MODELING INCREASED HEIGHT, DIAMETER, AND SPECIFIC GRAVITY EFFECTS ON YIELD ESTIMATES IN PLANTED LOBLOLLY PINE STANDS

by

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I. INTRODUCTION

Demands for wood products are increasing while forest land area is decreasing. Each year demand for wood increases because of population needs and the numerous ways in which wood is utilized. Further, more people have more leisure time for outdoor recreation. Hence timber producing lands are being utilized for recreation, lakes, commercial developments, and highways. This requires that more wood be produced on less growing space to meet the demands of our people. One way to meet these demands is to increase the yield per acre by intensive forest management.

Loblolly pine (*Pinus taeda L.*) is a fast growing species that is well suited for intensive management. Its range extends from Delaware and central Maryland south to central Florida and west to eastern Texas (Fowells 1965). Increases in loblolly pine yield are being sought by means of genetic improvement and by intensified cultural treatments including fertilization. Research is oriented towards the effects of genetic improvement and fertilization on height growth, diameter growth, and wood density of trees (N. C. State University 1971). Once the gains due to genetics and fertilization are known, foresters must be able to predict the stand yields. Current prediction techniques are based upon the products that are desired (e.g. lumber, plywood, fiber production, etc.). Yield prediction equations are needed that give consistent and accurate estimates of wood yield and yet such equations must be sufficiently flexible to allow genetic and fertilization effects to be entered at the proper time.

Many acres of loblolly pine have been planted in which increased growth rates are expected. In order to maintain accurate inventory records, a model is needed to predict the yield of these stands before they are harvested.

Objectives

The primary objective of this study was to evaluate specific models to discover those that could be used to predict the yield of even-aged loblolly pine stands while considering increased height, diameter, and specific gravity over varying site indices, densities, and ages. A secondary objective was to observe the increased yield at selected rotation ages when hypotehtical growth increases were applied at various points in the life of the stand.

Literature Review

Mathematical and graphical procedures have been used to predict yields of standing forest. These methods have ranged from crude estimation procedures to highly sophisticated mathematical models. Since direct approaches to growth estimation are expensive, the trend has been to use indirect prediction methods. The purpose of indirect prediction methods is to provide growth estimates at a cost lower than that of direct methods. Also, indirect prediction methods provide yield estimates over longer time spands than direct methods (Spurr, 1952).

The first American growth studies were by Cary (1896), Graves (1899), and Pinchot (1898). Concurrently, the normal yield tables (a German device) were introduced for American species by Pinchot and Graves (1896). Later normal yield tables were improved by the work of King (1916), McCarthy and Robertson (1921), and Fenska and Lauderburn (1924). From normal yield tables evolved our present day stand-projection tables for growth prediction. Current methods of yield-table construction are discussed by Husch, Miller, and Beers (1972).

Mathematical models used in the computation of stand projection tables have ranged from simple regression to multiple regression equations containing many independent variables (Spurr 1952). The use of multiple regression techniques for forest yield prediction were first employed by MacKinney and Chaiken (1939). Later, models that possessed the compatibility which must exist between growth and yield observations were employed by Buckman (1962), Clutter (1963), and others. Clutter's models were later refined by Sullivan and Clutter (1972).

Diameter distributions have been predicted by Bliss and Reinker (1964), Clutter and Bennett (1965), McGee and Della-Bianca (1967), and Strub (1972). The diameter distributions were used as a basis for yield predictions by Bennett and Clutter (1968) and Lenhart and Clutter (1971). Curtis (1972) gave a summary of yield tables and some alternative bases for yield tables for managed stands.

To date there have been no published reports describing models for use in predicting yields of forest stands derived from improved stock or intensified cultural treatments.

II. PROCEDURES

Data Source

Data used in this study were collected by field crews from several industrial forestry organizations as outlined by Burkhart, et al. (1972). Sample plots were located in selected old-field loblolly pine plantations in the Virginia Piedmont and Coastal Plain, and the Coastal Plain region of Delaware, Maryland, and North Carolina. One hundred and eighty-nine sample plots were taken from these plantations. Figure 1 shows the geographic distribution of the sample plots by counties. Table 1 contains the means, standard deviations, and correlation coefficients for age (years), average height of the dominant-codominant stand (feet), and stand density (number of trees per acre) for the sample plots.

One-tenth acre circular sample plots were taken at random from selected loblolly pine plantations. Sampling criteria included that the plantations be unthinned, free of evidence of heavy disease or insect infestations, free of interplanting, unburned, unpruned, free of wildlings, and at least 9 years of age.

On each plot, dbh was measured to the nearest 1-tenth inch for all trees in the 1-inch dbh class (i.e. .6 to 1.5 is the 1-inch dbh class) and above. The height of five to seven dominant and codominant trees was measured

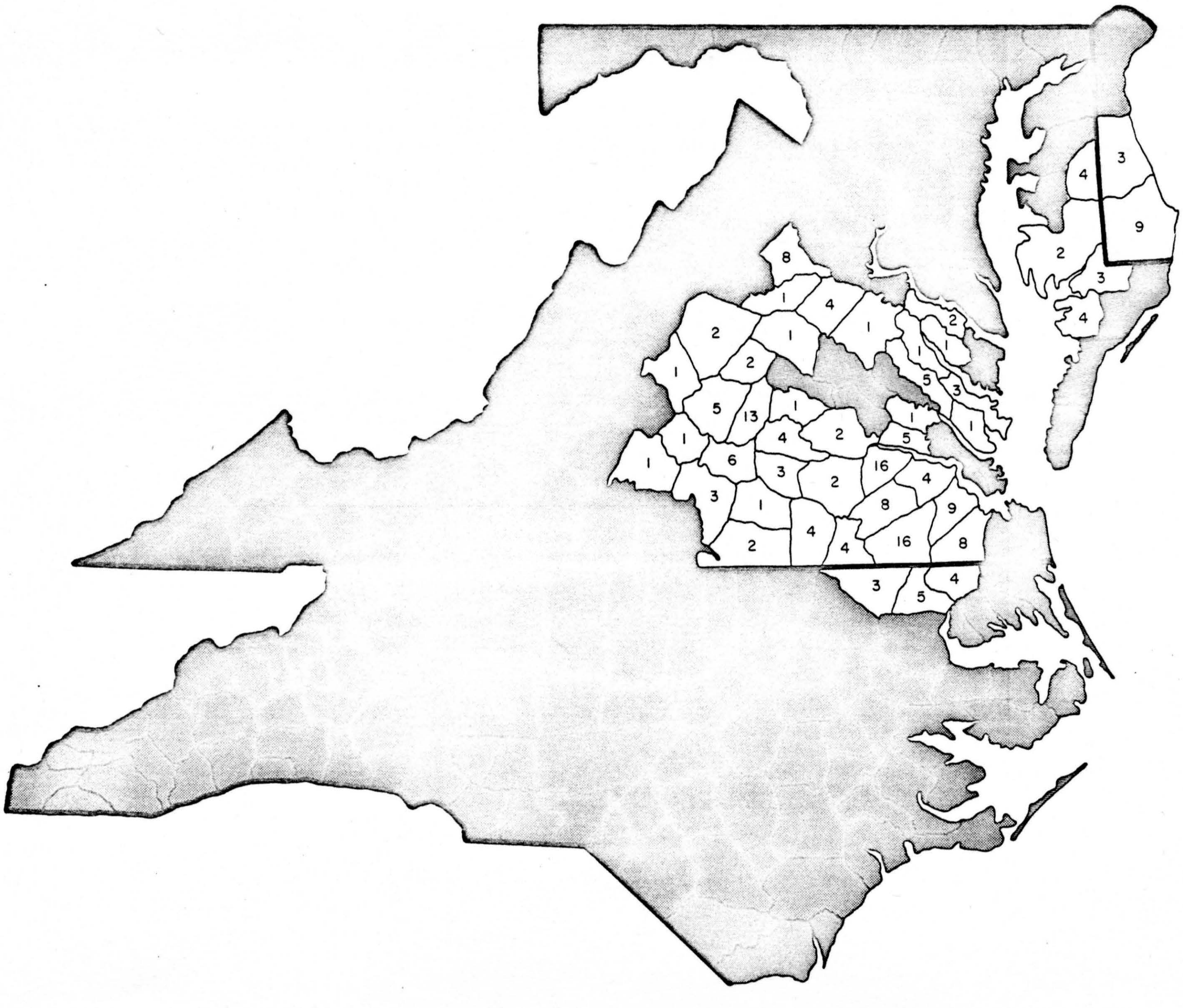
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Figure 1. Distribution of sample plots by counties in Delaware, Maryland, Virginia, and North Carolina

Table 1. Sample plot means, standard deviations, and correlation coefficients for age, height, and density

	Mean	Standard Deviation
Age (years)	16.61	4.80
Density (no. trees/acre)	751.85	282.50
Height (feet)	46.28	10.88
	Correlation Coefficients	
	Density	Height
Age	-.35	.89
Density		-.36*

*This correlation was made across all diameter classes and ages to the nearest foot. Total height was recorded to the nearest foot for at least one, but usually two trees per 1-inch dbh class. Stand age and number of trees per acre were recorded.

On each plot two trees were felled and cut into 4-foot sections for detailed mensurational measurements. Using the felled tree data, per-tree volume and weight equations were computed. The combined-variable equation (Spurr 1952) was used to compute cubic-foot volumes and specific gravity was expressed as a function of tree age. A list of per-tree equations used in this study is shown in Table 2.

For each plot a regression of the following form was fitted for predicting height:

$$\log_{10}H = b_0 + b_1(1/D)$$

where

H = total tree height in feet

D = dbh in inches

Substituting the measured diameters into the equation gives total height estimates for each tree. The dbh and height values were then available to be used in the various per-tree volume and weight equations.

From the dominant and codominant tree heights an equation for site index curves (base age 25) was computed as follows:

Table 2. Equations used to predict per-tree values when summarizing plot volumes and weights (Burkhart, *et al*. 1972)[1/]

Cubic Feet (inside bark)

Total Stem

$$CV = 0.11691 + 0.00185D^2H$$

Top diameter 3.0 inches outside bark

$$CV = -0.05729 + 0.00184D^2H$$

Top diameter 4.0 inches outside bark

$$CV = -0.46236 + 0.00185D^2H$$

Dry Weight--Pounds (inside bark)

Dry weight (pounds) of wood per tree was calculated as the predicted unextracted wood specific gravity (oven-dry weight, green volume basis) times 62.4 times the green cubic-foot volume.

$$\text{Dry Weight} = SG \times 62.4 \times CV$$

Specific gravity (inside bark) prediction equations used:

Total Stem

$$SG = 0.50927 - 1.38420(1/A)$$

Top diameter 3.0 inches outside bark

$$SG = 0.51074 - 1.33500(1/A)$$

Top diameter 4.0 inches outside bark

$$SG = 0.51627 - 1.32246(1/A)$$

1/ Throughout this table D denotes diameter at breast height in inches, H denotes total tree height in feet, A denotes total tree age in years, CV denotes cubic-foot volume (inside bark), and SG denotes specific gravity.

$$\log_{10}H_d = \log_{10}SI - 5.86537(1/A - 1/25)$$

where

H_d = average height of the dominants and codominants in feet

SI = site index (base age 25)

A = total stand age in years

These data from the sample plots were then used for the development of yield prediction models.

Model Development

An acceptable yield precition model must be consistent, accurate, flexible, simple, and accessible. Yield prediction models were tested by computing percentage increases in dry weight for specified increases in height, diameter, and specific gravity for varying site indices, trees per acre, and ages. To test prediction models, constant increases were used since actual values are not yet available. In the future, availability of such information will occur when analyses are made of the relatively recent work with improved stock and intensified cultural treatments. It was assumed that a model which does not perform well with constant increases will probably not perform well if other increase relationships are later established as being more appropriate. It was also assumed that mortality patterns would be the same for plantations with an increased growth rate as for the plot data that was available.

Dry weight per acre was chosen as the quantity to be predicted since specific gravity has no affect on the volume per se and specific gravity was one of the variables to be considered. Dry weight inside bark for total stem, for a stem to a 3-inch top diameter outside bark, and for a stem to a 4-inch top diameter outside bark were chosen for use in the evaluation. These limits were chosen since the computation for three values was just as easy as for one and because some industries may use the total stem and others may only use a merchantable stem.

The growth increases arbitrarily chosen were:

1. height increases of 10, 15, and 20 percent
2. diameter increases of 10, 15, and 20 percent
3. specific gravity increases of 1, 2, and 4 percent

Although these values are hypothetical, they are realistic in the sense of being close to the gains expected from tree improvement research (N. C. State University 1971). Table 3 shows the various combinations of percentage growth increases that were considered. Table 4 shows the expected increase (in percent) in dry weight for the various combinations of growth increases considered. These expected values were derived with the assumptions of constant growth increase, similar tree form, and similar

Table 3. Combinations of growth increases considered (in percent)[a]

D	H	SG	(D)(H)	(D)(SG)	(H)(SG)	(D)(H)(SG)
			Percent Increase			
10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

[a] D = diameter
H = height
SG = specific gravity

Table 4. Expected increase in dry weight yield under the assumption of constant growth increases for the values arbitrarily chosen (in percent)[a]

D	H	SG	(D)(H)	(D)(SG)	(H)(SG)	(D)(H)(SG)
			Percent Increase			
21	10	1	33	22	11	34
32	15	2	52	35	17	55
44	20	4	73	50	25	80

a
D = diameter

H = height

SG = specific gravity

mortality relative to unimproved stands.

After the most appropriate model was determined, it was used to satisfy the secondary objective. Constant growth increases were assumed up to the assumed point of crown closure (10 years) and then the stands were projected forward at the former rates. Next, it was assumed that intensified cultural treatments could maintain constant growth increases up to age 20 and then the stands were projected forward at the former rates.

As outlined in the following sections, two major yield prediction approaches were used in the evaluation, the multiple regression approach and the diameter distribution approach.

Multiple Regression Approach

The regression model selected to predict dry weight yield was that used by Burkhart, *et al*. (1972):

$$\text{Log}_{10}Y = b_0 + b_1(1/A) + b_2(H/A) + b_3(N/100) + b_4(A)(\text{Log}_{10}N)$$

where:

Y = dry weight in 1,000 pounds per acre

A = total stand age in years

H = average height of the dominants and codominants in feet

N = number of trees per acre (1-inch dbh class and above)

Burkhart, et al. (1972) found this model to result in a good fit to the data (in terms of a high coefficient of determination (R^2) and a low standard error of estimate ($S_{y \cdot x}$)) and to produce resulting yield estimates that were logical and consistent with prior knowledge of dry weight yield development in planted loblolly pine. Since the model was to predict yield after some constant increase in diameter growth, height growth, or specific gravity, the original tree data was increased by these constant amounts. Once the various combinations (Table 3) had been added to the original tree data, the dry weight was computed for each plot. The increases were calculated by the following equations:

$$H = [10^{(b_0 + b_1/D)}](I_h)$$

$$D = (D)(I_d)$$

$$SG = (b_0 + b_1/A)(I_{SG})$$

where

I_h = one plus the constant increase for height expressed as a decimal

I_d = one plus the constant increase for diameter expressed as a decimal

I_{SG} = one plus the constant increase for specific gravity expressed as a decimal

Dry Wt. = SG x 62.4 x CV

Dry weight for each combination of increases was computed on all 189 plots. Next, the adjusted values for each plot were put into the regression model and a regression analysis performed to determine new coefficients. This technique gave the coefficients for use in the regression model. For all combinations, the coefficient of determination (R^2) was quite high (.9291 or larger) and the standard error of estimate was relatively low (less than .0802).

