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Estimating the amount of wood per acre in loblolly and slash pine plantations in East Texas

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Estimating the Amount of Wood Per Acre in Loblolly and Slash Pine Plantations in East Texas[1]

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Abstract.--Two diameter distribution yield prediction systems are presented for loblolly pine (Pinus taeda L.) and slash pine (Pinus elliotti Engelm.) plantations located on non-old-fields in East Texas. A separate system was developed for each species based on the initial measurement of the East Texas Pine Plantation Research Project permanent plots.

Loblolly and slash pine plantations established on sites converted from mixed pine-hardwood stands in East Texas are approaching possible utilization. In order to optimize the utilization of these plantations, estimation of the amount of wood per acre is needed. If the per acre yields can be described on a diameter class basis, it would assist the forest manager in assigning different stumpage prices to various tree size classes.

This paper presents a method to predict the stand structure--number of trees per acre by diameter classes and individual total tree heights by dbh classes--and, subsequently, the amount of wood per acre by diameter classes for loblolly and slash pine plantations in East Texas.

PERMANENT PLOT MEASUREMENTS

The East Texas Pine Plantation Research Project (ETPPRP) permanent plots were installed and measured during the summers of 1982, 1983 and 1984. A total of 174 plots were established in loblolly pine plantations and 78 in slash pine plantations. Each permanent plot consists of two subplots--one to remain unthinned, and the other will eventually receive thinning treatments (Lenhart et al. 1985). The diameter distribution yield prediction systems were developed using data from the subplots-to-remain-unthinned (regression subplots), and the systems were evaluated using the subplots-to-be-thinned (evaluation subplots).

Observed values available for stand structure analysis were:

1. Age-number of growing seasons completed-(A).
2. Stand height-average height of the ten tallest trees-(H).
3. Total number of trees per acre by dbh class-(T).
4. Number of trees per acre by diameter class.
5. Minimum diameter-(DMIN).
6. Arithmetic mean diameter-(DMEAN).
7. Quadratic mean diameter-(DQMEAN).
8. Maximum diameter-(DMAX).

A site index (base age=25 years) value (S) was predicted for each plot using appropriate equations developed by Blackard (1985a, 1986) and Lenhart et al. (1986).

An exploratory analysis of fitting the Weibull distribution to the observed number of trees per acre by diameter class indicated that a regression subplot had to have trees in three dbh classes or more. If two dbh classes or less were occupied, the fitting routines would usually fail to find a solution. As a result, the number of loblolly pine plots available for analysis was reduced from 174 to 77, and the slash pine plots were reduced from 78 to 43.

For the 77 loblolly pine regression subplots, average stand parameters are:

1. Age=9 years.
2. Height of the ten tallest trees=31 feet.
3. Site index=72 feet.
4. Number of trees per acre=457.
5. Minimum diameter=1.2 inches.
6. Arithmetic mean diameter=4.2 inches.
7. Quadratic mean diameter=4.4 inches.

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For the 43 slash pine regression subplots, average stand parameters are:

1. Age=8 years.
2. Height of the ten tallest trees=27 feet.
3. Site index=67 feet.
4. Number of trees per acre=457.
5. Minimum diameter=1.2 inches.
6. Arithmetic mean diameter=4.2 inches.
7. Quadratic mean diameter=4.4 inches.

PREDICTING STAND STRUCTURE AND YIELD

A Weibull parameter recovery procedure developed by Burk and Burkhart (1984) was selected to fit the Weibull distribution to the regression subplots. Diameter distribution yield prediction systems for each species are described as:

Loblolly

1. Determine:

   a. Number of growing seasons completed since plantation establishment (A).

   b. Number of surviving trees per acre (T) at that age.

   c. Average total height of ten tallest trees (H) in plantation. If unknown, but site index (S)(base age=25 years) is known, then predict H using:

$$H=S((1-\exp(-0.08005275A))/0.8648429)^{1.628569}$$

(This equation was developed by Blackard 1985a, 1986 and Lenhart et al. 1986.)

2. Predict:

   a. Dbh of smallest tree (DMIN) in plantation, using:

$$DMIN=-0.08975+0.05913H-0.00126498T$$

$$(R^2=67\%)$$

If DMIN is less than 0, DMIN=0.

   b. Quadratic mean dbh (DQMEAN) for plantation, using:

$$DQMEAN=10^{(1.17470-12.93480(1/H)-0.000196042T)}$$

$$(R^2=96\%)$$

   c. Arithmetic mean dbh (DMEAN) for plantation, using:

$$DMEAN=-0.13343=0.99393DQMEAN$$

$$(r^2=99\%)$$

3. Compute the expected number of trees per acre for the plantation using the Weibull distribution. Weibull parameters are "recovered" with techniques developing by Burk and Burkhart (1984). The recovery process is:

   a. Location parameter (a) is equal to DMIN.

   b. Shape parameter (c) is calculated by solving the following equation:

$$(DQMEAN)^2-a^2-2a(DMEAN-a)$$
$$-(DMEAN-a)^2\,\Gamma(1+2/c)/\,\Gamma(1+1/c)=0$$

where: Γ=The complete gamma function.

   c. Scale parameter (b) is obtained using:

$$b=(DMEAN-a)/\,\Gamma(1+1/c)$$

Solve the Weibull distribution to determine the proportion (P) of T in each dbh class as:

$$d_l<P<d_u=\exp(-((d_l-a)/b)^c)-\exp(-((d_u-a)/b)^c)$$

where: d_l, & d_u=lower & upper bound of diameter class.

