1997

Estimating Crown Height for Unthinned Planted Pines in East Texas

Young Jin Lee

J. David Lenhart
Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University

Estimating Crown Height for Unthinned Planted Pines in East Texas

Young-Jin Lee *and* **J. David Lenhart,** *College of Forestry, Stephen F. Austin State University, Nacogdoches, TX, 75962-6109.*

ABSTRACT. *Stand-level models were derived to predict crown height or the distance from ground to the first live branch of unthinned planted loblolly (*Pinus taeda L.) *and slash (*Pinus elliottii Engelm.*) pine trees in East Texas. Average height of the tallest trees was the principal predictor in the models. In addition, the influence of number of planted trees per acre, nonplanted basal area and fusiform rust (*Cronartium quercuum [Berk.] Miyabe ex Shirai f. sp. *fusiforme) was considered. The models quantify the plantation ages when the butt log and successive lower stem logs are clear of live branches. This information may assist with merchandising the planted pines. South. J. Appl. For. 21(3):130–133.*

One aspect of pine plantation management is merchandising the planted trees into appropriate products. Many tree factors can influence the merchandising process, such as diameter, height, crown condition, stem quality, incidence of disease, and the length of lower stem from ground to the first live branch.

This length of the lower stem is equivalent to crown height, while the length of the upper stem from the first live branch to the top of the tree is the crown length. Crown ratio is defined as crown length divided by tree height. In addition to merchandising the trees, reliable information on expected values of crown length, crown ratio and crown height may assist in planning:

- Number of trees per acre to plant.
- Pruning specifications.
- Timing and intensity of intermediate harvests.
- Specifying optimum rotation ages.

Models for estimating crown ratio and crown height for individual trees have been developed in several studies (Ward 1964, Wykoff et al. 1982, Dell et al. 1979, Feduccia et al. 1979, Ek and Monserud 1975, Daniels and Burkhart 1975, Van Deusen and Biging 1985, Dyer and Burkhart 1987). Average stand crown ratio and average stand crown height have been estimated by Holdaway et al. (1979) and Cole and Jensen (1982). A "crown rise" model that estimated crown height on a stand-level basis was developed by Valentine et al. (1994). Several papers presented crown height increment prediction models for individual trees (Short and Burkhart

1992, Maguire and Hann 1990a,b and Liu et al. 1995).

In this paper, models are presented to estimate average stand crown height for unthinned loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliottii* Engelm.) plantations in East Texas.

Plantation Measurements

Information from permanent plots located in unthinned industrial loblolly and slash pine plantations throughout East Texas was analyzed in this study.[1] In 1982–1984, 256 plots were established in separate plantations to start the East Texas Pine Plantation Research Project (ETPPRP). By 1995, about 25% of the original ETPPRP plots have been destroyed by inadvertent acts of nature and man.

The plots are measured on a 3 yr cycle, and each plot consists of two subplots. A subplot is 100 ft × 100 ft, and all planted pines within a subplot were tagged and numbered At each measurement, values such as dbh, total height, crown height, and occurrence of fusiform rust (*Cronartium quercuum* [Berk.] Miyabe ex Shirai f. sp. *fusiforme*) are measured and recorded for each surviving planted pine tree in a subplot In addition, two sampling points are situated within each subplot for measuring and recording dbh values of nonplanted trees.

For this study, each subplot was a sampling unit. For an observation to be included in the data sets, crown height had to be 1 ft or more. As a result, the total number of observations

Table 1. Characterization of the East Texas loblolly and slash pine data.

Species Item	Minimum	Mean	Maximum
Loblolly (622 obs)			
Plantation age (A)—yr	3	12	27
Site index (base age 25 yr) (S)—ft	31	70	114
Number of surviving planted trees per acre (T)	87	469	998
Surviving planted trees basal area (B)—ft^2/ac	0	78	192
Stem fusiform rust percentage (R)	0	9	50
Height to first live branch (CH)—ft	1	14	43
Total height of ten tallest trees (H)—ft	8	40	77
Nonplanted trees basal area ($NPBA$)—ft^2/ac	0	7	86
Slash (551 obs)			
Plantation age (A)—yr	3	11	25
Site index (base age 25 yr) (S)—ft	15	75	109
Number of surviving planted trees per acre (T)	78	389	1,032
Surviving planted trees basal area (B)—ft^2/ac	0	56	166
Stem fusiform rust percentage (R)	0	40	94
Height to first live branch (CH)—ft	1	13	50
Total height of ten tallest trees (H)—ft	4	39	89
Nonplanted trees basal area ($NPBA$)—ft^2/ac	0	13	160

was 622 for loblolly and 551 for slash pine. Plantation stand-level variables are defined and characterized in Table 1 for both species.