The percentage difference between original and new dry weight yield for all growth increase combinations was computed for site index values of 40 to 90 (in increments of 10), ages of 4 to 40 years (in increments of 2) within each site index, and stand densities of 200 to 1500 trees per acre (in increments of 100) within each site index and each age class. Figure 2 shows the format of the tables of percentage increase in dry weight per acre computed.

Another cubic volume equation was calculated from the original tree data by means of a non-linear least squares procedure. The cubic volume equation was a modified combined-variable and had the following form:

Site Index 40

Trees Per Acre

Age (Yrs)	200	300	...	...	...	...	1500
4	–	–		. . .			–
6	–	–		. . .			–
8	–	–		. . .			–
.	.	.					
.	.	.					
.	.	.					
40	–	–		. . .			–

.
.
.

Site Index 90

Trees Per Acre

Age (Yrs)	200	300	...	...	...	...	1500
4	–	–		. . .			–
6	–	–		. . .			–
8	–	–		. . .			–
.							
.							
.							
40	–	–		. . .			–

Figure 2. Format of the tables computed for percentage increase in dry weight per acre

for stems to three and four-inch top diameters outside bark

$$CV = b_0 + b_1(D + X)^2H$$

for the total stem

$$CV = b_1(D + X)^2H$$

where:

X = some constant added to the diameter

It was believed that a cubic volume equation of this form could predict more logically for the small tree diameters than the combined-variable cubic volume equations since for very small values of D^2H the relationship is not linear. The following list shows the constants obtained for the modified combined-variable cubic volume equations:

1. CV (total stem) = $.001704(D + 0.42710)^2H$
2. CV (3-inch top) = $-.36042 + .001638(D + .71414)^2H$
3. CV (4-inch top) = $-.46918 + .001859(D + 0.0)^2H$

For the 4-inch top diameter equation X = 0, and b_0 and b_1 approached the same values as in the combined-variable cubic volume equation.

With these new cubic volumes equations, dry weights (1000 pounds per acre) were computed for the same 21 growth combinations on each plot. Dry weight for no increase in growth was also calculated for each plot. These plot values were computed because a different cubic-volume equation was used and the original dry weight is needed to get percentage figures. All procedures were the same as before except that a different cubic volume equation was used.

Diameter Distribution Approach

By Diameter Class Using Combined-Variable Cubic Volume Equations

Data from the 189 plots were used to solve for coefficients in the diameter distribution models developed by Strub (1972). Yield prediction with this model consisted of: (1) establishing maximum and minimum diameters from measurements of stand age, site index, and number of trees per acre, (2) developing a family of frequency curves for estimating the proportion of trees in each diameter class between the extremes, (3) predicting heights for trees of given diameters and age-site-stand density combinations, (4) calculating volumes for given heights and diameters from tree-volume equations, and (5) summing diameter-class volumes to obtain a per-acre volume estimate.

The equations used were:

$$D_{max} = 3.51556 + .100288(H_d) - .393213$$
$$(AN/10{,}000) + 19.79939(H_d/N)$$

$$D_{min} = -.00413 + .050117(H_d) - .270354(AN/10,000) + 16.2565(H_d/N)$$

$$\bar{\alpha} = 2.820632$$

$$\bar{\beta} = 2.914630$$

$$f(D_i) = \frac{\Gamma(\alpha+\beta)}{(D_{max}-D_{min})\Gamma(\alpha)\Gamma(\beta)} \left(\frac{D_i-D_{min}}{D_{max}-D_{min}}\right)^{\alpha-1} \left(1 - \frac{D_i-D_{min}}{D_{max}-D_{min}}\right)^{\beta-1}$$

$$D_{min} < D_i < D_{max} \quad \alpha,\beta > 0$$

$$\log_{10} H = [.5381470 + 4.1101454(1/AD_i) + 7797465 (\mathrm{Log}_{10} H_d) - 2.1028528/D_i + .3546846 ((\mathrm{Log}_{10} N)/D_i) - 1.1771308/A]$$

where:

H_d = average height of the dominant stand (feet)

A = stand age in years

N = stand density (number of trees per acre)

D_{max} = maximum tree diameter (as measured to the nearest 1-inch)

D_{min} = minimum tree diameter (as measured to the nearest 1-inch) a continuity correction of one half the class interval was substracted from D_{min} and added to D_{max}

D_i = average diameter for the i^{th} diameter class

$\Gamma(X)$ = gamma function of x

$f(D_i)$ = relative frequency of occurrence for any given diameter lying between D_{min} and D_{max}

H = mean total tree height for a given diameter class, D_i

The same constant growth increases and combinations that were discussed earlier were also used here. These increases were added to the following equations:

$$D_{max} = D_{max}(I_d)$$

$$D_{min} = D_{min}(_d)$$

$$H = (H)(I_h)$$

$$SG = (b_0 + b_1/A)(I_{SG})$$

$$CV = (b_0 + b_1D^2H)f(N)$$

where:

I_h = one plus the constant increase for height expressed as a decimal

I_d = one plus the constant increase for diameter expressed as a decimal

I_{SG} = one plus the constant increase for specific gravity expressed as a decimal

f(N) = number of trees in the specific diameter class

Dry Weight (per diameter class) = SG x 62.4 x CV

$$\text{Dry Weight (per acre)} = \sum_{i=1}^{n} \text{Dry Weight (per diameter class)}$$

where:

$\sum_{i=1}^{n}$ = the sum of all the diameter classes from D_{min} to D_{max} for total dry weight and from the 5-inch class to D_{max} for dry weight of stems to a 3 and 4-inch top diameter outside bark.

The percentage difference in dry weight yield was computed between the original yield and the new yield (after growth increase) for the various combinations. Again site index, age, and stand density varied over the ranges defined by Figure 2.

By Diameter Class Using Modified Combined-Variable Cubic-Volume Equations

To continue with the procedures used in multiple regression, the modified combined-variable cubic volume equations were used in conjunction with the diameter distribution formulae. Then the percentage difference in dry weight yield was computed between the original yield and the new yield. All other computations were as before except that a different cubic volume equation was used.

Unified Approach

The "unified" method of predicting dry weight yield was developed by Strub (1972, personal communication). With the same constants (i.e., α, β, D_{min}, and D_{max} values) that were calculated for the class interval method, the derived equations gave good predictions for dry weight yield. The following cubic-foot volume (inside bark) equations were computed from the per-tree data:

Total Stem

$$CV = a_0 + a_1 D^2 H_d$$

Stem to a 3-inch Top

$$CV = b_0 + b_1 D^2 H_d$$

Stem to a 4-inch Top

$$CV = c_0 + c_1 D^2 H_d$$

Cubic-foot volume per acre for the total stem of all trees in the 1-inch dbh class and above was then defined as:

$$CVT = \sum_{i=1}^{n} (a_0 + a_1 D_i^2 H_d)(N)(P_i)$$

The expressions for cubic-foot volume per acre to a 3-inch and to a 4-inch top diameter for all trees in the 5-inch dbh class and above are:

$$CV3 = \sum_{i=5}^{n} (b_0 + b_1 D_i^2 H_d)(N)(P_i)$$

$$CV4 = \sum_{i=5}^{n} (c_0 + c_1 D_i^2 H_d)(N)(P_i)$$

where

$a_0, a_1, b_0, b_1, c_0, c_1$ = coefficients of appropriate cubic volume equations

D_i = average diameter for the i^{th} diameter class

H_d = average height of dominant and codominant trees

N = number of trees per acre

P_i = probability of a tree being in the i^{th} diameter class

CVT = cubic-foot volume (inside bark) per acre of the total stem for all trees in the 1-inch dbh class and above

CV3 = cubic-foot volume (inside bark) per acre to a 3-inch top diameter for all trees in the 5-inch dbh class and above

CV4 = cubic-foot volume (inside bark) per acre to a 4-inch top diameter for all trees in the 5-inch dbh class and above.

If the number of class intervals increases without bound, the following models result for cubic-foot volume:

$$CVT = a_0N + a_1N\ H_d(D_{min})^2 + a_1N\ H_d(D_{max}-D_{min})^2$$

$$\left(\frac{\alpha(\alpha+1)}{(\alpha+\beta)(\alpha+\beta+1)}\right) + 2a_1N\ H_d(D_{max}-D_{min})D_{min}\left(\frac{\alpha}{\alpha+\beta}\right)$$

$$CV3 = b_0N\ P_{(\alpha,\beta)} + b_1N\ H_dD_{min}{}^2P_{(\alpha,\beta)} + b_1N\ H_d(D_{max}-D_{min})^2$$

$$\left(\frac{\alpha(\alpha+1)}{(\alpha+\beta)(\alpha+\beta+1)}\right)P_{(\alpha+2,\beta)} + 2b_1N\ H_d(D_{max}-D_{min})D_{min}\left(\frac{\alpha}{\alpha+\beta}\right)$$

$$P_{(\alpha+1,\beta)}$$

$$CV4 = C_0N\,P_{(\alpha,\beta)} + C_1N\,H_dD_{min}{}^2P_{(\alpha,\beta)} + C_1N\,H_d(D_{max}-D_{min})^2$$

$$\left(\frac{\alpha(\alpha+1)}{(\alpha+\beta)(\alpha+\beta+1)}\right)P_{(\alpha+2,\beta)} + 2C_1N\,H_d(D_{max}-D_{min})D_{min}$$

$$\left(\frac{\alpha}{\alpha+\beta}\right)P_{(\alpha+1,\beta)}$$

where

D_{min} = minimum tree diameter at breast height (inches)

D_{max} = maximum tree diameter at breast height (inches)

α and β = model parameters previously determined

$$P_{(\alpha,\beta)} = \int_{4.555}^{D_{max}} f(D;\alpha,\beta)dD = \int_{4.555}^{D_{max}} \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)(D_{max}-D_{min})}$$

$$\left(\frac{D_i-D_{min}}{D_{max}-D_{min}}\right)^{\alpha-1}\left(1-\frac{D_i-D_{min}}{D_{max}-D_{min}}\right)^{\beta-1}dD$$

Other parameters remain as defined previously. Dry weight was determined by the following formula:

Dry weight per acre (pounds) = (cubic volume) x 62.4 x (specific gravity)

where specific gravity is predicted from the equations in Table 2.

Except for height increases, constant growth increases were added to the same equations as in the class interval method. Increases in height were handled by adding to the dominant stand height, i.e.:

$$H = [SI\ 10^{-5.86537(1/A - 1/25)}]I_h$$

where

SI = site index

A = average stand age in years

I_h = one plus the constant increase for height expressed as a decimal

Using Strub's equations, dry weight yield was predicted before and after the growth increases. The percentage differences were computed for the various combinations of site index, age, and stand density that were previously used.

The modified combined-variable cubic volume equations, when fitted by non-linear least squares, were nearly the same as the combined-variable cubic volume equations because X approached zero. There was no need to consider these cubic volume equations since the two types were nearly equal.

Evaluation of Results

Expected percentage increases and predicted percentage increases were compared for each model and for each combination of growth increases. Under each model and each combination, dry weight (inside bark) percentage increases were predicted. The adequacy of the various approaches for handling arbitrary growth increases was judged by their accuracy and consistency with regard to expected increases under the assumptions made, and by flexibility and ease of use of the prediction techniques.

III. RESULTS AND DISCUSSION

Multiple Regression Appproach

The multiple regression yield equations derived when using combined-variable cubic volume equations are shown in Appendix Table 1. The yield equations derived when using modified combined-variable cubic volume equations are contained in Appendix Table 2.

Specific percentage increases in dry weight for the 21 combinations, using the regression model with the combined-variable cubic volume equations, are shown in Appendix Table 3. By comparing these values with the expected values given in Table 4, it can be seen that this yield model is not accurate or consistent. If diameter growth is increased by a constant 10 percent, a 21 percent increase in dry weight yield is expected. This regression model, with combined-variable cubic volume equations, predicted approximately 3 to 12 percent increase in dry weight yield depending on the stand density, site index, and age combination. This model was inaccurate and inconsistent, primarily for assumed increases in diameter growth.

Using the same regression model but with the modified combined-variable cubic volume equations, the same erroneous results resulted. With a 21 percent increase in dry weight expected for a diameter increase of 10 percent, this yield model predicted a 7 to 9 percent increase in dry weight depending again on stand density, site index, and age combination. Values for this regression model with modified combined-variable cubic volume equations are given in Appendix Table 4. The results indicate that this regression model will not perform adequately when growth increases are assumed and applied to the data resulting in new prediction surfaces.

Tables 3, 4, 5, 6, 7 listed in the Appendix contain only one site index (60) and selected values for age and stand density. This was done because the trends are the same for other site index and age values.

Diameter Distribution Approach

By diameter class using combined-variable cubic volume equations

Specific percentage increases in dry weight yield for the 21 combinations, using the diameter distribution approach by diameter class with the combined-variable cubic volume equations, are given in Appendix Table 5. By comparing these values with the expected values given in Table 4, one can see that this model is very consistent and fairly accurate. When diameter growth was increased by 10 percent, a 21 percent increase in dry weight yield was expected. This model predicted 24 to 25 percent increases, consistent and fairly close to the expected value. The increases for height growth and specific gravity were predicted exactly as expected (i.e. a 10 percent increase in height increased dry weight 10 percent and a 1 percent increase in specific gravity increases dry weight by 1 percent). As for flexibility of this model, increases can be added or removed at any point in time with minor changes in the computer program.

By diameter class using modified combined-variable cubic volume equations

Using the same diameter distribution model but with the modified combined-variable cubic volume equations, the results were approximately the same as the diameter distribution model with the combined-variable cubic volume equations. Values for this model are given in Appendix Table 6. Again, when diameter growth was increased by 10 percent, a 21 percent increase in dry weight yield was expected. This model predicted 22.8 to 23.8 percent increase in dry weight yield for total stem. It predicted 22 to 23 percent and 24 to 25 percent increases in dry weight yield for stems to a 3-inch and 4-inch top diameter outside bark, respectively. All other combinations involving diameter increases showed the same relative patterns. Increases in height and specific gravity were the same as for the diameter distribution model with the combined-variable cubic volume equations.

This diameter distribution model can be used to predict dry weight yield with constant growth increases for either type of cubic volume equations. The predictions for either type of cubic volume equations were consistent and accurate.

Since this seems to be the appropriate model to use in yield predictions, it was used to project selected growth increases of stands. For several cases where an increase in height and diameter were taken and projected only to ages of 10 and 20 years, the results showed that early increases drop off very fast when carried to rotation age. Evidence points to maintaining the growth increases to older ages or causing growth increases at later ages (as might be the case of fertilizing at age 15 or 20 and getting growth increases) before profitable returns can be assured. Figures 3-5 are graphs of several combinations of 10 percent increase in diameter and height growth to ages 10 and 20 years.

