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Tree Content and Taper Functions for Loblolly and Slash Pine Trees Planted on Non-Old-Fields in East Texas

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*ABSTRACT. Equations are presented to estimate total or partial stem content in cubic feet and pounds (green or dry) for loblolly pine (*Pinus taeda *L.) and slash pine (*Pinus elliotti *Engelm.) trees planted on non-old-fields in East Texas. Equations are included to estimate the content of the complete tree (stem and branches). In addition, a set of compatible stem taper functions are described.*

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Industrial forest landowners in East Texas are converting about 80% of their natural mixed pine-hardwood stands to loblolly and slash pine plantations. Since the early 1970s, the conversion process has been very active, and it is anticipated that during the 1990s, the land use change will be completed. At that time approximately 3 million acres of East Texas industrial forestland will be growing loblolly and slash pine plantations. About 85% of the planted acreage will be in loblolly pines and the remaining 15% in slash pines.

When future yield estimates and economic values of the planted pines are known, the magnitude and timing of thinnings or final harvest can be planned in an optimal manner. Such predictions of yield rely in part on information describing the amount of wood, bark, and needles in individual planted loblolly and slash pines on converted sites in East Texas.

Earlier growth and yield studies of pine plantations on old fields (abandoned agricultural land) in East Texas produced equations for estimating cubic foot volume, green weight, and dry weight of individual planted loblolly pine trees (Hasness and Lenhart 1972, Hicks et al. 1972, Hyink et al. 1972) and slash pine trees (King and Moehring 1974, Moehring et al. 1973). No information is available for individual planted pines on converted sites (non-old-fields) in East Texas. To meet this need, equations are presented to estimate the amount of wood, bark, and needles in the complete tree (branches and stem) and wood and bark for the total and partial stem. Units of measure are cubic feet, pounds of green contents, and pounds of dried contents. In addition, compatible taper functions are described.

TREE MEASUREMENTS

During winter 1986, sample trees were felled and measured. The sample trees were located adjacent to permanent growth and yield plots installed throughout East Texas as a part of the East Texas Pine Plantation Research Project[1] (Lenhart et al. 1985). Two trees with crowns in the upper canopy were selected adjacent to 34 loblolly and 26 slash pine plots, so as to obtain a wide geographical distribution and to fill a rectangular array of dbh and height classes. As a result, 65 loblolly and 52 slash pine trees were available for analysis (three loblolly pine sample trees were eliminated due to measurement errors). A list of sample trees by county is tabulated in Table 1. The distribution of sample trees by diameter and height classes are shown in Figures 1 and 2 for loblolly and

[1] Support from the participating companies, Champion International Corporation, International Paper Company, and Temple-EasTex, Inc., is appreciated.

Table 1. Number of sample trees by species and county.

County	Species	
	Loblolly	Slash
Angelina	—	6
Cass	2	—
Cherokee	6	—
Hardin	2	4
Harrison	2	—
Houston	4	—
Jasper	2	12
Liberty	2	2
Marion	2	—
Nacogdoches	4	—
Newton	10	8
Panola	1	—
Polk	4	2
Sabine	4	2
San Augustine	4	2
San Jacinto	4	—
Shelby	2	—
Trinity	—	2
Tyler	8	12
Walker	2	—
Total	65	52