On the average, the number of planted pines per acre was 469 for loblolly and 389 for slash, which translates into average spacing of about 9 ft × 10 ft for loblolly and about 10 ft × 11 ft for slash. At an average age of 12 yr, the distance from the ground to the first live loblolly pine branch was typically about 14 ft or about one-third of the average total tree height. Slash pine values were similar at 13 ft of height to first live branch.

Crown Height Estimation

In the development of their crown-rise model, Valentive et al. (1994) utilized loblolly pine data from the ETPPRP. However, that data set included observations between 1982–1990, and they excluded crown height values less than 6 ft. However, in our analysis, all crown height values 1 ft and higher were included, plus observations from 1982–1995. In this way the models in this report should apply to loblolly and slash pine plantations 3–30 yr old (Table 1) and be useful for tracking height to the lowest live branch during typical rotation ages.

Initially, the suitability of applying the crown-rise model to the expanded data sets was examined. However, the role of planted trees per acre in the Valentine model was not signifi-

cant, and the relationship between planted tree height *(H)* and crown height *(CH)* was not linear.

Subsequent examination of scattergrams for both species indicated a consistent linear relationship between ln*(CH)* and ln*(H)*. Linear regression analyses were performed to fit the two variables, and the results are Equations (1) and (3) (Table 2) for loblolly and slash, respectively. All variables were significant ($P \leq 0.05$) in the two equations.

Stem fusiform rust *(R)* and nonplanted trees *(NPBA)* are an extensive component of East Texas pine plantations (see Table 1). Multiple linear regressions were computed for predicting *CH* that included these two variables plus number of surviving planted trees per acre *(T)* and *H*, Equations (2) and (4) (Table 2). All variables were significant ($P \leq 0.05$) in both equations.

Applications

In the application of the crown height prediction equations, total stand height is a critical predictor. For some plantation management situations, total height may not be available. In those cases, if plantation age *(A)* and site index *(S)* are known, appropriate site index equations can be converted to estimate total height *(H)*, while realizing that this predicted *H* will have variation associated with it. The relevant site index (base age 25 yr) equations for East Texas are (Dirksmeyer et al. 1995):

Table 2. Height from ground to first live branch prediction equations for unthinned loblolly and slash pine plantations in East Texas.

Loblolly

$$CH = \exp[-5.55515 + 2.17801\ln(H)] \tag{1}$$
$$r^2 = 92.3\% \text{ and } RMSE = 0.26$$

$$CH = \exp[-6.13694 + 2.17634\ln(H) + 0.09754\ln(T) - 0.00462R + 0.003551 NPBA] \tag{2}$$
$$R^2 = 92.8\% \text{ and } RMSE = 0.25$$

Slash

$$CH = \exp[-4.53934 + 1.90930\ln(H)] \tag{3}$$
$$r^2 = 89.2\% \text{ and } RMSE = 0.30$$

$$CH = \exp[-4.82006 + 2.05610\ln(H) + 0.00327\ln(T) - 0.00731R + 0.00253 NPBA] \tag{4}$$
$$R^2 = 92.7\% \text{ and } RMSE = 0.25$$

Loblolly

$$S = H(0.89997/(1 - \exp(-0.09209A)))^{1.66142} \qquad (5)$$

Slash

$$S = H(0.71642/(1 - \exp(-0.05041A)))^{1.30389} \qquad (6)$$

For tracking CH over time, a site index equation provides increasing total height values. If Equations (2) or (4) are used for tracking CH over time, a survival equation may be required to allow for a reduction in future number of trees per acre. Survival models by Adams et al. (1996) may be suitable for East Texas.