Unified Approach

Specific percentage increases in dry weight yield for the various combinations, using Strub's unified diameter distribution approach, are given in Appendix Table 7. Comparison of these values with the expected values given in Table 4, demonstrates that this model

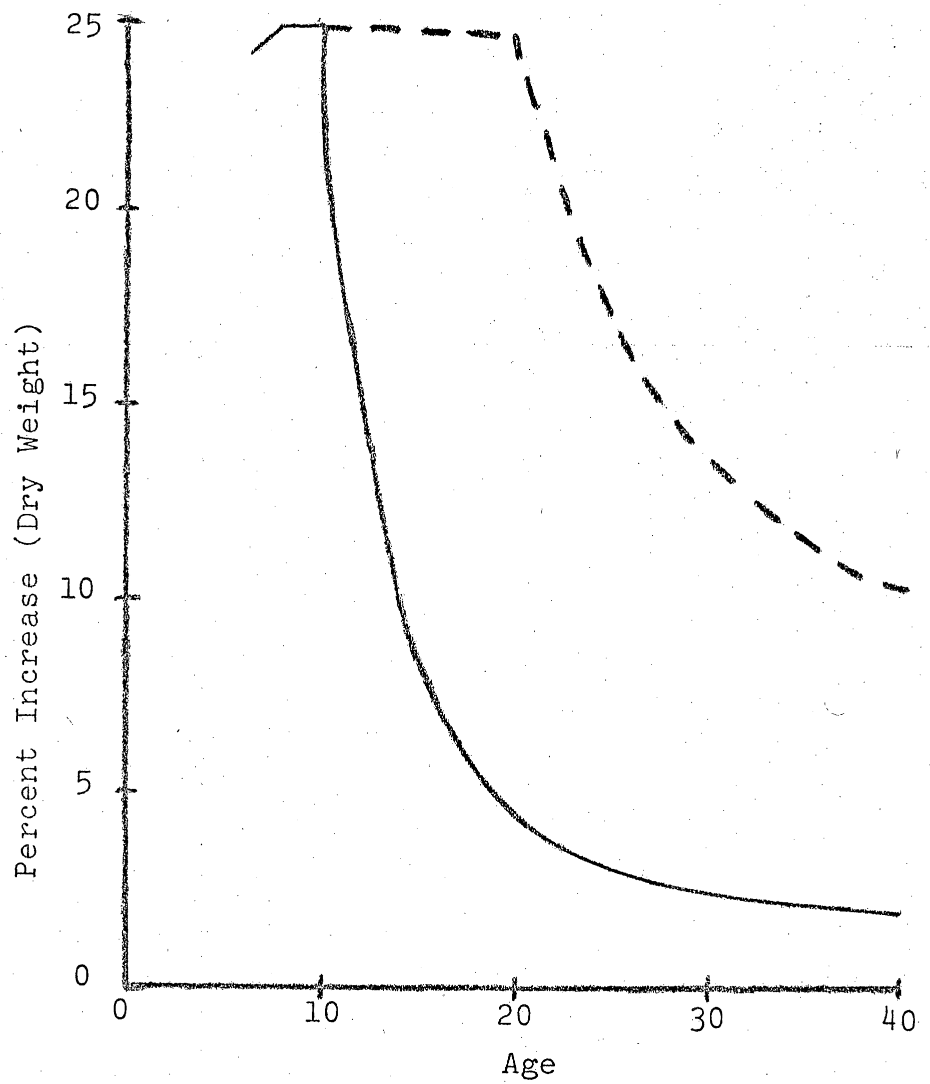

Figure 3. Graph of 10 percent increase in diameter growth to age 10 and to age 20 for a stand growing on site index 60 land with 800 trees per acre

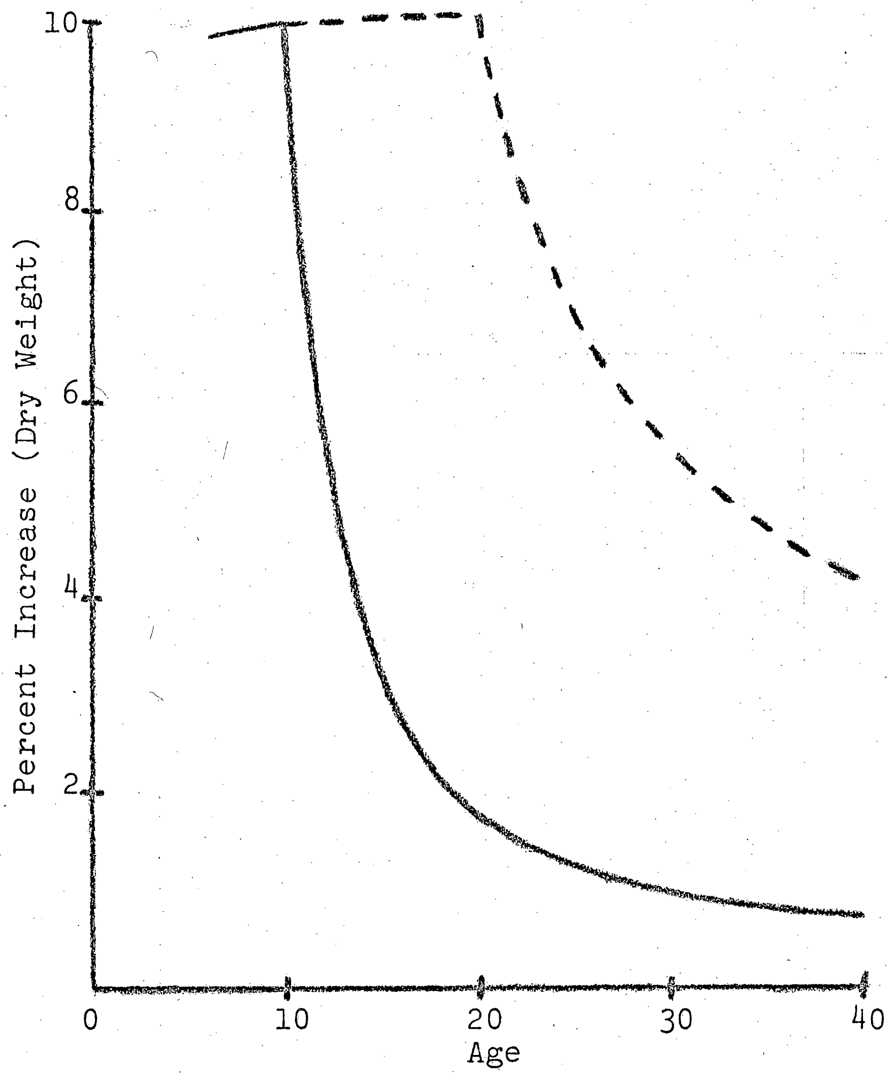

Figure 4. Graph of 10 percent increase in height growth to age 10 and to age 20 for a stand growing on site index 60 land with 800 trees per acre

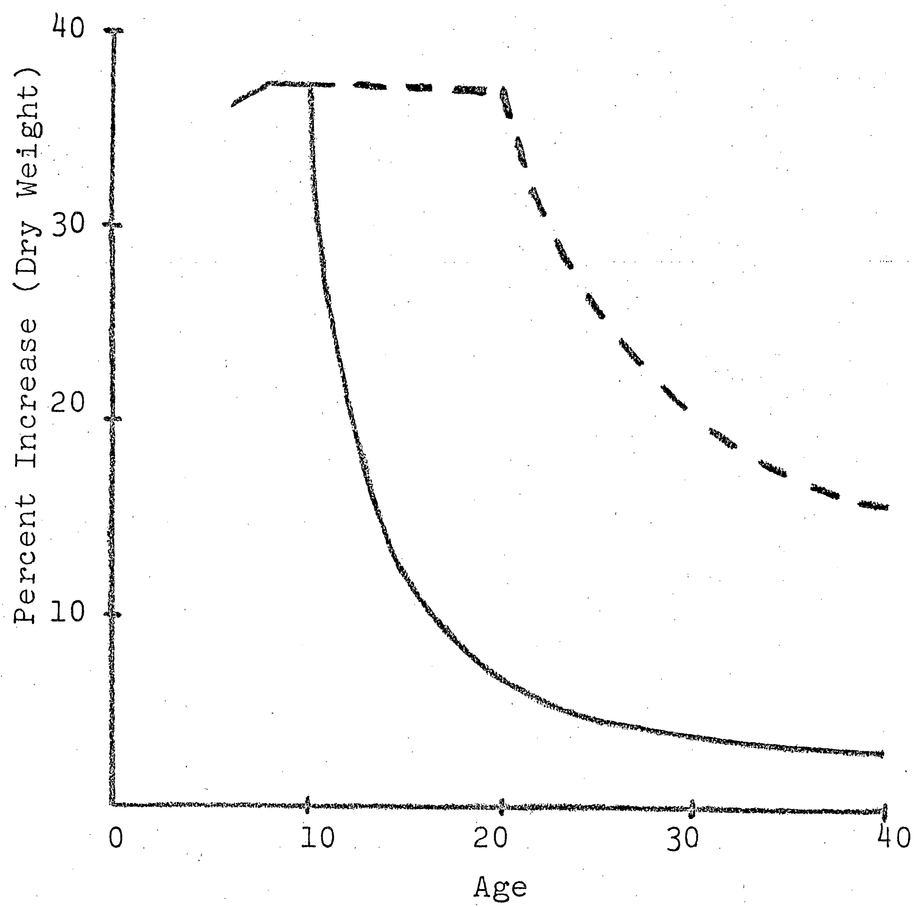

Figure 5. Graph of 10 percent increase in diameter and height growth to age 10 and to age 20 for a stand growing on site index 60 land with 800 trees per acre

does not predict well at young ages and low site indices for increases involving diameter growth. The predictions in dry weight yield for older ages (above 20) and high site indices (above 60) were fairly accurate and consistent. This was possibly due to the use of the height of the dominant trees in the equations. Site sample-trees used to establish site index curves, were restricted to those that had been dominants or codominants throughout the life of the stand and free of damage. The raw data ranged in age from 9 to 35 years and in site index from 47 to 84.

For yield predictions influenced by height increases, the values varied more than by the class interval method, but still the model should be considered good for yield prediction. Specific gravity increases were as expected (i.e. 1 percent increase in specific gravity increased dry weight by 1 percent).

IV. CONCLUSIONS AND RECOMMENDATIONS

It appears that the diameter distribution approach by diameter class is a good model to use in dry weight predictions when constant increase in diameter growth, height growth, or specific gravity are incurred. There is very little difference between the predicted values obtained when the combined-variable or the modified combined-variables cubic volume equations are used. The predictions resulting when the combined-variables equations were used are preferred by the author since the percentage increases for total stem, stems to a 3-inch top diameter outside bark, and stems to a 4-inch top diameter outside bark were all nearly equal for all ages, site indices, and densities. With either type of cubic volume equations, this model was better than the multiple regression model and the diameter distribution model with the unified equations.

The diameter distribution approach by diameter class has qualities of accuracy, consistency, and flexibility. Assuming that diameter increases may change the form of a tree, the slightly higher predictions over expected predictions could then be explained. The model is very consistent over all site indices, ages, and densities. The flexibility of this model can be shown by the ease of adding these increases, by the points in time where increases can be added or removed (any point in time), and by the points in time that the model can be started (i.e. predictions can be made for increases by starting to compute the dry weight one year before the increases are to be added). It appears this is the most appropriate model to use for dry weight predictions when growth increases are expected and are to be incorporated.

Using this model, the projection of constant growth increases on stands showed that early growth increases mean very little when carried to rotation age. To obtain profitable returns, growth increases must be maintained or induced at later ages.

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APPENDICES

Appendix Table 1. Yield equations for original data and combinations of growth increases using combined-variable cubic volume equations[a]

Equation:[b]		b_0	b_1	b_2	b_3	b_4	(R^2)[c]	$(S_{y \cdot x})$[c]
Code								
0,0	T	.90223	-7.79316	.31881	.00720	.00864	.9479	.0503
	3	1.09538	-11.76794	.40689	-.01385	.00655	.9291	.0727
	4	1.07452	-13.84583	.45142	-.01635	.00637	.9369	.0768
1,1	T	.92583	-8.18661	.33049	.00456	.00880	.9457	.0537
	3	.99050	-10.86113	.41558	-.01614	.00794	.9310	.0756
	4	.98426	-13.02220	.45984	-.01849	.00762	.9380	.0801
1,2	T	.94278	-7.84660	.29094	.00713	.00863	.9482	.0504
	3	1.01539	-10.67165	.37220	-.01502	.00770	.9300	.0743
	4	1.00361	-12.59053	.40854	-.01723	.00747	.9376	.0779
1,3	T	.90849	-7.79515	.31818	.00730	.00862	.9479	.0503
	3	.98029	-10.69940	.40927	-.01501	.00769	.9300	.0743
	4	.97125	-12.91498	.45488	-.01752	.00737	.9382	.0786
1,4	T	.96639	-8.24747	.30195	.00439	.00880	.9461	.0537
	3	1.02890	-10.82652	.37764	-.01601	.00797	.9312	.0753
	4	1.02128	-12.70989	.41338	-.01828	.00772	.9375	.0794
1,5	T	.93034	-8.18457	.33039	.00456	.00880	.9457	.0537
	3	.99371	-10.85323	.41553	-.01609	.00795	.9312	.0754
	4	.98666	-13.00587	.45998	-.01854	.00764	.9380	.0802
1,6	T	.94702	-7.84258	.29087	.00712	.00863	.9481	.0504
	3	1.01879	-10.67120	.37226	-.01496	.00771	.9301	.0742
	4	1.00622	-12.57639	.40870	-.01729	.00749	.9375	.0779

Appendix Table 1. (continued)

Equation:[b] Code		b_0	b_1	b_2	b_3	b_4	$(R^2)^c$	$(S_{y \cdot x})^c$
1,7	T	.96907	-8.23320	.30195	.00438	.00881	.9460	.0537
	3	1.03401	-10.83762	.37780	-.01603	.00796	.9311	.0754
	4	1.02545	-12.70991	.41317	-.01818	.00772	.9376	.0793
2,1	T	.96635	-8.24502	.33110	.00486	.00876	.9470	.0531
	3	.99793	-10.25264	.40130	-.01211	.00824	.9349	.0702
	4	.99841	-12.31300	.44327	-.01468	.00790	.9414	.0745
2,2	T	.96114	-7.85704	.27860	.00707	.00863	.9480	.0505
	3	1.03335	-10.64917	.35572	-.01493	.00771	.9302	.0741
	4	1.02067	-12.45436	.38871	-.01702	.00751	.9374	.0775
2,3	T	.91205	-7.79394	.31828	.00731	.00862	.9478	.0503
	3	.98328	-10.70030	.40973	-.01505	.00769	.9299	.0744
	4	.97291	-12.90399	.45500	-.01742	.00739	.9384	.0784
2,4	T	1.02403	-8.30920	.28977	.00463	.00877	.9472	.0533
	3	1.05938	-10.23176	.34842	-.01198	.00823	.9353	.0699
	4	1.05619	-11.92641	.37905	-.01416	.00799	.9409	.0734
2,5	T	.97441	-8.23661	.33100	.00485	.00877	.9470	.0531
	3	1.00775	-10.26296	.40114	-.01206	.00823	.9352	.0701
	4	1.00923	-12.31862	.44294	-.01469	.00788	.9415	.0744
2,6	T	.97152	-7.87372	.27856	.00708	.00862	.9481	.0505
	3	1.04123	-10.64911	.35587	-.01494	.00772	.9302	.0741
	4	1.02971	-12.46544	.38900	-.01709	.00751	.9372	.0777
2,7	T	1.03270	-8.30730	.28971	.00463	.00877	.9472	.0533
	3	1.06666	-10.22262	.34855	-.01201	.00824	.9352	.0700
	4	1.06591	-11.93118	.37896	-.01418	.00798	.9409	.0734

Appendix Table 1. (continued)