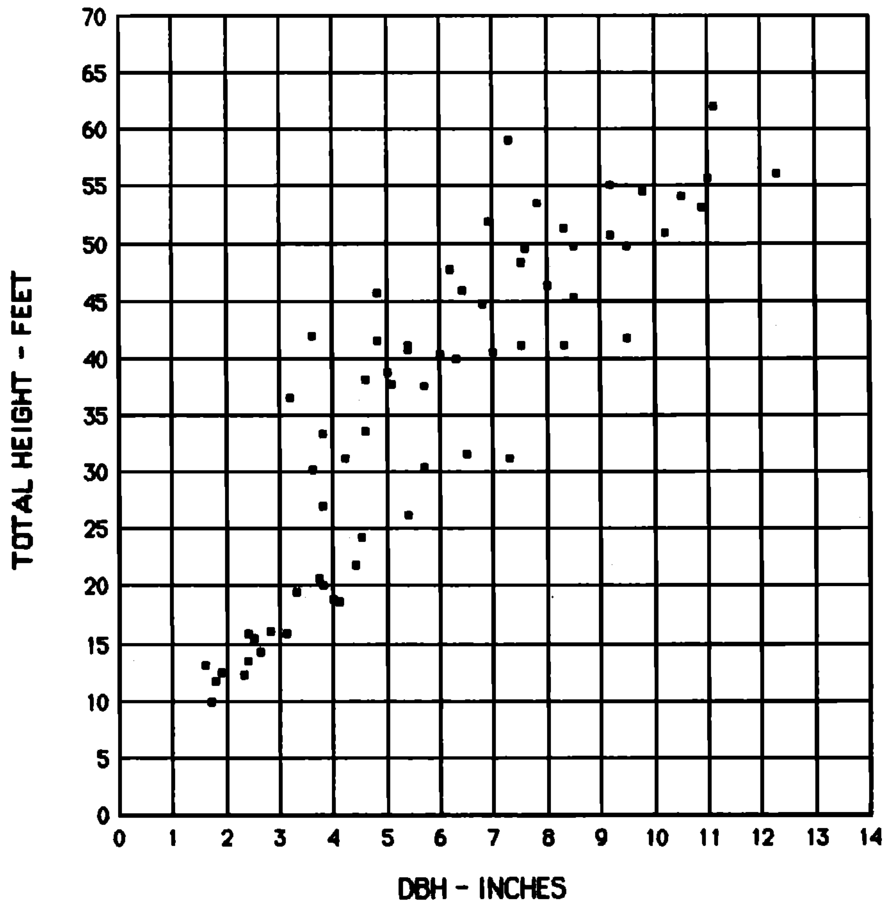

Figure 1. Number of loblolly pine sample trees by dbh and height (n = *65 trees).*

slash pine, respectively. In spite of diligent attempts by the field crew, relatively tall loblolly pine trees in the 1.5–3.0 in. dbh range could not be located for sampling.

Prior to felling a sample tree, the dbh was measured. After felling, the total height from ground to tip of stem was determined. All branches were removed and weighed—wood, bark, and needles. A representative branch was selected to be weighed with and without needles. Eight branch segments about 1 ft in length were randomly selected to be weighed with and without bark. Using these subsample values, appropriate ratios were calculated to convert the total weight of the branches to the weight of its three basic components—wood, bark, and needles. The branch segments were subsequently oven-dried, and a ratio was determined to calculate the dry weight of the wood in the branches.

The stem was bucked into 3-ft long bolts, and each bolt was weighed. A 1–3 in. thick disk was sawn from the bottom of each bolt and weighed with and without bark. The peeled disks were subsequently oven-dried. Using the disk values, ratios were computed to convert each bolt weight into green and dry weight of wood only. Diameter with and without bark was measured at each buck point, and cubic-foot volume of wood and bark and wood only was calculated using Smalian's formula. For each sample tree, appropriate ratios of stem volume to stem weight were multiplied by total branch weight to obtain an estimate of the volume of wood and bark and wood only in the branches. For these relatively small and young trees, stem ratios should be reasonably representative of branch ratios.

COMPLETE TREE CONTENT PREDICTION

Plottings of observed complete tree content, excluding stump, in stem and branches (C) over diameter in inches at 4.5 ft above ground (D) and total tree height above ground in feet (H) indicated that the model

$$C = b0D^{b1}H^{b2} \quad (1)$$

was most suitable. After unweighted nonlinear regression analyses, the following prediction equations were determined:

Loblolly

$$CTCFWB = 0.006389D^{2.242262}H^{0.668729} \quad (2)$$

$$CTCFW = 0.002196D^{2.263525}H^{0.872831} \quad (3)$$

$$CTGWWBN = 0.281257D^{2.096304}H^{0.831283} \quad (4)$$

$$CTGWWB = 0.163420D^{2.106849}H^{0.946895} \quad (5)$$

$$CTGWW = 0.124659D^{2.165630}H^{0.960704} \quad (6)$$

$$CTDWW = 0.060286D^{2.12686}H^{0.970500} \quad (7)$$

Slash

$$CTCFWB = 0.004023D^{2.010570}H^{0.934455} \quad (8)$$

$$CTCFW = 0.001090D^{2.016044}H^{1.117842} \quad (9)$$

$$CTGWWBN = 0.324671D^{2.108976}H^{0.813285} \quad (10)$$

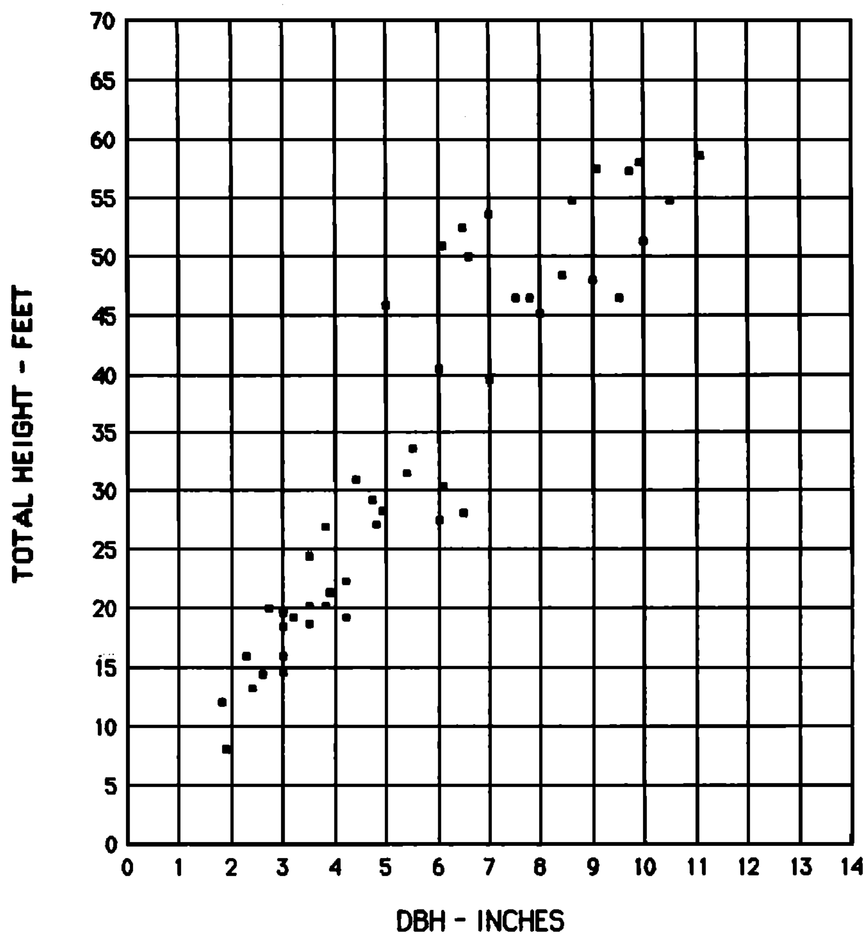

Figure 2. Number of slash pine sample trees by dbh and height (n = 52 *trees*).

$$CTGWWB = 0.156208 D^{2.033507} H^{1.011965} \quad (11)$$

$$CTGWW = 0.113526 D^{2.094336} H^{1.023721} \quad (12)$$

$$CTDWW = 0.045237 D^{2.179459} H^{1.027380} \quad (13)$$

with

R^2 = 99% for each of the 12 equations[2]

where

$CTCFWB$ = complete tree cubic feet of wood and bark,

$CTCFW$ = complete tree cubic feet of wood,

$CTGWWBN$ = complete tree green weight in pounds of wood, bark and needles,

$CTGWWB$ = complete tree green weight in pounds of wood and bark,

$CTGWW$ = complete tree green weight in pounds of wood and

$CTDWW$ = complete tree dry weight in pounds of wood.

Values for the bark and needle components can be obtained by subtraction between the appropriate predicted values from the equations listed above.

STEM CONTENT PREDICTION

A stem content prediction model, originally developed by McTague (1985) and subsequently modified by Pienaar et al. (1985), was selected for analysis. For cubic foot volume of wood and bark, the modified version is

$$C = b_0 D^{b1} H^{b2} - 0.00545415 (1 - (2/b3))(d^{b3}/D^{b3-2}) (H - 4.5), \quad (14)$$

where

d = upper stem diameter outside bark.

Equation (14) incorporates a constraint that requires the implicit taper function to predict a partial stem height of 4.5 ft, when $d = D$.

After fitting, Equation (14) reduces to the form to be used for other tree content measures:

$$C = c_0 D^{c1} H^{c2} - c3(d^{c4}/D^{c4-2})(H - 4.5) \quad (15)$$

The McTague-Pienaar models, Equations (14) and (15), have several additional desirable properties:

1. Treat total stem content as a special case of partial stem content, when $d = 0$.
2. Predict stem content between stump and any upper stem diameter limit.
3. Convert to well-behaved taper functions.