In East Texas pine plantations, a 10% incidence of stem fusiform rust is fairly uniform across plantation age for loblolly pine (Lenhart et al. 1994). However, rust incidence in slash pine tends to increase from about 25% at age 5 to about 60% at age 20. More specific information on East Texas rust transition trends is described by Schabenberger (1995) and Schabenberger et al.(1995).

For this data set (see Table 1), the average basal area of the nonplanted trees (NPBA) is 7 ft²/ac and 13 ft²/ac for loblolly and slash pine, respectively. Plottings of NPBA over age indicated no particular trend.

Number of Clear Logs by Rotation Ages

Equations (1) and (3) may be used in conjunction with Equations (5) and (6), respectively, to quantify the plantation ages when the first 17 ft log and successive 17 ft logs are expected to be clear of live branches. Surviving planted trees per acre are not factors in Equations (1) and (3).

In this manner, Figures 1 and 2 were developed for loblolly and slash pine plantations, respectively, for site index = 70 ft (base age 25 yr). The butt log is expected to be first clear of live branches at about 13 yr for loblolly and 15 yr for slash, and the first two logs are estimated to be clear at 21 and 24 yr for loblolly and slash, respectively.

The log quantification process was repeated for other site index classes, and the results presented in Table 3 Crown height is sensitive to site index. On less productive land, it may take 22 or 23 yr for the butt log to become clear of live branches. On more productive land, the butt log may be clear by 11 or 12 yr, and the first 4 logs or 68 ft may be clear by 25 or 29 yr.

This information may assist in merchandising the planted pines, but it may also facilitate developing schedules to artificially remove live branches. If a management plan has a pruning of live branches along the first 17 ft of stem for a 20 yr old loblolly pine plantation on site index 70 ft land, the activity may not be needed, because the branches may have
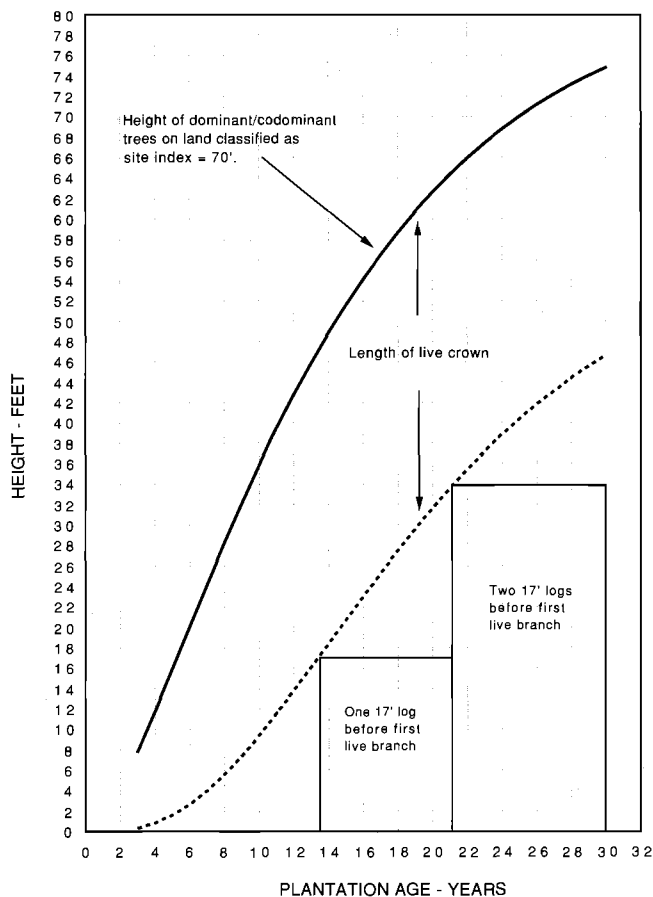