Equation:[b]		b_0	b_1	b_2	b_3	b_4	(R^2)[c]	$(S_{y.x})$[c]
Code								
3,1	T	1.06082	-7.98840	.32297	.00670	.00860	.9480	.0509
	3	1.06085	-9.11900	.37055	-.00513	.00847	.9337	.0648
	4	1.05600	-10.74743	.40601	-.00767	.00824	.9398	.0682
3,2	T	.98077	-7.89215	.26745	.00699	.00862	.9481	.0505
	3	1.05453	-10.66085	.34078	-.01500	.00770	.9298	.0743
	4	1.03868	-12.35246	.37112	-.01697	.00753	.9368	.0775
3,3	T	.92115	-7.79470	.31822	.00728	.00862	.9479	.0503
	3	.99231	-10.71045	.40979	-.01503	.00769	.9299	.0745
	4	.97932	-12.87770	.45509	-.01755	.00741	.9382	.0786
3,4	T	1.13687	-8.04868	.27088	.00646	.00861	.9483	.0511
	3	1.13821	-9.07468	.30845	-.00510	.00848	.9336	.0647
	4	1.13388	-10.36963	.33213	-.00715	.00832	.9388	.0673
3,5	T	1.07652	-7.97583	.32295	.00670	.00861	.9481	.0509
	3	1.07704	-9.11666	.37072	-.00515	.00847	.9336	.0648
	4	1.07345	-10.74614	.40585	-.00766	.00824	.9399	.0681
3,6	T	.99775	-7.89572	.26756	.00699	.00862	.9481	.0505
	3	1.06863	-10.63941	.34085	-.01496	.00772	.9300	.0742
	4	1.05854	-12.36798	.37086	-.01696	.00751	.9368	.0775

Appendix Table 1. (continued)

Equation:[b]		b_0	b_1	b_2	b_3	b_4	$(R^2)^c$	$(S_{y \cdot x})^c$
Code								
3,7	T	1.15403	-8.04843	.27088	.00646	.00861	.9483	.0511
	3	1.15544	-9.07629	.30839	-.00508	.00848	.9336	.0647
	4	1.15060	-10.36836	.33210	-.00712	.00833	.9389	.0673

[a]Code 0,0 = original equation

Code (a,b) b =

a	1 D	2 H	3 SG	4 (D)(H)	5 (D)(SG)	6 (H)(SG)	7 (D)(H)(SG)
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem
3 = stem to a 3 inch top diameter outside bark
4 = stem to a 4 inch top diameter outside bark

[b]Equation = $\log_{10} Y = b_0 + b_1(1/A) + b_2(H/A) + b_3(N/100) + b_4(A)(\log_{10} N)$ where Y is dry wt. (1000 pounds per acre), A is total stand age in years, H is average height of the dominants and codominants in feet, and N is the number of stems per acre (one-inch dbh class and above)

[c]R^2 = coefficient of determination
$S_{y \cdot x}$ = standard error of estimate

Appendix Table 2. Yield equations for original data and combinations of growth increases using modified combined-variable cubic volume equations[a]

Code	Equations:[b]	b_0	b_1	b_2	b_3	b_4	$(R^2)^c$	$(S_{y \cdot x})^c$
0,0	T	.92433	-8.17144	.32440	.00738	.00835	.9494	.0502
	3	1.00543	-11.67562	.42579	-.01447	.00724	.9330	.0754
	4	.96920	-12.95453	.45554	-.01748	.00736	.9383	.0786
1,1	T	.95161	-8.52554	.33554	.00480	.00850	.9473	.0533
	3	1.02778	-11.72275	.42936	-.01529	.00748	.9332	.0764
	4	.98653	-13.05525	.46056	-.01853	.00761	.9382	.0802
1,2	T	.96327	-8.16801	.29537	.00739	.00836	.9496	.0501
	3	1.04535	-11.49845	.38457	-.01438	.00729	.9321	.0753
	4	1.00303	-12.60258	.40921	-.01724	.00749	.9376	.0780
1,3	T	.92870	-8.17159	.32438	.00738	.00835	.9494	.0502
	3	1.00659	-11.65730	.42606	-.01449	.00727	.9328	.0756
	4	.97042	-12.92902	.45568	-.01755	.00739	.9382	.0788
1,4	T	.99137	-8.52579	.30542	.00480	.00851	.9475	.0532
	3	1.06972	-11.57146	.38767	-.01511	.00750	.9327	.0761
	4	1.02303	-12.74201	.41396	-.01828	.00771	.9375	.0795
1,5	T	.95640	-8.52917	.33553	.00480	.00850	.9474	.0533
	3	1.03164	-11.71397	.42903	-.01522	.00748	.9335	.0762
	4	.99042	-13.04385	.46044	-.01858	.00762	.9381	.0802
1,6	T	.96727	-8.16124	.29530	.00738	.00837	.9495	.0501
	3	1.05118	-11.51033	.38437	-.01432	.00728	.9324	.0751
	4	1.01034	-12.63464	.40938	-.01726	.00746	.9375	.0781

Appendix Table 2. (continued)

Equation:[b]		b_0	b_1	b_2	b_3	b_4	$(R^2)^c$	$(S_{y \cdot x})^c$
Code								
1,7	T	.99433	-8.51511	.30551	.00479	.00852	.9475	.0533
	3	1.07412	-11.56687	.38752	-.01509	.00750	.9328	.0760
	4	1.02734	-12.73409	.41362	-.01822	.00772	.9376	.0794
2,1	T	.99259	-8.53555	.33483	.00529	.00846	.9485	.0526
	3	1.04250	-11.05207	.41254	-.01112	.00773	.9371	.0706
	4	1.00223	-12.34403	.44359	-.01474	.00788	.9414	.0746
2,2	T	.98203	-8.16130	.28244	.00742	.00837	.9494	.0502
	3	1.06422	-11.42744	.36669	-.01424	.00730	.9320	.0751
	4	1.02372	-12.49386	.38921	-.01703	.00750	.9375	.0775
2,3	T	.93322	-8.17217	.32439	.00736	.00834	.9493	.0503
	3	1.01134	-11.65864	.42614	-.01456	.00727	.9327	.0756
	4	.97502	-12.93283	.45551	-.01743	.00739	.9385	.0785
2,4	T	1.05083	-8.51992	.29133	.00530	.00848	.9486	.0525
	3	1.10013	-10.82174	.35562	-.01093	.00780	.9362	.0704
	4	1.05771	-11.94608	.37952	-.01420	.00799	.9410	.0734
2,5	T	1.00070	-8.52885	.33481	.00527	.00847	.9484	.0526
	3	1.04923	-11.04223	.41281	-.01115	.00775	.9371	.0707
	4	1.01081	-12.34858	.44365	-.01471	.00788	.9416	.0745
2,6	T	.99069	-8.15491	.28232	.00739	.00837	.9495	.0502
	3	1.07436	-11.43628	.36658	-.01425	.00729	.9320	.0751
	4	1.03241	-12.49155	.38936	-.01712	.00750	.9373	.0777
2,7	T	1.05913	-8.51497	.29129	.00529	.00848	.9486	.0525
	3	1.10814	-10.81801	.35558	-.01089	.00780	.9363	.0703
	4	1.06830	-11.95832	.37939	-.01420	.00797	.9409	.0735

Appendix Table 2. (continued)

Equation:[b]		b_0	b_1	b_2	b_3	b_4	$(R^2)^c$	$(S_{y \cdot x})^c$
Code								
3,1	T	1.08187	-8.16968	.32452	.00738	.00835	.9493	.0503
	3	1.09734	-9.71706	.37914	-.00415	.00804	.9352	.0652
	4	1.05874	-10.76733	.40633	-.00772	.00824	.9398	.0683
3,2	T	1.00220	-8.17316	.27065	.00738	.00835	.9495	.0502
	3	1.08504	-11.37562	.35028	-.01422	.00730	.9317	.0750
	4	1.04275	-12.38982	.37141	-.01700	.00751	.9370	.0775
3,3	T	.93966	-8.16396	.32458	.00738	.00836	.9494	.0502
	3	1.02170	-11.67259	.42594	-.01451	.00725	.9328	.0756
	4	.98170	-12.91467	.45582	-.01760	.00741	.9384	.0786
3,4	T	1.15977	-8.16602	.27063	.00738	.00836	.9495	.0502
	3	1.17741	-9.50624	.31243	-.00383	.00807	.9344	.0647
	4	1.13576	-10.38860	.33244	-.00714	.00832	.9390	.0673
3,5	T	1.09881	-8.17190	.32461	.00738	.00735	.9493	.0503
	3	1.11444	-9.71907	.37921	-.00417	.00804	.9351	.0652
	4	1.07580	-10.76271	.40609	-.00769	.00824	.9399	.0682
3,6	T	1.01891	-8.17029	.27064	.00739	.00835	.9495	.0502
	3	1.10046	-11.36616	.35042	-.01423	.00731	.9316	.0751
	4	1.06071	-12.39382	.37127	-.01698	.00751	.9369	.0775

Appendix Table 2. (continued)

Equation:[b]		b_0	b_1	b_2	b_3	b_4	$(R^2)^c$	$(S_{y \cdot x})^c$
Code								
3,7	T	1.17649	-8.16646	.27070	.00739	.00836	.9495	.0502
	3	1.19420	-9.50032	.31241	-.00386	.00808	.9343	.0647
	4	1.15156	-10.37680	.33246	-.00716	.00833	.9389	.0674

[a]Code 0,0 = original equation

Code (a,b)

a \ b =	1 D	2 H	3 SG	4 (D)(H)	5 (D)(SG)	6 (H)(SG)	7 (D)(H)(SG)
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem
3 = stem to a 3 inch top diameter outside bark
4 = stem to a 4 inch top diameter outside bark

[b]Equation = $\log_{10}Y = b_0 + b_1(1/A) + b_2(H/A) + b_3(N/100) + b_4(A)(\log_{10}N)$ where Y is dry wt. (1000 pound per acre), A is total stand age in years, H is average height of the dominants and codominants in feet, and N is the number of stems per acre (one-inch dbh class and above)

[c]R^2 = coefficient of determination
$S_{y \cdot x}$ = standard error of estimate

APPENDIX TABLE 3. PERCENTAGE INCREASES IN DRY WEIGHT PER ACRE FOR THE CHOSEN GROWTH COMBINATIONS (REGRESSION MODEL AND COMBINED-VARIABLE CUBIC VOLUME EQUATIONS)[a]

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,1)					
10	T	1.52	0.93	0.34	-0.24	-0.83	-1.41
	3	8.41	8.11	7.77	7.40	7.01	6.61
	4	9.05	8.76	8.43	8.08	7.71	7.32
20	T	7.15	6.56	5.97	5.37	4.77	4.17
	3	6.37	6.35	6.24	6.08	5.87	5.62
	4	7.09	7.05	6.94	6.77	6.56	6.31
30	T	8.59	8.03	7.45	6.87	6.28	5.69
	3	11.04	11.29	11.42	11.46	11.42	11.32
	4	11.21	11.42	11.51	11.52	11.47	11.36
		COMBINATION (2,1)					
10	T	10.48	9.91	9.34	8.77	8.20	7.63
	3	24.02	24.90	25.73	26.52	27.28	28.02
	4	27.37	28.22	29.02	29.78	30.51	31.23
20	T	17.09	16.51	15.93	15.34	14.75	14.17
	3	15.77	16.95	18.03	19.04	20.00	20.91
	4	17.52	18.63	19.65	20.61	21.51	22.37
30	T	18.57	18.01	17.44	16.87	16.29	15.71
	3	22.00	23.63	25.10	26.45	27.72	28.92
	4	22.85	24.36	25.73	26.99	28.17	29.29
		COMBINATION (3,1)					
10	T	40.15	39.98	39.81	39.64	39.47	39.30
	3	69.36	73.40	77.45	81.51	85.61	89.76
	4	83.66	88.01	92.36	96.73	101.15	105.61
20	T	42.91	42.73	42.55	42.37	42.19	42.01
	3	41.22	45.10	48.92	52.72	56.53	60.35
	4	45.12	49.06	52.95	56.82	60.69	64.58
30	T	43.04	42.84	42.65	42.46	42.28	42.10
	3	49.04	53.67	58.18	62.64	67.06	71.49
	4	51.42	56.07	60.60	65.08	69.53	73.97

APPENDIX TABLE 3. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,2)					
10	T	9.11	9.09	9.07	9.05	9.03	9.01
	3	15.23	15.16	15.06	14.93	14.77	14.60
	4	18.71	18.71	18.67	18.61	18.52	18.42
20	T	9.70	9.68	9.65	9.63	9.61	9.59
	3	9.06	9.23	9.32	9.36	9.36	9.33
	4	10.03	10.25	10.40	10.50	10.57	10.60
30	T	9.72	9.70	9.67	9.65	9.63	9.61
	3	12.04	12.44	12.73	12.95	13.11	13.21
	4	12.50	12.95	13.30	13.57	13.78	13.95
		COMBINATION (2,2)					
10	T	13.71	13.68	13.64	13.61	13.57	13.54
	3	20.67	20.62	20.54	20.43	20.29	20.14
	4	26.17	26.24	26.27	26.26	26.24	26.20
20	T	14.46	14.43	14.39	14.35	14.31	14.28
	3	13.99	14.19	14.31	14.38	14.41	14.40
	4	15.44	15.75	15.97	16.15	16.28	16.38
30	T	14.49	14.45	14.41	14.37	14.34	14.30
	3	17.10	17.56	17.90	18.15	18.34	18.48
	4	17.99	18.55	18.99	19.35	19.65	19.89
		COMBINATION (3,2)					
10	T	18.23	18.17	18.11	18.05	17.99	17.93
	3	26.07	26.00	25.89	25.75	25.59	25.41
	4	33.50	33.60	33.64	33.66	33.65	33.62
20	T	19.41	19.34	19.28	19.22	19.15	19.09
	3	19.18	19.36	19.47	19.52	19.53	19.50
	4	20.90	21.24	21.50	21.70	21.86	21.98
30	T	19.46	19.39	19.32	19.26	19.19	19.13
	3	22.43	22.88	23.21	23.45	23.62	23.75
	4	23.44	24.05	24.54	24.94	25.28	25.56

APPENDIX TABLE 3. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION(1,3)					
10	T	1.00	1.02	1.04	1.06	1.09	1.11
	3	5.46	5.40	5.30	5.18	5.04	4.89
	4	4.89	4.80	4.68	4.54	4.39	4.22
20	T	0.91	0.92	0.94	0.96	0.98	1.00
	3	0.07	0.22	0.31	0.34	0.34	0.32
	4	0.36	0.46	0.51	0.51	0.48	0.42
30	T	0.85	0.87	0.88	0.90	0.91	0.93
	3	2.86	3.23	3.49	3.69	3.83	3.93
	4	2.82	3.12	3.32	3.47	3.56	3.62
		COMBINATION (2,3)					
10	T	1.94	1.96	1.98	2.01	2.03	2.05
	3	6.42	6.34	6.24	6.11	5.95	5.79
	4	5.76	5.69	5.60	5.48	5.35	5.20
20	T	1.83	1.85	1.86	1.88	1.91	1.93
	3	0.99	1.13	1.20	1.23	1.22	1.19
	4	1.06	1.19	1.25	1.28	1.27	1.24
30	T	1.76	1.77	1.79	1.81	1.82	1.84
	3	3.75	4.12	4.38	4.57	4.70	4.79
	4	3.48	3.80	4.04	4.21	4.33	4.40
		COMBINATION (3,3)					
10	T	4.00	4.02	4.04	4.05	4.07	4.09
	3	8.46	8.39	8.29	8.16	8.01	7.85
	4	8.01	7.92	7.79	7.65	7.48	7.30
20	T	3.90	3.91	3.92	3.94	3.95	3.97
	3	3.05	3.20	3.28	3.31	3.31	3.28
	4	3.03	3.14	3.18	3.18	3.15	3.09
30	T	3.84	3.85	3.86	3.87	3.88	3.89
	3	5.91	6.28	6.55	6.75	6.89	6.99
	4	5.51	5.82	6.04	6.19	6.29	6.34