Data available for nonlinear regression analysis utilizing the McTague-Pienaar models consisted of 745 observations for loblolly and 540 observations for slash pine trees. The resulting prediction equations are:

Loblolly

$$SCFWB = 0.002103 D^{1.958489} H^{1.062348} - 0.0020323 d^{3.187878} D^{-1.187878}(H - 4.5) \quad (16)$$

$$SCFW = 0.000928 D^{1.973735} H^{1.213909} - 0.0017510 d^{2.903589} D^{-0.903589}(H - 4.5) \quad (17)$$

$$SGWWB = 0.060132 D^{1.868148} H^{1.290705} - 0.121899 d^{2.819859} D^{-0.819859}(H - 4.5) \quad (18)$$

$$SGWW = 0.052448 D^{1.911549} H^{1.283176} - 0.114417 d^{2.823696} D^{-0.823696}(H - 4.5) \quad (19)$$

$$SDWW = 0.025909 D^{1.879303} H^{1.286569} - 0.051803 d^{2.907340} D^{-0.907340}(H - 4.5) \quad (20)$$

Slash

$$SCFWB = 0.002021 D^{1.790506} H^{1.183087} - 0.0024438 d^{3.62363} D^{-1.62363}(H - 4.5) \quad (21)$$

[2] All R^2 values in this paper calculated using nonlinear regression results as:

$R^2 = ((n - 1)(\text{std. dev. dep. var.})^2 - \text{Residual SS})/((n - 1)(\text{std. dev. dep. var.})^2)(100)$

$$SCFW = 0.000838D^{1.859712}H^{1.301838} - 0.0019160d^{3.508595} D^{-1.508595}(H - 4.5) \quad (22)$$

$$SGWWB = 0.079853D^{1.816699}H^{1.255593} - 0.139970d^{3.430826} D^{-1.430826}(H - 4.5) \quad (23)$$

$$SGWW = 0.065306D^{1.85780}H^{1.253557} - 0.124615d^{3.453380} D^{-1.453380}(H - 4.5) \quad (24)$$

$$SDWW = 0.026738D^{1.898673}H^{1.277228} - 0.060061d^{3.601110} D^{-1.601110}(H - 4.5) \quad (25)$$

with

$R^2 = 97 - 98\%$ for each of the 12 equations.

where

$SCFWB$ = stem cubic feet of wood and bark to upper stem dob,

$SCFW$ = stem cubic feet of wood to upper stem dob,

$SGWWB$ = stem green weight in pounds of wood and bark to upper stem dob,

$STGWW$ = stem green weight of wood in pounds to upper stem dob and

$STDWW$ = stem dry weight of wood in pounds to upper stem dob.

TAPER FUNCTIONS

Using procedures described by Pienaar et al. (1985), the following compatible taper functions were derived from Equations (16) and (17) for loblolly and Equations (21) and (22) for slash pine:

Loblolly

$$\text{upper stem dob} = D((H - h)/(H - 4.5))^{0.841837} \quad (26)$$

where

h = position on upper stem where dob occurs.

which is solved for h as:

$$h = H - (H - 4.5)(\text{dob}/D)^{1.187878} \quad (27)$$

$$\text{upper stem dib} = 0.885852D((H - h)/(H - 4.5))^{0.722175} \quad (28)$$

where

h = position on upper stem where dib occurs

which is solved for h as:

$$h = H - 1.182741(H - 4.5)(\text{dib}/D)^{1.384706} \quad (29)$$

Slash

$$\text{upper stem dob} = D((H - h)/(H - 4.5))^{0.615903} \quad (30)$$

$$h = H - (H - 4.5)(\text{dob}/D)^{1.623631} \quad (31)$$

$$\text{upper stem dib} = 0.87127D((H - h)/(H - 4.5))^{0.580480} \quad (32)$$

$$h = H - 1.267900(H - 4.5)(\text{dib}/D)^{1.722714} \quad (33)$$

APPLICATION

Two examples are presented to illustrate the application of the estimation equations to two different mensurational problems. The first example partitions a loblolly pine tree into multiple products, and the second example compares branch characteristics between loblolly and slash pine trees.

Example 1

Consider a loblolly pine tree with a dbh of 10.2 in. and total height of 72 ft. We would like to partition this tree into three possible products—peeler bolts, chip-n-saw segment, and pulp chips and determine the cubic feet of wood in each partition. The following grading standards will be used:

1. Peeler bolts—lengths of 8.6, 17.2, 25.8, etc. ft and minimum small end dib of 8 in.
2. Chip-n-saw—random length up to a minimum small end dib of 4 in.
3. Pulp chips—remaining wood between 4 in. dib and tip of tree.

Peeler Bolts. Use Equation (28) to determine that the dib at 8.6 ft is 8.6 in., but the dib at 17.2 ft is 7.8 in. Thus, only the first 8.6 ft of this tree meets the grading standards for peeler bolts. Use Equation (17) to determine the volume of wood in the bolt to be 9.19 ft^3.

