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DESIGN AND DEVELOPMENT OF A MULTIPURPOSE FOREST PROJECTION SYSTEM FOR SOUTHERN FORESTS

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Information contained herein is available to all without regard to race, color, sex, or national origin.

Design and Development of a Multipurpose Forest Projection System for Southern Forests[1]

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INTRODUCTION

SIMILARITIES in physiographic regions and forestry land use exist among states in the South. Therefore, data about forest growth processes from one state may be applicable to similar areas in other states of the region. Data from Georgia were used in development of the forest growth projection system reported herein, but the system should be applicable to similar physiographic areas in Alabama and other Southern States.

Georgia has a total land area of 37.3 million acres, of which 64 percent is classified as commercial forestland *(11)*. Within Georgia, five physiographic regions exist, as shown by the accompanying map: Lower Coastal Plain, Upper Coastal Plain, Piedmont, Ridge and Valley, and Blue Ridge. These regions are occupied by six major forest types and a variety of tree species. Due to the size and diversity of the forest resource found within the State, the development of growth and mortality models for Georgia was formidable. When developing models, this size and diversity had to be considered. Thus, a large dataset was required to model the numerous conditions represented.

This report documents the modeling process used to derive a forest growth projection system for Georgia. This system is an individual tree distance independent simulation package for predicting tree and stand growth *(7)*. Models were developed to predict live crown ratio, annual diameter increment, bole length, and mortality. These models

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[1] Project jointly funded by Alabama Agricultural Experiment Station, Forest Resources System Institute (FORS), and Georgia Forestry Commission.

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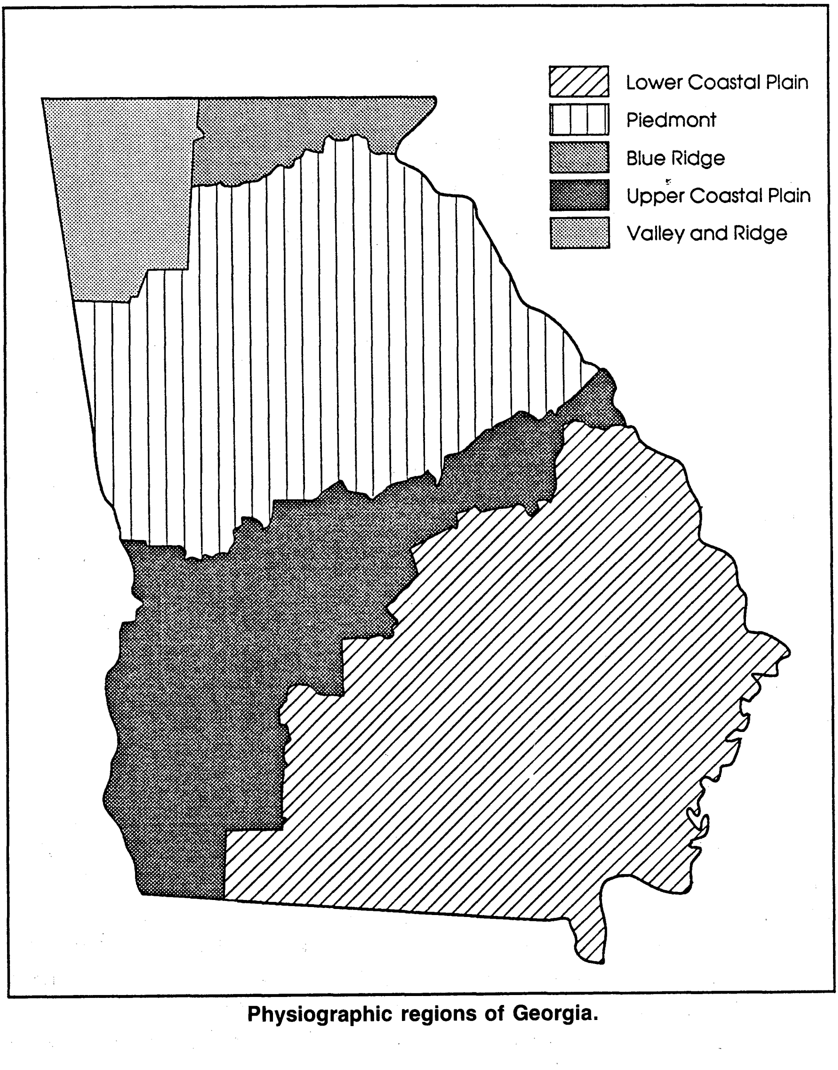

Physiographic regions of Georgia.

were then implemented into the TWIGS 2.0 framework *(3)*. Only the major results of these efforts are presented. If more information is desired, refer to Bolton and Meldahl *(2)*.

The development of growth and mortality models is an ongoing process. With each new model, many different statistical techniques were investigated to insure that the growth processes were adequately modeled. In addition, several new techniques were developed and utilized in the modeling process.

DATA

The data for this study were obtained from the U.S. Forest Service Renewable Resources Evaluation Project. The data were from the Forest Survey of Georgia and were collected by the Southeastern Forest Experiment Station over a 3-year period beginning in 1980. In this survey, plots were systematically located on a 3-mile grid with a random start in each county of the State. These plots were based on a 10-point cluster design, with a distance of 70 feet between points. On commercial forest land, timber volume recordings were made on only three of the points. On these points, a fixed and a variable radius plot were established. The variable radius plots were used for all trees greater than or equal to 5 inches dbh, and were based on a basal area factor of 37.5. The fixed area plots were used for all trees smaller than 5 inches dbh and were based on a radius of 6.8 feet. For more detailed information on the Survey, please refer to Tansey *(11)*.