APPENDIX TABLE 3. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,4)					
10	T	10.81	10.13	9.44	8.76	8.08	7.40
	3	19.65	19.36	19.03	18.67	18.27	17.86
	4	24.72	24.47	24.18	23.85	23.50	23.13
20	T	17.76	17.06	16.37	15.67	14.96	14.26
	3	17.15	17.18	17.11	16.97	16.78	16.55
	4	18.97	19.02	18.99	18.89	18.74	18.55
30	T	19.43	18.76	18.08	17.40	16.71	16.01
	3	22.38	22.72	22.92	23.01	23.01	22.95
	4	23.45	23.82	24.04	24.16	24.20	24.18
		COMBINATION (2,4)					
10	T	25.70	24.99	24.28	23.57	22.86	22.15
	3	43.14	44.19	45.19	46.15	47.07	47.96
	4	53.78	55.01	56.18	57.31	58.41	59.48
20	T	34.27	33.54	32.80	32.07	31.33	30.59
	3	33.22	34.62	35.90	37.10	38.24	39.33
	4	36.58	38.08	39.47	40.79	42.04	43.25
30	T	36.10	35.39	34.67	33.95	33.22	32.49
	3	40.28	42.19	43.91	45.51	47.01	48.43
	4	42.50	44.50	46.32	48.02	49.62	51.15
		COMBINATION (3,4)					
10	T	66.44	66.14	65.85	65.56	65.28	64.99
	3	104.14	109.03	113.92	118.84	123.80	128.82
	4	131.50	137.30	143.11	148.96	154.88	160.87
20	T	70.97	70.66	70.35	70.05	69.75	69.45
	3	69.47	74.14	78.75	83.33	87.91	92.52
	4	76.15	81.20	86.20	91.18	96.17	101.19
30	T	71.26	70.94	70.63	70.32	70.01	69.70
	3	78.73	84.31	89.74	95.11	100.44	105.77
	4	83.42	89.35	95.16	100.90	106.62	112.35

APPENDIX TABLE 3. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,5)					
10	T	2.56	1.97	1.38	0.78	0.19	-0.40
	3	9.51	9.22	8.89	8.54	8.16	7.76
	4	10.23	9.93	9.59	9.23	8.84	8.44
20	T	8.22	7.63	7.03	6.43	5.82	5.22
	3	7.42	7.41	7.32	7.17	6.97	6.74
	4	8.19	8.14	8.02	7.84	7.62	7.37
30	T	9.69	9.12	8.54	7.95	7.36	6.76
	3	12.17	12.45	12.60	12.65	12.63	12.55
	4	12.40	12.61	12.70	12.71	12.65	12.53
		COMBINATION (2,5)					
10	T	12.75	12.17	11.59	11.00	10.42	9.84
	3	26.42	27.33	28.19	29.01	29.80	30.56
	4	29.97	30.83	31.64	32.41	33.15	33.88
20	T	19.46	18.87	18.28	17.68	17.08	16.48
	3	18.08	19.30	20.41	21.45	22.44	23.38
	4	19.85	20.98	22.01	22.97	23.88	24.75
30	T	21.02	20.45	19.87	19.29	18.70	18.11
	3	24.43	26.10	27.61	29.00	30.30	31.54
	4	25.21	26.73	28.10	29.37	30.56	31.69
		COMBINATION (3,5)					
10	T	45.80	45.62	45.45	45.28	45.11	44.93
	3	76.03	80.23	84.42	88.63	92.88	97.19
	4	91.08	95.61	100.14	104.70	109.30	113.95
20	T	48.56	48.37	48.18	48.00	47.82	47.64
	3	46.74	50.77	54.73	58.67	62.62	66.58
	4	50.96	55.07	59.12	63.14	67.18	71.23
30	T	48.71	48.51	48.32	48.13	47.95	47.76
	3	54.83	59.63	64.31	68.93	73.52	78.11
	4	57.54	62.38	67.10	71.76	76.39	81.02

APPENDIX TABLE 3. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,6)					
10	T	10.21	10.19	10.17	10.15	10.13	10.11
	3	16.35	16.30	16.21	16.09	15.96	15.80
	4	20.02	20.00	19.95	19.87	19.77	19.65
20	T	10.76	10.74	10.71	10.69	10.67	10.64
	3	10.18	10.37	10.48	10.54	10.56	10.55
	4	11.19	11.41	11.55	11.64	11.70	11.72
30	T	10.78	10.75	10.72	10.70	10.67	10.65
	3	13.25	13.68	14.00	14.23	14.41	14.54
	4	13.75	14.20	14.55	14.81	15.02	15.18
		COMBINATION (2,6)					
10	T	15.93	15.89	15.86	15.82	15.79	15.75
	3	23.07	23.03	22.94	22.82	22.68	22.53
	4	28.66	28.71	28.71	28.69	28.64	28.58
20	T	16.84	16.80	16.76	16.72	16.69	16.65
	3	16.33	16.53	16.66	16.73	16.76	16.76
	4	17.86	18.15	18.37	18.53	18.64	18.72
30	T	16.88	16.84	16.79	16.75	16.71	16.67
	3	19.56	20.03	20.38	20.64	20.84	20.98
	4	20.48	21.02	21.46	21.80	22.09	22.32
		COMBINATION (3,6)					
10	T	22.94	22.88	22.82	22.76	22.69	22.63
	3	31.16	31.11	31.01	30.88	30.73	30.55
	4	38.83	38.92	38.97	38.99	38.98	38.95
20	T	24.22	24.15	24.08	24.02	23.95	23.89
	3	23.84	24.05	24.18	24.25	24.28	24.27
	4	25.79	26.14	26.41	26.61	26.78	26.90
30	T	24.27	24.20	24.13	24.06	23.99	23.92
	3	27.27	27.76	28.12	28.40	28.60	28.75
	4	28.40	29.02	29.52	29.93	30.27	30.56

APPENDIX TABLE 3. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,7)					
10	T	11.92	11.23	10.54	9.85	9.16	8.47
	3	20.78	20.49	20.15	19.77	19.37	18.95
	4	25.89	25.67	25.40	25.10	24.77	24.42
20	T	18.81	18.12	17.41	16.71	16.00	15.29
	3	18.34	18.36	18.28	18.13	17.93	17.69
	4	20.08	20.17	20.16	20.09	19.97	19.80
30	T	20.51	19.84	19.16	18.47	17.77	17.07
	3	23.57	23.91	24.09	24.17	24.17	24.10
	4	24.64	25.04	25.29	25.44	25.51	25.52
		COMBINATION (2,7)					
10	T	28.24	27.51	26.79	26.06	25.33	24.61
	3	46.04	47.11	48.12	49.08	50.01	50.92
	4	56.85	58.10	59.29	60.43	61.54	62.62
20	T	36.95	36.21	35.46	34.70	33.95	33.20
	3	35.86	37.28	38.58	39.80	40.96	42.06
	4	39.30	40.82	42.23	43.56	44.83	46.05
30	T	38.81	38.09	37.36	36.62	35.88	35.13
	3	43.08	45.02	46.78	48.40	49.92	51.37
	4	45.29	47.31	49.16	50.87	52.50	54.04
		COMBINATION (3,7)					
10	T	73.15	72.85	72.55	72.25	71.95	71.65
	3	112.28	117.38	122.47	127.60	132.77	138.00
	4	140.84	146.89	152.96	159.07	165.25	171.50
20	T	77.86	77.54	77.22	76.91	76.59	76.28
	3	76.26	81.13	85.93	90.70	95.48	100.28
	4	83.34	88.62	93.84	99.04	104.26	109.51
30	T	78.17	77.84	77.51	77.19	76.86	76.55
	3	85.92	91.72	97.39	102.98	108.54	114.09
	4	91.02	97.23	103.30	109.30	115.28	121.27

Appendix Table 3. (continued)

a) Combination (a,b)

	b = 1	2	3	4	5	6	7
a	D	H	SG	DH	DSG	HGS	DHSG
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem

3 = stem to a 3-inch top diameter outside bark

4 = stem to a 4-inch top diameter outside bark

SI = 60 for all combinations

where:

D = diameter at breast height (inches)

H = total tree height (feet)

SG = specific gravity

SI = site index

APPENDIX TABLE 4. PERCENTAGE INCREASES IN DRY WEIGHT PER ACRE FOR THE CHOSEN GROWTH COMBINATIONS(REGRESSION MODEL AND MODIFIED COMBINED-VARIABLE CUBIC VOLUME EQUATIONS)[a]

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,1)					
10	T	2.98	2.40	1.81	1.23	0.65	0.07
	3	7.04	6.88	6.72	6.55	6.38	6.21
	4	5.23	5.03	4.81	4.59	4.37	4.15
20	T	8.14	7.55	6.97	6.38	5.78	5.19
	3	9.20	9.08	8.96	8.82	8.68	8.53
	4	8.07	7.91	7.73	7.54	7.34	7.14
30	T	9.42	8.86	8.29	7.72	7.13	6.55
	3	10.64	10.58	10.49	10.39	10.28	10.15
	4	9.64	9.52	9.38	9.23	9.06	8.88
		COMBINATION (2,1)					
10	T	12.77	12.25	11.73	11.21	10.69	10.17
	3	24.18	25.25	26.32	27.38	28.44	29.50
	4	23.01	23.90	24.79	25.66	26.54	27.41
20	T	18.27	17.75	17.22	16.70	16.17	15.64
	3	19.32	20.46	21.58	22.68	23.77	24.86
	4	18.58	19.55	20.50	21.44	22.35	23.26
30	T	19.51	19.01	18.50	17.98	17.46	16.94
	3	21.70	22.97	24.20	25.41	26.60	27.78
	4	21.07	22.18	23.25	24.29	25.31	26.31
		COMBINATION (3,1)					
10	T	43.89	43.89	43.89	43.89	43.89	43.89
	3	72.38	76.78	81.26	85.81	90.46	95.20
	4	77.63	81.95	86.34	90.80	95.34	99.96
20	T	43.86	43.86	43.86	43.86	43.86	43.86
	3	45.33	49.26	53.22	57.25	61.33	65.49
	4	46.63	50.44	54.28	58.16	62.09	66.08
30	T	43.83	43.83	43.83	43.83	43.83	43.83
	3	48.42	52.65	56.90	61.19	65.53	69.94
	4	49.56	53.69	57.83	61.98	66.18	70.43

APPENDIX TABLE 4. (CONTINUED)

AGE		500	600	700	800	900	1000
		TREES PER ACRE					
		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,2)					
10	T	9.89	9.89	9.90	9.90	9.91	9.91
	3	12.74	12.77	12.80	12.83	12.86	12.89
	4	14.63	14.72	14.81	14.89	14.97	15.05
20	T	9.91	9.92	9.92	9.93	9.93	9.94
	3	10.84	10.88	10.92	10.96	10.99	11.03
	4	11.04	11.15	11.26	11.36	11.45	11.55
30	T	9.91	9.92	9.92	9.93	9.94	9.94
	3	10.73	10.79	10.84	10.88	10.92	10.96
	4	11.03	11.17	11.30	11.42	11.53	11.64
		COMBINATION (2,2)					
10	T	14.96	14.97	14.99	15.00	15.01	15.03
	3	18.97	19.05	19.12	19.20	19.27	19.34
	4	21.73	21.89	22.04	22.19	22.34	22.48
20	T	14.96	14.98	15.00	15.01	15.03	15.05
	3	16.10	16.19	16.27	16.36	16.43	16.51
	4	16.55	16.73	16.91	17.07	17.23	17.39
30	T	15.01	15.04	15.06	15.08	15.10	15.11
	3	15.91	16.01	16.10	16.19	16.27	16.36
	4	16.43	16.64	16.84	17.02	17.20	17.38
		COMBINATION (3,2)					
10	T	19.87	19.87	19.87	19.87	19.87	19.87
	3	25.29	25.38	25.46	25.54	25.63	25.71
	4	28.88	29.06	29.23	29.40	29.57	29.73
20	T	19.89	19.89	19.89	19.89	19.89	19.89
	3	21.56	21.66	21.75	21.84	21.93	22.02
	4	22.03	22.23	22.43	22.61	22.79	22.96
30	T	19.85	19.85	19.85	19.85	19.85	19.85
	3	21.28	21.39	21.49	21.59	21.69	21.78
	4	21.72	21.96	22.18	22.38	22.58	22.78

APPENDIX TABLE 4. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,3)					
10	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.02	1.02	1.02	1.02	1.02	1.02
	4	1.07	1.05	1.04	1.03	1.02	1.01
20	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.01	1.01	1.01	1.01
	4	0.96	0.95	0.94	0.94	0.93	0.92
30	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.09	1.10	1.11	1.11	1.12	1.13
	4	1.03	1.03	1.03	1.03	1.02	1.01
		COMBINATION (2,3)					
10	T	1.96	1.95	1.95	1.94	1.93	1.93
	3	2.07	2.05	2.04	2.02	2.00	1.99
	4	2.09	2.10	2.12	2.14	2.15	2.17
20	T	1.90	1.90	1.89	1.88	1.87	1.87
	3	2.06	2.05	2.04	2.02	2.01	1.99
	4	2.02	2.05	2.07	2.09	2.11	2.12
30	T	1.84	1.83	1.82	1.82	1.81	1.80
	3	2.15	2.14	2.13	2.13	2.12	2.10
	4	2.13	2.16	2.19	2.21	2.23	2.25
		COMBINATION (3,3)					
10	T	3.95	3.95	3.95	3.96	3.96	3.96
	3	4.00	3.99	3.99	3.98	3.97	3.96
	4	4.23	4.21	4.19	4.17	4.14	4.12
20	T	3.92	3.93	3.93	3.93	3.94	3.94
	3	4.03	4.02	4.02	4.01	4.00	4.00
	4	4.07	4.06	4.05	4.03	4.02	4.00
30	T	3.94	3.95	3.95	3.95	3.96	3.96
	3	4.07	4.06	4.06	4.05	4.05	4.04
	4	4.21	4.21	4.20	4.19	4.18	4.17