Figure 1. Depiction of estimated height and crown height values for ascertaining plantation ages when first and second logs are clear of live branches for unthinned East Texas loblolly pine plantations.
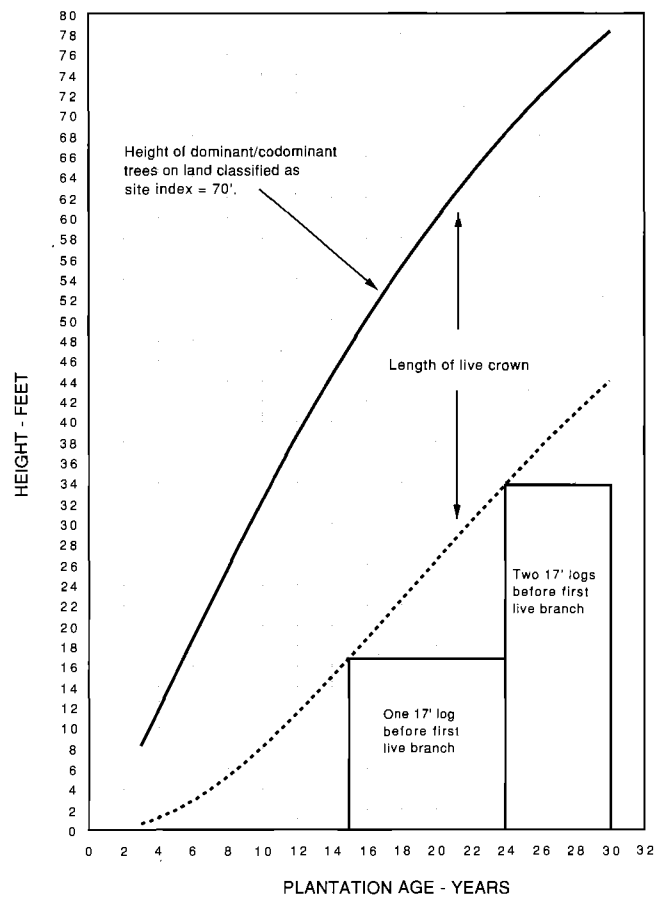

Figure 2. Depiction of estimated height and crown height values for ascertaining plantation ages when first and second logs are clear of live branches for unthinned East Texas slash pine plantations.

Table 3. Plantation ages at which successive 17 ft logs above ground are expected to first become clear of live branches by site index classes in unthinned loblolly and slash pine plantations in East Texas.

Site index class (ft)	Log 1 Loblolly	Log 1 Slash	Log 2 Loblolly	Log 2 Slash	Log 3 Loblolly	Log 3 Slash	Log 4 Loblolly	Log 4 Slash
				(yr)				
50	22	23	—	—	—	—	—	—
60	17	18	29	—	—	—	—	—
70	13	15	21	24	—	—	—	—
80	12	13	17	20	24	28	—	—
90	11	12	15	18	19	23	25	29

already died up to a crown height of 34 ft. Note that dead branches are probably present along this stem length.

Influence of Plantation Parameters on Crown Height

In Equations (2) and (4), a positive slope coefficient indicates that as trees per acre increases, CH is expected to rise. In contrast, as the percent of stem rust incidence increases, CH tends to decrease. And as the basal area of the nonplanted vegetation increases, CH is predicted to increase.

Using Equations (2) and (4), crown heights were predicted across a wide range of combinations of values for the stand parameters—H, T, R and $NPBA$. For the same range of H values, crown heights were estimated using Equations (1) and (3). Crown heights estimated with Equations (1) and (3) were subtracted from crown heights predicted using Equations (2) and (4), and percent differences were calculated relative to values from Equations (1) and (3).

Several representative examples of the comparisons are:

- For H = 60 ft, T = 500, R = 30% and letting NPBA vary from 10 to 50 ft^2, the percent differences ranged from −8% to 6% for loblolly and 16% to 28% for slash.
- For H = 60 ft, T = 500, NPBA = 30 ft^2 and letting R vary from 10 to 30%, the percent differences ranged from 8% to −10% for loblolly and 41% to 5% for slash.
- For H = 60 ft, R = 30%, $NPBA$ = 30 ft^2 and letting T vary from 300 to 700, the percent differences ranged from −6% to 2% for loblolly and were constant at 22% for slash.

Examination of the differences for other plantation parameter combinations supported the conclusion that crown height is influenced by these plantation characteristics. It appears that the magnitude and nature of the sensitivity differs between planted loblolly and planted slash pine.