Chip-n-saw. Use Equation (17) to determine the volume of wood between the stump and the 4 in. dib as 15.51 ft^3. Then the difference between 15.51 and 9.19 results in 6.32 ft^3 of wood in the chip-n-saw segment. Use Equation (29) to compute the stem length between stump and the 4 in. dib to be 45.7 ft. Subtract the 8.6 ft for the peeler bolt, and the stem length to be utilized as chip-n-saw is 37.1 ft.

Pulp Chips. Use Equation (17) to calculate the volume of wood in the total stem (let d = 0 in.) as 16.33 ft^3. Subtract the peeler bolt volume and the chip-n-saw volume from the total stem volume and the volume of pulp chips in the top segment is 0.81 ft^3.

Example 2

Another example of applying these equations is to compare branch and needle content characteristics between loblolly and slash pine trees with the same D and H values, such as 3.6 in. and 18.4 ft, respectively.

Loblolly. Use Equations (4) and (5) to determine the complete tree green weight of wood, bark, and needles to be 46.42 lb and wood and bark to be 38.28 lb. The difference between the two values results in an estimated 8.14 lb of needles for this tree.

With Equation (18), the green weight of wood and bark in the total stem (d = 0) is predicted to be 28.24 lb. Subtract the 28.24 from 38.28 (from above) and the amount of wood and bark in the branches is estimated at 10.04 lb.

Slash. In a similar manner, use Equations (10) and (11) to determine the complete tree green weight of wood, bark, and needles to be 51.68 lb and wood and bark to be 40.26 lb. The resulting weight of needles for this slash pine tree is 11.42 lb, which is 40% more pounds of needles than the loblolly pine tree.

Equation (23) is used to calculate the green weight of wood and bark in the total stem to be 31.70 lb. The amount of wood and bark in the branches is determined to be 8.56 lb, which is 15% less wood and bark than the loblolly pine tree. □

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Taking Increment Cores with Power Tools

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ABSTRACT. High-quality increment cores can now be extracted from trees by powering increment borers with light-weight generators to operate electric drills or by using engine-powered drills that weigh less than 9 lb but develop 1.2 hp.

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Taking increment cores to measure previous stem growth of numerous trees is tedious and can well be a hand-blistering experience if the standard increment borer and hand-turning operation is used. In addition, the outer rings of the core will frequently "corkscrew" during the initial attempt to start and align the borer while simultaneously pushing it against the tree. Neither blisters nor corkscrew cores need be tolerated if the person doing the work has only to concentrate on pushing the borer against the tree while a machine turns the borer shaft.

Several machines have already been developed to drive increment borers, but the power sources have been rather massive or a special borer bit was needed. Stonecypher and Cech (1960) developed an electrically powered borer that required a trailer-mounted generator for power. A more compact unit is described by Prestemon (1965) where an electric drill was powered by a 12-v lead-acid battery, but only a small custom borer could be used. Echols (1969) developed a borer system that used a hydraulic motor to power a 12-mm increment borer. The hydraulic pump and Briggs and Stratton gasoline engine power supply required the use of a trailer or cart for portability. A more portable system was described by Greig (1971) that used a standard boring attachment that was fitted to a chain saw to power the increment borers. Upon inquiry locally, I found that only the Stihl chain-saw dealer was currently able to provide such an attachment. It would fit several Stihl saw models and cost about $120 retail.

A power system has recently been used at the Southern Forest Fire Laboratory, Macon, Georgia,

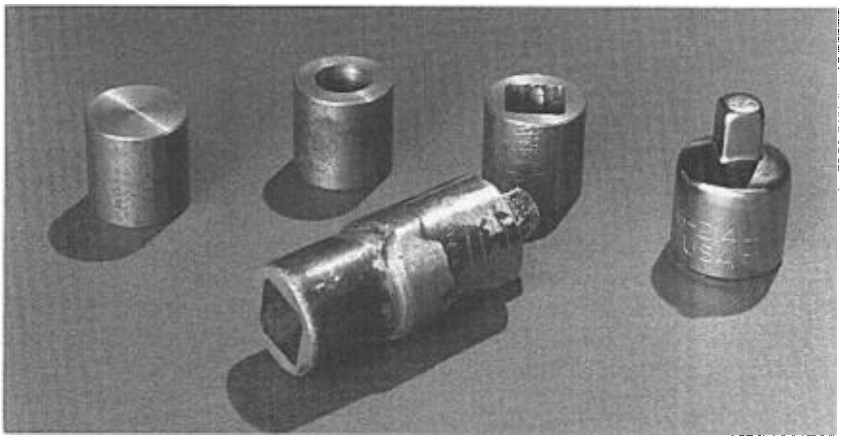

Figure 1. The sequence of steps followed to build an adapter to connect the reduction gear, attached to the drill, to the increment borer.