APPENDIX TABLE 4. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,4)					
10	T	13.21	12.57	11.93	11.29	10.65	10.02
	3	20.30	20.18	20.05	19.91	19.77	19.63
	4	20.24	20.09	19.94	19.77	19.60	19.42
20	T	18.95	18.31	17.67	17.02	16.38	15.73
	3	20.79	20.73	20.65	20.55	20.45	20.34
	4	19.91	19.85	19.75	19.65	19.52	19.39
30	T	20.39	19.78	19.16	18.53	17.89	17.26
	3	22.19	22.18	22.15	22.10	22.03	21.95
	4	21.58	21.59	21.56	21.51	21.43	21.34
		COMBINATION (2,4)					
10	T	29.75	29.16	28.57	27.98	27.39	26.80
	3	47.23	48.59	49.93	51.27	52.61	53.95
	4	48.53	49.83	51.11	52.38	53.65	54.92
20	T	36.00	35.42	34.83	34.23	33.63	33.03
	3	38.43	39.84	41.23	42.60	43.96	45.31
	4	37.82	39.18	40.51	41.81	43.10	44.37
30	T	37.49	36.93	36.36	35.78	35.19	34.60
	3	41.05	42.64	44.18	45.69	47.17	48.64
	4	40.52	42.08	43.57	45.03	46.45	47.86
		COMBINATION (3,4)					
10	T	72.66	72.67	72.67	72.67	72.67	72.68
	3	113.19	118.81	124.53	130.35	136.29	142.37
	4	123.72	129.51	135.39	141.37	147.47	153.69
20	T	72.66	72.66	72.67	72.67	72.68	72.68
	3	75.84	80.74	85.70	90.73	95.84	101.05
	4	77.83	82.75	87.71	92.72	97.81	102.99
30	T	72.67	72.68	72.68	72.69	72.70	72.70
	3	79.21	84.49	89.79	95.15	100.58	106.09
	4	80.98	86.32	91.66	97.03	102.46	107.97

APPENDIX TABLE 4. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,5)					
10	T	4.03	3.44	2.85	2.26	1.67	1.09
	3	8.08	7.94	7.79	7.64	7.49	7.33
	4	6.38	6.17	5.94	5.71	5.47	5.24
20	T	9.28	8.70	8.10	7.50	6.91	6.31
	3	10.15	10.06	9.95	9.83	9.70	9.57
	4	9.18	9.00	8.82	8.62	8.41	8.19
30	T	10.60	10.03	9.46	8.87	8.29	7.70
	3	11.61	11.56	11.50	11.41	11.31	11.20
	4	10.79	10.67	10.52	10.36	10.18	9.99
		COMBINATION (2,5)					
10	T	15.10	14.57	14.04	13.50	12.97	12.44
	3	26.73	27.82	28.90	29.98	31.05	32.13
	4	25.42	26.34	27.25	28.15	29.05	29.95
20	T	20.70	20.17	19.63	19.09	18.55	18.00
	3	21.78	22.94	24.08	25.20	26.32	27.42
	4	20.97	21.97	22.95	23.91	24.85	25.79
30	T	22.01	21.50	20.98	20.45	19.92	19.38
	3	24.28	25.58	26.85	28.08	29.30	30.50
	4	23.52	24.67	25.77	26.83	27.88	28.91
		COMBINATION (3,5)					
10	T	49.62	49.62	49.62	49.62	49.62	49.62
	3	79.25	83.82	88.47	93.20	98.02	102.94
	4	84.73	89.24	93.82	98.47	103.21	108.03
20	T	49.63	49.63	49.63	49.63	49.63	49.63
	3	51.16	55.24	59.36	63.53	67.77	72.09
	4	52.42	56.39	60.39	64.44	68.53	72.70
30	T	49.60	49.60	49.60	49.60	49.60	49.60
	3	54.37	58.77	63.18	67.64	72.14	76.72
	4	55.47	59.78	64.09	68.42	72.80	77.23

APPENDIX TABLE 4. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,6)					
10	T	11.08	11.09	11.09	11.09	11.10	11.10
	3	13.80	13.85	13.90	13.94	13.99	14.03
	4	15.61	15.69	15.77	15.84	15.91	15.98
20	T	11.09	11.09	11.10	11.11	11.11	11.12
	3	11.97	12.03	12.08	12.13	12.18	12.23
	4	12.19	12.29	12.38	12.46	12.55	12.63
30	T	11.13	11.14	11.15	11.16	11.17	11.18
	3	11.87	11.94	11.99	12.05	12.11	12.16
	4	12.09	12.21	12.32	12.42	12.52	12.61
		COMBINATION (2,6)					
10	T	17.31	17.31	17.32	17.32	17.33	17.33
	3	21.35	21.42	21.49	21.56	21.63	21.70
	4	24.26	24.40	24.53	24.65	24.78	24.90
20	T	17.22	17.24	17.25	17.25	17.26	17.27
	3	18.47	18.56	18.63	18.71	18.78	18.86
	4	18.94	19.10	19.25	19.40	19.53	19.67
30	T	17.26	17.28	17.29	17.31	17.32	17.33
	3	18.25	18.35	18.43	18.52	18.60	18.68
	4	18.78	18.97	19.15	19.32	19.47	19.63
		COMBINATION (3,6)					
10	T	24.66	24.66	24.67	24.67	24.67	24.67
	3	30.30	30.39	30.48	30.56	30.65	30.73
	4	34.09	34.28	34.47	34.65	34.83	35.01
20	T	24.64	24.64	24.64	24.65	24.65	24.65
	3	26.36	26.47	26.56	26.66	26.75	26.84
	4	27.03	27.24	27.45	27.64	27.84	28.02
30	T	24.59	24.59	24.59	24.60	24.60	24.60
	3	26.08	26.20	26.31	26.41	26.51	26.61
	4	26.74	26.99	27.23	27.45	27.67	27.87

APPENDIX TABLE 4. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,7)					
10	T	14.39	13.74	13.10	12.45	11.80	11.16
	3	21.55	21.44	21.31	21.18	21.05	20.91
	4	21.54	21.41	21.27	21.12	20.97	20.81
20	T	20.12	19.48	18.83	18.18	17.52	16.86
	3	21.99	21.93	21.86	21.77	21.67	21.56
	4	21.18	21.13	21.06	20.97	20.87	20.75
30	T	21.58	20.97	20.35	19.72	19.08	18.43
	3	23.40	23.40	23.37	23.33	23.26	23.19
	4	22.95	22.98	22.97	22.94	22.89	22.82
		COMBINATION (2,7)					
10	T	32.36	31.75	31.15	30.54	29.93	29.33
	3	50.13	51.53	52.91	54.29	55.67	57.05
	4	51.44	52.76	54.06	55.36	56.65	57.93
20	T	38.65	38.05	37.44	36.83	36.22	35.60
	3	41.09	42.55	43.98	45.38	46.78	48.17
	4	40.54	41.92	43.27	44.59	45.89	47.19
30	T	40.15	39.57	38.99	38.39	37.79	37.19
	3	43.75	45.39	46.97	48.52	50.05	51.56
	4	43.22	44.78	46.29	47.76	49.20	50.63
		COMBINATION (3,7)					
10	T	79.54	79.54	79.55	79.56	79.56	79.57
	3	121.93	127.76	133.70	139.75	145.92	152.23
	4	132.77	138.79	144.89	151.11	157.44	163.90
20	T	79.54	79.55	79.56	79.57	79.57	79.58
	3	83.03	88.13	93.29	98.51	103.82	109.23
	4	84.88	90.00	95.15	100.36	105.65	111.02
30	T	79.53	79.55	79.56	79.57	79.58	79.59
	3	86.62	92.12	97.63	103.20	108.85	114.58
	4	88.19	93.74	99.29	104.87	110.52	116.25

Appendix Table 4. (continued)

a) Combination (a,b)

b =	1	2	3	4	5	6	7
a	D	H	SG	DH	DSG	HGS	DHSG
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem

3 = stem to a 3-inch top diameter outside bark

4 = stem to a 4-inch top diameter outside bark

SI = 60 for all combinations

where:

D = diameter at breast height (inches)

H = total tree height (feet)

SG = specific gravity

SI = site index

APPENDIX TABLE 5. PERCENTAGE INCREASES IN DRY WEIGHT PER ACRE FOR THE CHOSEN GROWTH COMBINATIONS (DIAMETER DISTRIBUTION AND COMBINED-VARIABLE CUBIC VOLUME EQUATIONS)[a]

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,1)					
10	T	25.03	25.11	25.02	24.92	24.87	24.88
	3	25.22	25.28	25.18	25.06	25.01	25.00
	4	25.67	25.69	25.55	25.40	25.32	25.30
20	T	24.33	24.44	24.48	24.49	24.53	24.58
	3	24.37	24.47	24.51	24.52	24.56	24.61
	4	24.45	24.55	24.59	24.59	24.63	24.67
30	T	24.06	24.15	24.22	24.27	24.33	24.39
	3	24.08	24.17	24.24	24.29	24.35	24.41
	4	24.13	24.21	24.28	24.33	24.39	24.44
		COMBINATION (2,1)					
10	T	38.59	38.61	38.60	38.56	38.53	38.50
	3	38.88	38.88	38.84	38.78	38.74	38.70
	4	39.57	39.51	39.41	39.31	39.23	39.16
20	T	37.49	37.69	37.74	37.76	37.86	37.93
	3	37.55	37.74	37.78	37.81	37.90	37.97
	4	37.67	37.86	37.90	37.91	38.00	38.07
30	T	37.07	37.22	37.34	37.43	37.49	37.60
	3	37.10	37.24	37.36	37.46	37.51	37.62
	4	37.17	37.31	37.43	37.52	37.57	37.68
		COMBINATION (3,1)					
10	T	52.95	52.94	52.84	52.77	52.78	52.82
	3	53.35	53.30	53.17	53.08	53.07	53.08
	4	54.30	54.16	53.96	53.80	53.74	53.71
20	T	51.38	51.58	51.70	51.75	51.83	51.92
	3	51.45	51.65	51.76	51.81	51.89	51.98
	4	51.62	51.81	51.92	51.96	52.02	52.11
30	T	50.76	50.94	51.13	51.24	51.35	51.48
	3	50.80	50.98	51.16	51.27	51.38	51.51
	4	50.90	51.07	51.25	51.35	51.46	51.59

APPENDIX TABLE 5. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,2)					
10	T	9.95	9.95	9.96	9.96	9.96	9.97
	3	10.02	10.02	10.02	10.02	10.02	10.02
	4	10.20	10.18	10.17	10.16	10.14	10.14
20	T	9.99	9.99	9.99	9.99	9.99	9.99
	3	10.00	10.00	10.00	10.00	10.00	10.00
	4	10.04	10.04	10.03	10.03	10.03	10.03
30	T	9.99	9.99	10.00	10.00	10.00	10.00
	3	10.00	10.00	10.00	10.00	10.00	10.00
	4	10.02	10.02	10.02	10.02	10.02	10.02
		COMBINATION (2,2)					
10	T	14.92	14.93	14.94	14.94	14.95	14.95
	3	15.04	15.03	15.03	15.03	15.03	15.03
	4	15.31	15.28	15.25	15.23	15.22	15.20
20	T	14.99	14.99	14.99	14.99	14.99	14.99
	3	15.01	15.01	15.01	15.01	15.01	15.01
	4	15.06	15.05	15.05	15.05	15.05	15.04
30	T	14.99	14.99	14.99	14.99	14.99	14.99
	3	15.00	15.00	15.00	15.00	15.00	15.00
	4	15.03	15.03	15.03	15.03	15.03	15.03
		COMBINATION (3,2)					
10	T	19.90	19.91	19.92	19.92	19.93	19.93
	3	20.05	20.05	20.04	20.04	20.04	20.03
	4	20.41	20.37	20.34	20.31	20.29	20.27
20	T	19.98	19.98	19.98	19.98	19.98	19.99
	3	20.01	20.01	20.01	20.01	20.01	20.01
	4	20.08	20.07	20.07	20.06	20.06	20.06
30	T	19.99	19.99	19.99	19.99	19.99	19.99
	3	20.01	20.01	20.00	20.00	20.00	20.00
	4	20.04	20.04	20.04	20.04	20.04	20.03

APPENDIX TABLE 5. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,3)					
10	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
20	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
30	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
		COMBINATION (2,3)					
10	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
20	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
30	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
		COMBINATION (3,3)					
10	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00
20	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00
30	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00

APPENDIX TABLE 5. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,4)					
10	T	37.49	37.57	37.48	37.37	37.32	37.33
	3	37.77	37.83	37.72	37.59	37.53	37.52
	4	38.44	38.44	38.27	38.10	38.00	37.96
20	T	36.75	36.87	36.92	36.94	36.98	37.03
	3	36.81	36.92	36.97	36.98	37.02	37.07
	4	36.93	37.04	37.08	37.08	37.12	37.17
30	T	36.46	36.56	36.64	36.70	36.76	36.82
	3	36.49	36.59	36.67	36.72	36.79	36.85
	4	36.56	36.65	36.73	36.78	36.84	36.90
		COMBINATION (2,4)					
10	T	59.30	59.33	59.32	59.29	59.25	59.23
	3	59.75	59.74	59.69	59.63	59.57	59.53
	4	60.81	60.71	60.58	60.44	60.33	60.23
20	T	58.10	58.33	58.38	58.41	58.53	58.61
	3	58.18	58.41	58.46	58.48	58.59	58.67
	4	58.38	58.60	58.63	58.65	58.75	58.82
30	T	57.62	57.79	57.93	58.04	58.10	58.23
	3	57.67	57.83	57.97	58.08	58.14	58.27
	4	57.78	57.94	58.07	58.17	58.23	58.36
		COMBINATION (3,4)					
10	T	83.44	83.43	83.32	83.25	83.27	83.31
	3	84.07	84.01	83.84	83.73	83.72	83.73
	4	85.57	85.37	85.08	84.87	84.78	84.73
20	T	81.63	81.87	82.02	82.08	82.18	82.29
	3	81.75	81.99	82.12	82.18	82.27	82.38
	4	82.03	82.24	82.37	82.41	82.49	82.58
30	T	80.90	81.11	81.34	81.47	81.61	81.77
	3	80.97	81.18	81.40	81.53	81.66	81.82
	4	81.12	81.32	81.54	81.66	81.79	81.94

APPENDIX TABLE 5. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,5)					
10	T	26.28	26.36	26.27	26.17	26.12	26.12
	3	26.47	26.53	26.43	26.31	26.26	26.25
	4	26.93	26.95	26.81	26.66	26.58	26.55
20	T	25.57	25.68	25.73	25.74	25.78	25.83
	3	25.61	25.72	25.76	25.77	25.81	25.86
	4	25.69	25.79	25.83	25.84	25.87	25.92
30	T	25.30	25.39	25.47	25.52	25.58	25.63
	3	25.32	25.41	25.48	25.53	25.59	25.65
	4	25.37	25.45	25.52	25.57	25.63	25.69
		COMBINATION (2,5)					
10	T	41.36	41.38	41.37	41.33	41.30	41.27
	3	41.66	41.65	41.61	41.56	41.51	41.47
	4	42.36	42.30	42.20	42.10	42.01	41.94
20	T	40.24	40.45	40.49	40.52	40.62	40.69
	3	40.30	40.50	40.54	40.56	40.66	40.73
	4	40.43	40.62	40.65	40.67	40.76	40.83
30	T	39.81	39.96	40.08	40.18	40.24	40.35
	3	39.84	39.99	40.11	40.20	40.26	40.37
	4	39.91	40.06	40.18	40.27	40.32	40.43
		COMBINATION (3,5)					
10	T	59.07	59.05	58.95	58.88	58.89	58.93
	3	59.48	59.43	59.30	59.20	59.19	59.21
	4	60.48	60.33	60.11	59.95	59.89	59.86
20	T	57.43	57.64	57.77	57.82	57.90	58.00
	3	57.51	57.71	57.83	57.88	57.96	58.05
	4	57.69	57.88	57.99	58.03	58.10	58.19
30	T	56.79	56.97	57.17	57.28	57.40	57.54
	3	56.83	57.01	57.21	57.32	57.44	57.57
	4	56.93	57.11	57.30	57.41	57.52	57.65