Literature Cited

ADAMS, D.E., J.D. LENHART, A.B. VAUGHN, AND J. LAPONGAN. 1996. Predicting survival of East Texas loblolly and slash pine plantations infected with fusiform rust. South. J. Appl. For. 20(1):30–35.

COLE, D.M., AND C.E. JENSEN. 1982. Models for describing vertical crown development of lodgepole pine stands. USDA For. Serv. Res. Pap. INT-292. 10 p.

DANIELS, R.F., AND H.E. BURKHART. 1975. Simulation of individual tree growth and stand development in managed loblolly pine plantations. Sch. of For. & Wildl. Resour., VPI&SU. Publ. FWS-5-75. Blacksburg, VA. 73 p.

DELL, T.R., D.P. FEDUCCIA, T.E. CAMPBELL, W.F. MANN JR., AND B.H. POLMER. 1979. Yields of unthinned slash pine plantations on cutover sites in the West Gulf Region. USDA For. Serv. Res. Pap. SO-147.

DIRKSMEYER, G., K. SCOTT, C. VANDER SCHAAF, AND R. WORTHY. 1995. Site index equations for loblolly and slash pine plantations in East Texas Update: 1995. Coll. of For. SFASU. ETPPRP Rep. 37. 6 p.

DYER, M. E., AND H. E. BURKHART. 1987. Compatible crown ratio and crown height models. Can. J. For. Res. 17:572–574.

EK, A.R., AND R.A. MONSERUD. 1975. Methodology for modeling forest stand dynamics. Sch. of Natur. Resour., Staff Pap. Series No. 2. Univ. of Wisconsin, Madison.

FEDUCCIA, D.P., T.R. DELL, W.F. MANN, AND B.H. POLMER. 1979. Yields of unthinned loblolly pine plantations on cutover sites in the West Gulf Region. USDA For. Serv. Res. Pap. SO-148.

HOLDAWAY, M.R., R.A. LEARY, AND J.L. THOMPSON. 1979. Estimating mean stand crown ratio from stand variables. P. 27–30 in A generalized forest growth projection system applied to the Lake States Region. USDA For. Serv. Gen. Tech. Rep. NC-49.

LENHART, J.D., T.G. GREGOIRE, G.D. KRONRAD, AND A.G. HOLLEY. 1994. Characterizing fusiform rust incidence and distribution in East Texas. South. J. Appl. For. 18(1):29–34.

LIU, J., H.E. BURKHART, AND R.L. AMATEIS. 1995. Projecting crown measures for loblolly pine trees using a generalized thinning response function. For. Sci. 41:43–53.

MAGUIRE, D.A., AND D.W. HANN. 1990a. Constructing models for direct prediction of 5-year crown recession in southwestern Oregon Douglas-fir. Can. J. For. Res. 20:1044–1052.

MAGUIRE, D.A., AND D.W. HANN. 1990b. A sampling strategy for estimating past crown recession on temporary growth plots. For. Sci. 36:549–563.

SCHABENBERGER, O. 1995. The analysis of longitudinal ordinal data. Ph.D. diss., VPI&SU. 383 p.

SCHABENBERGER, O., T.G. GREGOIRE, AND J.D. LENHART. 1995. Average observed fusiform rust transition paths. SFASU College of Forestry. ETPPRP Rep. 38. 5 p.

SHORT, E.A. III, AND H.E. BURKHART. 1992. Predicting crown-height increment for thinned and unthinned loblolly pine plantations. For. Sci. 38:594–610.

VALENTINE, H.T., A.R. LUDLOW, AND G.M. FURNIVAL. 1994. Modeling crown rise in even-aged stands of Sitka spruce or loblolly pine. For. Ecol. Manage. 69:189–197.

VAN DEUSEN, P.C., AND G.S. BIGING. 1985. STAG-A STAnd Generator for Mixed Species Stands Version 2.0. Univ. of Calif. Dep. of For. and Resource Manage. Res. Note No. 11.

WARD, W.W. 1964. Live crown ratio and stand density in young even-age red oak stands. For. Sci. 10:56–65.

WYKOFF, W.R., N.L. CROOKSTON, AND A.R. STAGE. 1982. User's guide to the Prognosis model. USDA For. Serv. Gen. Tech. Rep. INT-133.