25	7	1						54
10	1.33	1.88							6	15	17	7	2					47
12	-0.32	1.33						2	10	16	7	1						36
15	1.17	2.85					1	2	10	6	9	7	3	3				41
All	–0.12	1.68	0	0	1	3	7	29	114	190	104	24	5	3	0	0	0	480

$$S = \exp\left\{5.43844 + [\ln(H) - 5.438441\left(\frac{A}{I}\right)^{0.55033}\right\} \quad (5)$$

or

$$S = \exp\left\{5.43844 + [\ln(40) - 5.43844]\left(\frac{20}{25}\right)^{0.55033}\right\}$$

$$= e^{3.89106} = 49 \text{ ft}$$

The third example involves height projection. Given current stand height of 65 ft at age 22, future height at age 27 of a direct-seeded longleaf pine stand can be predicted from Equation (4) as follows:

$$H_2 = \exp\left\{5.68300 + [\ln(65) - 5.683001\left(\frac{22}{27}\right)^{0.53408}\right\}$$

$$= e^{4.33069} = 76 \text{ ft}$$

Summary

Data from permanent plots in direct-seeded stands of loblolly and longleaf pines were used to develop site index equations. The Bailey and Clutter (1974) model was selected for stand height prediction. Site index curves were presented for both species based on these equations. Further analysis revealed that short-term height projection from these site index models should be satisfactory for direct-seeded loblolly and longleaf pine stands in Louisiana.

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