APPENDIX TABLE 5. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,6)					
10	T	11.05	11.05	11.06	11.06	11.06	11.07
	3	11.13	11.12	11.12	11.12	11.12	11.12
	4	11.31	11.29	11.27	11.26	11.25	11.24
20	T	11.09	11.09	11.09	11.09	11.09	11.09
	3	11.11	11.10	11.10	11.10	11.10	11.10
	4	11.14	11.14	11.13	11.13	11.13	11.13
30	T	11.09	11.09	11.09	11.10	11.10	11.10
	3	11.10	11.10	11.10	11.10	11.10	11.10
	4	11.12	11.12	11.12	11.12	11.12	11.12
		COMBINATION (2,6)					
10	T	17.22	17.23	17.24	17.24	17.24	17.25
	3	17.34	17.33	17.33	17.33	17.33	17.33
	4	17.61	17.58	17.56	17.54	17.52	17.51
20	T	17.29	17.29	17.29	17.29	17.29	17.29
	3	17.31	17.31	17.31	17.31	17.31	17.31
	4	17.36	17.36	17.35	17.35	17.35	17.34
30	T	17.29	17.29	17.29	17.29	17.29	17.29
	3	17.30	17.30	17.30	17.30	17.30	17.30
	4	17.33	17.33	17.33	17.33	17.33	17.33
		COMBINATION (3,6)					
10	T	24.70	24.71	24.71	24.72	24.73	24.73
	3	24.85	24.85	24.84	24.84	24.84	24.84
	4	25.22	25.18	25.15	25.12	25.10	25.08
20	T	24.78	24.78	24.78	24.78	24.78	24.78
	3	24.81	24.81	24.81	24.81	24.81	24.81
	4	24.88	24.87	24.87	24.87	24.86	24.86
30	T	24.79	24.79	24.79	24.79	24.79	24.79
	3	24.81	24.81	24.81	24.80	24.80	24.80
	4	24.84	24.84	24.84	24.84	24.84	24.84

APPENDIX TABLE 5. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,7)					
10	T	38.86	38.95	38.86	38.74	38.70	38.70
	3	39.15	39.21	39.09	38.96	38.90	38.89
	4	39.83	39.83	39.66	39.48	39.38	39.34
20	T	38.12	38.24	38.29	38.31	38.35	38.40
	3	38.18	38.29	38.34	38.35	38.39	38.44
	4	38.30	38.41	38.45	38.45	38.49	38.54
30	T	37.83	37.92	38.01	38.06	38.13	38.19
	3	37.86	37.95	38.03	38.09	38.16	38.22
	4	37.93	38.02	38.10	38.15	38.21	38.27
		COMBINATION (2,7)					
10	T	62.48	62.52	62.51	62.47	62.44	62.41
	3	62.94	62.94	62.89	62.82	62.76	62.72
	4	64.03	63.92	63.79	63.65	63.54	63.44
20	T	61.26	61.50	61.55	61.58	61.70	61.78
	3	61.35	61.58	61.63	61.65	61.76	61.84
	4	61.55	61.77	61.80	61.82	61.92	61.99
30	T	60.77	60.95	61.09	61.20	61.26	61.39
	3	60.82	60.99	61.13	61.24	61.30	61.43
	4	60.93	61.10	61.23	61.33	61.40	61.52
		COMBINATION (3,7)					
10	T	90.78	90.77	90.65	90.58	90.60	90.64
	3	91.43	91.37	91.20	91.08	91.06	91.08
	4	93.00	92.78	92.49	92.27	92.17	92.12
20	T	88.90	89.15	89.30	89.37	89.46	89.58
	3	89.02	89.26	89.41	89.47	89.56	89.67
	4	89.31	89.53	89.66	89.71	89.79	89.89
30	T	88.14	88.36	88.60	88.73	88.87	89.04
	3	88.21	88.42	88.66	88.79	88.93	89.09
	4	88.36	88.57	88.80	88.93	89.06	89.22

Appendix Table 5. (continued)

a) Combination (a,b)

b =	1	2	3	4	5	6	7
a	D	H	SG	DH	DSG	HGS	DHSG
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem

3 = stem to a 3-inch top diameter outside bark

4 = stem to a 4-inch top diameter outside bark

SI = 60 for all combinations

where:

D = diameter at breast height (inches)

H = total tree height (feet)

SG = specific gravity

SI = site index

APPENDIX TABLE 6. PERCENTAGE INCREASES IN DRY WEIGHT PER ACRE FOR THE CHOSEN GROWTH COMBINATIONS(DIAMETER DISTRIBUTION AND MODIFIED COMBINED-VARIABLE CUBIC VOLUME EQUATIONS)[a]

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,1)					
10	T	23.31	23.31	23.17	23.02	22.94	22.90
	3	22.54	22.47	22.28	22.10	21.98	21.90
	4	25.68	25.69	25.55	25.41	25.33	25.30
20	T	23.14	23.18	23.18	23.14	23.14	23.16
	3	22.45	22.46	22.42	22.36	22.34	22.33
	4	24.45	24.55	24.59	24.59	24.63	24.67
30	T	23.03	23.06	23.08	23.09	23.11	23.13
	3	22.42	22.41	22.40	22.39	22.38	22.38
	4	24.13	24.21	24.28	24.33	24.39	24.44
		COMBINATION (2,1)					
10	T	35.85	35.76	35.65	35.54	35.43	35.34
	3	34.61	34.42	34.23	34.05	33.89	33.74
	4	39.58	39.51	39.42	39.32	39.23	39.16
20	T	35.60	35.70	35.66	35.62	35.65	35.66
	3	34.51	34.55	34.47	34.38	34.37	34.35
	4	37.67	37.86	37.90	37.91	38.00	38.07
30	T	35.43	35.49	35.53	35.55	35.55	35.60
	3	34.46	34.46	34.46	34.44	34.40	34.41
	4	37.17	37.31	37.43	37.52	37.57	37.68
		COMBINATION (3,1)					
10	T	49.08	48.91	48.69	48.51	48.42	48.35
	3	47.31	47.00	46.68	46.41	46.24	46.10
	4	54.31	54.17	53.96	53.81	53.75	53.72
20	T	48.71	48.77	48.78	48.73	48.72	48.73
	3	47.19	47.16	47.10	47.00	46.93	46.89
	4	51.63	51.81	51.92	51.96	52.02	52.11
30	T	48.46	48.51	48.58	48.60	48.62	48.67
	3	47.10	47.07	47.08	47.03	47.01	47.00
	4	50.90	51.07	51.25	51.35	51.46	51.59

APPENDIX TABLE 6. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,2)					
10	T	10.00	10.00	10.00	10.00	10.00	10.00
	3	10.13	10.12	10.11	10.10	10.09	10.09
	4	10.21	10.19	10.17	10.16	10.15	10.14
20	T	10.00	10.00	10.00	10.00	10.00	10.00
	3	10.03	10.03	10.02	10.02	10.02	10.02
	4	10.04	10.04	10.03	10.03	10.03	10.03
30	T	10.00	10.00	10.00	10.00	10.00	10.00
	3	10.02	10.02	10.01	10.01	10.01	10.01
	4	10.02	10.02	10.02	10.02	10.02	10.02
		COMBINATION (2,2)					
10	T	15.00	15.00	15.00	15.00	15.00	15.00
	3	15.20	15.18	15.16	15.15	15.14	15.13
	4	15.31	15.28	15.26	15.24	15.22	15.21
20	T	15.00	15.00	15.00	15.00	15.00	15.00
	3	15.04	15.04	15.04	15.03	15.03	15.03
	4	15.06	15.05	15.05	15.05	15.05	15.04
30	T	15.00	15.00	15.00	15.00	15.00	15.00
	3	15.02	15.02	15.02	15.02	15.02	15.02
	4	15.03	15.03	15.03	15.03	15.03	15.03
		COMBINATION (3,2)					
10	T	20.00	20.00	20.00	20.00	20.00	20.00
	3	20.27	20.24	20.22	20.20	20.19	20.17
	4	20.41	20.37	20.34	20.31	20.29	20.27
20	T	20.00	20.00	20.00	20.00	20.00	20.00
	3	20.06	20.05	20.05	20.05	20.04	20.04
	4	20.08	20.07	20.07	20.06	20.06	20.06
30	T	20.00	20.00	20.00	20.00	20.00	20.00
	3	20.03	20.03	20.03	20.03	20.03	20.02
	4	20.04	20.04	20.04	20.04	20.04	20.03

APPENDIX TABLE 6. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,3)					
10	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
20	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
30	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
		COMBINATION (2,3)					
10	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
20	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
30	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
		COMBINATION (3,3)					
10	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00
20	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00
30	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00

APPENDIX TABLE 6. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,4)					
10	T	35.65	35.64	35.49	35.33	35.23	35.19
	3	34.93	34.83	34.62	34.41	34.27	34.18
	4	38.45	38.45	38.28	38.10	38.01	37.97
20	T	35.45	35.50	35.49	35.46	35.46	35.47
	3	34.73	34.73	34.69	34.62	34.60	34.59
	4	36.93	37.04	37.08	37.08	37.12	37.17
30	T	35.33	35.36	35.39	35.40	35.42	35.44
	3	34.67	34.67	34.66	34.64	34.64	34.63
	4	36.56	36.65	36.73	36.78	36.85	36.90
		COMBINATION (2,4)					
10	T	56.23	56.12	56.00	55.87	55.75	55.64
	3	55.00	54.76	54.53	54.31	54.11	53.94
	4	60.83	60.72	60.59	60.45	60.34	60.24
20	T	55.94	56.05	56.01	55.96	56.00	56.01
	3	54.73	54.77	54.67	54.57	54.56	54.54
	4	58.38	58.60	58.63	58.65	58.75	58.82
30	T	55.75	55.81	55.86	55.88	55.88	55.94
	3	54.66	54.65	54.65	54.62	54.58	54.59
	4	57.78	57.94	58.07	58.17	58.23	58.36
		COMBINATION (3,4)					
10	T	78.90	78.69	78.42	78.22	78.10	78.02
	3	77.04	76.65	76.23	75.90	75.67	75.49
	4	85.59	85.38	85.10	84.89	84.79	84.74
20	T	78.45	78.52	78.53	78.48	78.47	78.48
	3	76.68	76.65	76.57	76.44	76.36	76.31
	4	82.03	82.25	82.37	82.41	82.49	82.59
30	T	78.15	78.21	78.30	78.31	78.35	78.40
	3	76.55	76.51	76.52	76.46	76.43	76.43
	4	81.12	81.32	81.54	81.66	81.79	81.94

APPENDIX TABLE 6. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,5)					
10	T	24.55	24.54	24.40	24.26	24.17	24.13
	3	23.76	23.69	23.50	23.32	23.20	23.12
	4	26.93	26.95	26.81	26.66	26.58	26.55
20	T	24.37	24.41	24.41	24.38	24.37	24.39
	3	23.68	23.68	23.65	23.59	23.56	23.56
	4	25.69	25.79	25.83	25.84	25.87	25.92
30	T	24.26	24.29	24.31	24.32	24.34	24.36
	3	23.64	23.64	23.63	23.61	23.61	23.60
	4	25.37	25.45	25.53	25.57	25.63	25.69
		COMBINATION (2,5)					
10	T	38.57	38.48	38.36	38.25	38.14	38.05
	3	37.30	37.10	36.91	36.73	36.57	36.42
	4	42.37	42.30	42.21	42.11	42.02	41.95
20	T	38.31	38.41	38.38	38.33	38.36	38.37
	3	37.20	37.24	37.16	37.07	37.06	37.04
	4	40.43	40.62	40.65	40.67	40.76	40.83
30	T	38.14	38.20	38.24	38.26	38.26	38.31
	3	37.15	37.15	37.14	37.13	37.09	37.10
	4	39.91	40.06	40.18	40.27	40.32	40.43
		COMBINATION (3,5)					
10	T	55.05	54.87	54.63	54.45	54.35	54.28
	3	53.21	52.88	52.54	52.27	52.09	51.94
	4	60.49	60.34	60.12	59.96	59.90	59.87
20	T	54.66	54.72	54.73	54.68	54.67	54.68
	3	53.07	53.05	52.98	52.87	52.81	52.77
	4	57.69	57.88	57.99	58.03	58.10	58.19
30	T	54.40	54.45	54.53	54.54	54.57	54.61
	3	52.98	52.95	52.96	52.91	52.89	52.88
	4	56.93	57.11	57.30	57.41	57.52	57.65

APPENDIX TABLE 6. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,6)					
10	T	11.10	11.10	11.10	11.10	11.10	11.10
	3	11.24	11.22	11.21	11.20	11.19	11.19
	4	11.31	11.29	11.27	11.26	11.25	11.24
20	T	11.10	11.10	11.10	11.10	11.10	11.10
	3	11.13	11.13	11.12	11.12	11.12	11.12
	4	11.14	11.14	11.13	11.13	11.13	11.13
30	T	11.10	11.10	11.10	11.10	11.10	11.10
	3	11.12	11.12	11.11	11.11	11.11	11.11
	4	11.12	11.12	11.12	11.12	11.12	11.12
		COMBINATION (2,6)					
10	T	17.30	17.30	17.30	17.30	17.30	17.30
	3	17.51	17.48	17.47	17.45	17.44	17.43
	4	17.62	17.59	17.56	17.54	17.52	17.51
20	T	17.30	17.30	17.30	17.30	17.30	17.30
	3	17.34	17.34	17.34	17.33	17.33	17.33
	4	17.36	17.35	17.35	17.35	17.35	17.34
30	T	17.30	17.30	17.30	17.30	17.30	17.30
	3	17.32	17.32	17.32	17.32	17.32	17.32
	4	17.33	17.33	17.33	17.33	17.33	17.33
		COMBINATION (3,6)					
10	T	24.80	24.80	24.80	24.80	24.80	24.80
	3	25.08	25.05	25.03	25.01	24.99	24.98
	4	25.23	25.19	25.15	25.13	25.10	25.09
20	T	24.80	24.80	24.80	24.80	24.80	24.80
	3	24.86	24.85	24.85	24.85	24.84	24.84
	4	24.88	24.87	24.87	24.87	24.86	24.86
30	T	24.80	24.80	24.80	24.80	24.80	24.80
	3	24.83	24.83	24.83	24.83	24.83	24.83
	4	24.85	24.84	24.84	24.84	24.84	24.84

APPENDIX TABLE 6. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,7)					
10	T	37.00	37.00	36.84	36.68	36.59	36.54
	3	36.28	36.18	35.96	35.75	35.61	35.52
	4	39.84	39.84	39.66	39.49	39.39	39.35
20	T	36.80	36.85	36.85	36.81	36.81	36.83
	3	36.07	36.08	36.04	35.97	35.94	35.93
	4	38.30	38.41	38.45	38.46	38.49	38.54
30	T	36.68	36.72	36.74	36.75	36.78	36.80
	3	36.02	36.01	36.01	35.99	35.98	35.98
	4	37.93	38.02	38.10	38.15	38.21	38.27
		COMBINATION (2,7)					
10	T	59.35	59.25	59.12	58.98	58.86	58.75
	3	58.10	57.86	57.62	57.39	57.19	57.01
	4	64.04	63.93	63.80	63.66	63.54	63.45
20	T	59.05	59.17	59.13	59.08	59.12	59.13
	3	57.83	57.87	57.77	57.67	57.65	57.63
	4	61.55	61.77	61.80	61.82	61.92	62.00
30	T	58.86	58.93	58.98	59.00	59.00	59.06
	3	57.75	57.75	57.74	57.71	57.67	57.68
	4	60.94	61.10	61.23	61.34	61.40	61.52
		COMBINATION (3,7)					
10	T	86.06	85.84	85.56	85.34	85.22	85.14
	3	84.13	83.71	83.28	82.93	82.70	82.51
	4	93.01	92.80	92.50	92.28	92.18	92.13
20	T	85.59	85.67	85.67	85.62	85.60	85.62
	3	83.75	83.71	83.63	83.50	83.41	83.36
	4	89.31	89.54	89.66	89.71	89.79	89.89
30	T	85.28	85.34	85.43	85.45	85.48	85.54
	3	83.61	83.57	83.58	83.52	83.49	83.48
	4	88.37	88.58	88.80	88.93	89.06	89.22