Multiply each P by T to obtain the expected number of trees per acre (n) in each dbh class.

4. Predict the total height (h) of each tree with dbh class mid-point dbh (d) (5.0, 6.0, etc.) using:

$$h=\exp(\ln(H)+0.0071609-0.125051\ln(A)(\ln(DMAX)-\ln(d))$$
$$-0.133671\ln(H/A)(\ln(DMAX)-\ln(d))$$
$$+0.0043391\ln(T)(\ln(DMAX)-\ln(d))$$

$$(R^2=68\%)$$

Where: DMAX=Dbh of largest tree in plantation.

(This equation developed by Blackard 1985b, 1986.)

5. Estimate the content (cubic feet, green weight, etc.) of the tree representing each dbh class mid-point.

   An equation to estimate the cubic feet of wood (CFW) in a planted loblolly pine tree in East Texas is:

$$CFW=0.000928d^{1.973735}h^{1.213909}$$

$$(R^2=99\%)$$

(This equation developed by Wiswell et al. 1986.)

6. For the loblolly pine plantation, we now know:

   a. The number of trees per acre (n) for each dbh class.

b. The cubic feet of wood per tree (CFW) for each dbh class.

Multiply CFW by n to obtain the cubic feet of wood per acre by dbh class.
Sum the CFW values across all dbh classes to determine the total cubic feet of wood per acre.

By selective summing across specified dbh classes, the CFW per acre by various tree size groups or different products (pulp, chip-n-saw, lumber, plywood, etc.) can be calculated.

Slash

1. Determine:

   a. Number of growing seasons completed since plantation establishment.

   b. Number of surviving trees per acre at that age.

   c. Average total height of ten tallest trees in plantation. If unknown, but site index (base age=25 years) is known, then predict H using:

$$H=S((1-\exp(-0.07488801A))/0.846215)^{1.4502401}$$

(This equation was developed by Blackard 1986, 1985a and Lenhart et al. 1986.)

2. Predict:

   a. Dbh of smallest tree in plantation, using:

$$DMIN=-0.22481+0.06496H-0.00126741T$$

$$(R^2 66\%)$$

If DMIN is less than 0, DMIN=0.

   b. Quadratic mean dbh for plantation, using:

$$DQMEAN=10^{(1.09600-11.70271(1/H)-0.000162166T)}$$

$$(R^2=96\%)$$

   c. Arithmetic mean dbh for plantation, using:

$$DMEAN=-0.12272+0.99560DQMEAN$$

$$(r^2=99\%)$$

3. Compute the expected number of trees per acre for the plantation using the Weibull distribution. Weibull parameters are "recovered" with technique developed by Burk and Burkhart (1984). The recovery process is:

   a. Location parameter is equal to DMIN.

   b. Shape parameter is calculated by solving the following equation:

$$(DQMEAN)^2-a^2-2a(DMEAN-a)$$
$$-(DMEAN-a)^2\Gamma(1+2/c)/\Gamma(1+1/c)=0$$

   c. Scale parameter is obtained using:

$$b=(DMEAN-1)/\Gamma(1+1/c)$$

Solve the Weibull distribution to determine the proportion of T in each dbh class as:

$$d_l<P<d_u=\exp(-((d_l-a)/b)^c)-\exp(-((d_u-a)/b^c)$$

Computer software can be easily developed to solve Eq. 7.

Multiply each P by T to obtain the expected number of trees per acre in each dbh class.

4. Predict the total height (h) of each tree with dbh class mid-point dbh (d)(5.0, 6.0, etc.) using:

$$H-\exp(\ln(H)+0.0045959-0.166041\ln(A)(\ln(DMAX)$$
$$-\ln(d)$$
$$-0.151721\ln(H/A)(\ln(DMAX)-\ln(d)$$

$$(R^2=69\%)$$

(This equation developed by Blackard 1985a, 1986.)

5. Estimate the content (cubic feet, green weight, etc.) of the tree representing each dbh class mid-point.

An equation to estimate the cubic feet of wood in a planted slash pine tree in East Texas is:

$$CFW=0.000838d^{1.859736}h^{1.301908}$$

$$(R^2=99\%)$$

(This equation developed by Hackett 1986.)

6. For the slash pine plantation, we now know:

   a. The number of trees per acre for each dbh class.

   b. The cubic feet of wood per tree for each dbh class.

Multiply CFW by n to obtain the cubic feet of wood per acre by dbh class.

Sum the CFW values across all dbh classes to determine the total cubic feet of wood per acre.

By selective summing across specified dbh classes, the CFW per acre by various tree size groups or different products (pulp, chip-n-saw, lumber, plywood, etc.) can be calculated.

EVALUATION

Loblolly

Using evaluation subplot values, plottings of the differences between observed yields and predicted yields against various stand parameters indicated no adverse trends. On the average, an under-prediction of 44 cubic feet or 7 percent occurred.

Slash

Based on the evaluation subplot values, plottings of the differences between observed yields and predicted yields against various parameters indicated no adverse trends. On the average, an under-prediction 37 cubic feet or 11 percent occurred.

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