Appendix Table 6. (continued)

a) Combination (a,b)

b =	1	2	3	4	5	6	7
a	D	H	SG	DH	DSG	HGS	DHSG
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem

3 = stem to a 3-inch top diameter outside bark

4 = stem to a 4-inch top diameter outside bark

SI = 60 for all combinations

where:

D = diameter at breast height (inches)

H = total tree height (feet)

SG = specific gravity

SI = site index

APPENDIX TABLE 7. PERCENTAGE INCREASES IN DRY WEIGHT PER ACRE FOR THE CHOSEN GROWTH COMBINATIONS (DIAMETER DISTRIBUTION BY UNIFIED APPROACH)a)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,1)					
10	T	22.28	22.40	22.51	22.60	22.69	22.76
	3	31.82	33.67	35.31	36.79	38.18	39.49
	4	58.64	64.90	70.70	76.24	81.62	86.96
20	T	21.25	21.28	21.30	21.32	21.35	21.37
	3	22.18	22.32	22.45	22.61	22.83	23.10
	4	24.29	25.24	26.27	27.31	28.35	29.38
30	T	21.14	21.16	21.18	21.19	21.21	21.22
	3	21.66	21.75	21.82	21.90	21.97	22.04
	4	22.67	22.90	23.15	23.56	24.08	24.68
		COMBINATION (2,1)					
10	T	34.22	34.41	34.57	34.71	34.84	34.96
	3	48.57	51.41	53.94	56.25	58.40	60.45
	4	91.03	101.24	110.79	119.95	128.93	137.90
20	T	32.63	32.68	32.71	32.75	32.78	32.81
	3	34.06	34.28	34.47	34.70	35.00	35.37
	4	37.22	38.55	40.05	41.58	43.13	44.69
30	T	32.47	32.50	32.52	32.54	32.57	32.59
	3	33.27	33.40	33.52	33.63	33.73	33.84
	4	34.82	35.17	35.54	36.08	36.81	37.67
		COMBINATION (3,1)					
10	T	46.69	46.94	47.16	47.35	47.53	47.70
	3	65.90	69.77	73.23	76.39	79.35	82.18
	4	125.21	139.82	153.58	166.87	179.96	193.11
20	T	44.52	44.58	44.63	44.68	44.72	44.77
	3	46.47	46.76	47.03	47.32	47.70	48.16
	4	50.72	52.38	54.31	56.32	58.37	60.44
30	T	44.30	44.34	44.37	44.40	44.43	44.46
	3	45.39	45.57	45.73	45.88	46.03	46.17
	4	47.51	47.98	48.47	49.15	50.05	51.14

APPENDIX TABLE 7. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,2)					
10	T	10.61	10.67	10.72	10.76	10.80	10.84
	3	13.06	13.26	13.43	13.56	13.68	13.79
	4	18.81	19.38	19.84	20.23	20.58	20.88
20	T	10.12	10.13	10.14	10.15	10.16	10.17
	3	10.56	10.63	10.69	10.74	10.79	10.84
	4	11.47	11.64	11.78	11.90	12.00	12.09
30	T	10.07	10.08	10.08	10.09	10.10	10.10
	3	10.32	10.36	10.39	10.43	10.46	10.49
	4	10.80	10.91	11.00	11.09	11.17	11.25
		COMBINATION (2,2)					
10	T	15.92	16.00	16.08	16.14	16.20	16.26
	3	19.58	19.89	20.14	20.35	20.52	20.68
	4	28.21	29.07	29.77	30.35	30.86	31.32
20	T	15.18	15.20	15.22	15.23	15.25	15.26
	3	15.84	15.94	16.03	16.11	16.19	16.25
	4	17.20	17.46	17.67	17.85	18.00	18.14
30	T	15.10	15.11	15.13	15.14	15.15	15.16
	3	15.47	15.53	15.59	15.64	15.69	15.74
	4	16.20	16.36	16.51	16.64	16.76	16.88
		COMBINATION (3,2)					
10	T	21.22	21.34	21.44	21.52	21.60	21.68
	3	26.11	26.52	26.85	27.13	27.36	27.57
	4	37.62	38.76	39.69	40.47	41.15	41.76
20	T	20.24	20.26	20.29	20.31	20.33	20.35
	3	21.12	21.26	21.38	21.48	21.58	21.67
	4	22.94	23.28	23.56	23.79	24.00	24.19
30	T	20.14	20.15	20.17	20.18	20.20	20.21
	3	20.63	20.71	20.79	20.85	20.92	20.99
	4	21.59	21.81	22.01	22.19	22.35	22.50

APPENDIX TABLE 7. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,3)					
10	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
20	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
30	T	1.00	1.00	1.00	1.00	1.00	1.00
	3	1.00	1.00	1.00	1.00	1.00	1.00
	4	1.00	1.00	1.00	1.00	1.00	1.00
		COMBINATION (2,3)					
10	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
20	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
30	T	2.00	2.00	2.00	2.00	2.00	2.00
	3	2.00	2.00	2.00	2.00	2.00	2.00
	4	2.00	2.00	2.00	2.00	2.00	2.00
		COMBINATION (3,3)					
10	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00
20	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00
30	T	4.00	4.00	4.00	4.00	4.00	4.00
	3	4.00	4.00	4.00	4.00	4.00	4.00
	4	4.00	4.00	4.00	4.00	4.00	4.00

APPENDIX TABLE 7. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,4)					
10	T	35.12	35.31	35.48	35.62	35.76	35.88
	3	48.35	50.69	52.73	54.59	56.30	57.92
	4	86.05	94.24	101.78	108.94	115.88	122.74
20	T	33.49	33.54	33.58	33.61	33.65	33.68
	3	34.96	35.18	35.38	35.61	35.91	36.25
	4	38.19	39.44	40.74	42.04	43.32	44.58
30	T	33.32	33.35	33.38	33.40	33.42	33.45
	3	34.14	34.28	34.40	34.51	34.62	34.73
	4	35.74	36.10	36.47	37.02	37.69	38.43
		COMBINATION (2,4)					
10	T	55.27	55.57	55.83	56.06	56.27	56.46
	3	76.03	79.81	83.15	86.18	88.99	91.66
	4	138.70	152.92	166.16	178.82	191.21	203.55
20	T	52.70	52.77	52.84	52.89	52.94	52.99
	3	55.01	55.36	55.67	56.01	56.44	56.94
	4	60.02	61.84	63.84	65.85	67.86	69.86
30	T	52.44	52.48	52.52	52.56	52.60	52.63
	3	53.73	53.94	54.13	54.31	54.49	54.65
	4	56.24	56.80	57.38	58.14	59.13	60.25
		COMBINATION (3,4)					
10	T	77.25	77.67	78.03	78.35	78.64	78.92
	3	106.13	111.52	116.31	120.68	124.75	128.62
	4	197.56	219.07	239.27	258.72	277.87	297.07
20	T	73.66	73.76	73.85	73.93	74.00	74.07
	3	76.89	77.37	77.81	78.27	78.83	79.48
	4	83.82	86.21	88.90	91.66	94.45	97.24
30	T	73.29	73.36	73.41	73.46	73.51	73.56
	3	75.09	75.39	75.66	75.91	76.15	76.39
	4	78.60	79.39	80.18	81.18	82.45	83.95

APPENDIX TABLE 7. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,5)					
10	T	23.51	23.63	23.73	23.83	23.91	23.99
	3	33.14	35.01	36.66	38.16	39.56	40.88
	4	60.22	66.55	72.41	78.00	83.43	88.83
20	T	22.46	22.49	22.52	22.54	22.56	22.58
	3	23.40	23.54	23.67	23.83	24.06	24.33
	4	25.53	26.49	27.53	28.58	29.63	30.68
30	T	22.35	22.37	22.39	22.40	22.42	22.43
	3	22.88	22.96	23.04	23.12	23.19	23.26
	4	23.90	24.13	24.39	24.79	25.32	25.93
		COMBINATION (2,5)					
10	T	36.91	37.09	37.26	37.40	37.53	37.66
	3	51.54	54.44	57.02	59.37	61.57	63.66
	4	94.85	105.26	115.00	124.34	133.50	142.66
20	T	35.28	35.33	35.37	35.40	35.44	35.47
	3	36.74	36.96	37.16	37.39	37.70	38.08
	4	39.96	41.32	42.85	44.42	46.00	47.58
30	T	35.12	35.15	35.17	35.19	35.22	35.24
	3	35.93	36.06	36.19	36.30	36.41	36.52
	4	37.52	37.87	38.25	38.80	39.55	40.42
		COMBINATION (3,5)					
10	T	52.56	52.82	53.05	53.25	53.43	53.60
	3	72.53	76.56	80.16	83.45	86.53	89.47
	4	134.22	149.42	163.73	177.54	191.16	204.84
20	T	50.30	50.36	50.42	50.47	50.51	50.56
	3	52.33	52.63	52.91	53.22	53.60	54.08
	4	56.75	58.47	60.48	62.58	64.71	66.86
30	T	50.07	50.11	50.14	50.18	50.21	50.24
	3	51.20	51.39	51.56	51.72	51.87	52.02
	4	53.41	53.90	54.41	55.11	56.05	57.18

APPENDIX TABLE 7. (CONTINUED)

		TREES PER ACRE					
		500	600	700	800	900	1000
AGE		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,6)					
10	T	11.72	11.78	11.83	11.87	11.91	11.95
	3	14.19	14.40	14.56	14.70	14.82	14.92
	4	20.00	20.58	21.04	21.44	21.78	22.09
20	T	11.22	11.23	11.25	11.26	11.27	11.28
	3	11.67	11.73	11.79	11.85	11.90	11.94
	4	12.58	12.75	12.90	13.02	13.12	13.21
30	T	11.17	11.18	11.18	11.19	11.20	11.21
	3	11.42	11.46	11.50	11.53	11.57	11.60
	4	11.91	12.01	12.11	12.20	12.29	12.36
		COMBINATION (2,6)					
10	T	18.24	18.32	18.40	18.47	18.53	18.59
	3	21.98	22.29	22.54	22.75	22.93	23.09
	4	30.78	31.65	32.36	32.96	33.48	33.95
20	T	17.48	17.50	17.52	17.54	17.55	17.57
	3	18.16	18.26	18.35	18.43	18.51	18.58
	4	19.55	19.81	20.02	20.20	20.36	20.50
30	T	17.40	17.42	17.43	17.44	17.45	17.46
	3	17.78	17.84	17.90	17.95	18.00	18.05
	4	18.52	18.69	18.84	18.97	19.10	19.21
		COMBINATION (3,6)					
10	T	26.07	26.19	26.29	26.39	26.47	26.55
	3	31.16	31.59	31.93	32.21	32.46	32.68
	4	43.12	44.31	45.28	46.09	46.80	47.43
20	T	25.05	25.07	25.10	25.12	25.14	25.16
	3	25.97	26.11	26.23	26.34	26.44	26.54
	4	27.85	28.21	28.50	28.75	28.96	29.15
30	T	24.94	24.96	24.97	24.99	25.00	25.02
	3	25.46	25.54	25.62	25.69	25.76	25.82
	4	26.46	26.68	26.89	27.07	27.24	27.40

APPENDIX TABLE 7. (CONTINUED)

AGE		500	600	700	800	900	1000
		TREES PER ACRE					
		DRY WEIGHT INCREASE (PERCENT)					
		COMBINATION (1,7)					
10	T	36.47	36.67	36.83	36.98	37.11	37.24
	3	49.83	52.19	54.26	56.13	57.87	59.50
	4	87.91	96.18	103.80	111.03	118.04	124.97
20	T	34.83	34.87	34.91	34.95	34.98	35.01
	3	36.31	36.53	36.73	36.97	37.27	37.62
	4	39.58	40.83	42.15	43.46	44.75	46.03
30	T	34.66	34.69	34.71	34.74	34.76	34.78
	3	35.48	35.62	35.74	35.86	35.97	36.08
	4	37.10	37.46	37.84	38.39	39.06	39.82
		COMBINATION (2,7)					
10	T	58.38	58.68	58.94	59.18	59.39	59.59
	3	79.55	83.41	86.81	89.90	92.77	95.49
	4	143.47	157.98	171.49	184.40	197.03	209.62
20	T	55.76	55.83	55.89	55.95	56.00	56.05
	3	58.11	58.47	58.78	59.13	59.57	60.08
	4	63.22	65.08	67.12	69.17	71.22	73.26
30	T	55.49	55.53	55.58	55.61	55.65	55.68
	3	56.80	57.02	57.22	57.40	57.58	57.75
	4	59.36	59.94	60.53	61.31	62.31	63.46
		COMBINATION (3,7)					
10	T	84.34	84.77	85.15	85.48	85.79	86.07
	3	114.37	119.98	124.97	129.51	133.74	137.76
	4	209.46	231.84	252.84	273.07	292.99	312.95
20	T	80.61	80.71	80.80	80.88	80.96	81.03
	3	83.96	84.47	84.92	85.40	85.98	86.66
	4	91.17	93.66	96.45	99.33	102.23	105.13
30	T	80.22	80.29	80.35	80.40	80.45	80.50
	3	82.10	82.41	82.68	82.95	83.20	83.44
	4	85.75	86.57	87.39	88.43	89.75	91.31

Appendix Table 7. (continued)

a) Combination (a,b)

b =	1	2	3	4	5	6	7
a	D	H	SG	DH	DSG	HGS	DHSG
	Percent Increase						
1	10	10	1	(10)(10)	(10)(1)	(10)(1)	(10)(10)(1)
2	15	15	2	(15)(15)	(15)(2)	(15)(2)	(15)(15)(2)
3	20	20	4	(20)(20)	(20)(4)	(20)(4)	(20)(20)(4)

T = total stem

3 = stem to a 3-inch top diameter outside bark

4 = stem to a 4-inch top diameter outside bark

SI = 60 for all combinations

where:

D = diameter at breast height (inches)

H = total tree height (feet)

SG = specific gravity

SI = site index

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Modeling Increased Height, Diameter, and Specific Gravity Effects on Yield Estimates in Planted Loblolly Pine Stands

by

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(ABSTRACT)

Increased growth of *Pinus taeda L.* plantations is expected from genetic improvement and intensified cultural practice. It is necessary for forest managers to have a means for estimating the yield of forest stands after increased growth occurs. Several models were tested to determine which could best predict dry weight yield after certain constant growth increases were assumed. The data used consisted of 189, one-tenth acre sample plots taken in loblolly pine plantations located in piedmont and coastal plain Virginia, and coastal plain Delaware, Maryland, and North Carolina. Constant growth increases in diameter, height, and wood density were considered. The models considered were multiple regression and the diameter distribution approach using the beta distribution. Under the diameter distribution approach alternatives involving a piecewise integration over diameter class limits and a "unified" approach were considered. The

models were compared to each other and to expected yield increases when determining their consistency, accuracy, flexibility, and simplicity. Recommendations concerning the different models were made.