Forest Survey collects a multitude of information. As with most large sets of data, considerable time was spent examining the data and understanding variable definitions. For the purposes of modeling growth, some survey data variables are defined in ways which prohibit their use or make them difficult to use in analyses of growth. In addition, two other problems are inherent in using Survey data: Stand history is never completely known, and the sample design used was not optimal for modeling growth. However, these weaknesses in the data were not severe enough to preclude their use, and survey data provide a reasonable representation of current forest lands in Georgia. Furthermore, no other data have been found which cover the numerous growing conditions found throughout the State.

Competition variables are an integral part of a distance-independent projection system. They consist of such variables as basal area larger, trees per acre larger, number of trees per acre, and basal area per acre. The competition variable basal area larger is defined as the amount of basal area per acre greater than or equal to the basal area of the current tree. Similarly, trees per acre larger is defined as the number of trees per acre that are greater than or equal to the current tree. During the 10-year span that these measurements covered, many trees were cut, died, or grew on to the plot. Competition variables were thus needed that would measure the effect of these trees leaving and entering the plot. Therefore, for the purposes of modeling, those trees which were ongrowth/ingrowth 1/2 of their time 1 value was contributed to the time 2 competition variables. Likewise, those trees which died or were cut were allowed to contribute 1/2 of their time 1 values to their time 2 competition variables. For example, if a tree died, then half of what that stem represents in basal area/acre at the initial measurement (time 1) was figured into the competition variables (i.e. basal area larger) for the second remeasurement period (time 2).

One of the more important variables used in growth modeling is some measure of site quality. Unfortunately, site index is not directly collected by Forest Survey. Instead a site is placed into site classes, based on the potential yield of that site. This is calculated by measuring the total height and age of a dominant tree which represents the sample location. Site class is then determined by reading the appropriate graph, Appendix 1. This site class can be converted to a site index figure using the table in Appendix 1. This was not a very accurate way to measure site index, but necessary for using these data. The paucity of information dealing with natural stands in the Southeast leaves few alternatives to this approach.

Physiographic regions were based on maps presented by Walker and Perkins *(15)*, and which are currently being used by the Georgia Forestry Commission. Because the most detailed location variable within these data was county, physiographic regions were broken down according to counties. A listing of counties assigned to regions for the purposes of modeling is presented in Appendix 2.

METHODS

Four different sets of models for individual trees were developed to predict tree growth. Models were developed to predict crown ratio, annual diameter increment, bole length, and mortality. Four assumptions on tree growth were adhered to in the development of the methodology for deriving these models. First, species grow differently on the same site, e.g., loblolly pine versus sweetgum on the same site. Second, individual species may grow differently in the different physiographic regions of Georgia, e.g., loblolly pine in the Ridge and Valley versus loblolly pine in the Lower Coastal Plain, given identical stand conditions (age, site, density, etc.). Next, an individual tree may grow differently in different forest types, e.g., loblolly pine in the loblolly pine forest type versus loblolly pine in the oak-pine forest type, given identical stand conditions (age, site, density, etc.). Finally, species could be separated into three major divisions: pines, oaks, and non-oaks. Any of these assumptions may be argued; however, it was felt that they provide a reasonable representation of tree and stand growth.

Imposing the above assumptions on the data resulted in a rather large four dimensional matrix [physiographic region (5 regions), forest type (18 types), species division (3 divisions), and species (> 75 species)]. It was not desirable or practical to develop models for all cells within this matrix. Therefore, a clustering analysis was developed to shrink this matrix. This clustering algorithm is a heuristic attempt to group like cells of the large matrix together.

Next, regression analysis was used to derive a mathematical model for the characteristic being modeled (crown, diameter increment, bole length, mortality). This process first involved running a stepwise regression procedure to select variables for possible inclusion in the model for the aspect of growth being modeled. Then through repeated efforts to reduce the residual sum of squares and from examination of plots of residuals, a model form was selected for each major species division of the data (pines, oaks, non-oaks). Because cluster analysis also separates unlike groups, model forms can vary for clusters within each separation.

CLUSTER ANALYSIS

The goal of cluster analysis is to combine similar groups and separate those which are dissimilar. Thus, for the characteristic of interest, the elements within a cluster should be more similar to each other than they are to elements of another cluster. Use of cluster analysis for grouping species was described by Meldahl et al. *(8)*. For more discussion on the principles of cluster analysis, please refer to Everitt *(6)* and/or Turner *(12)*.

This clustering process was conducted for each model and species division. It starts by identifying the smallest feasible cell of the matrix, or species groups (SP_G). A SP_G contained at least 30 observations and/or exhibited a good distribution of the variable being modeled. These groupings were considered the smallest possible units in the clustering process. The reductions were rather arbitrary, but were based on keeping a species within similar forest types (see Appendix 6 for forest type definitions) within physiographic regions.

The first step in this reduction was to find species within the five different physiographic regions which had enough observations within a forest type to be considered a separate SP__G. Next, within a physiographic region, the pine forest types (F__TYPE $<$ 40), the upland oak forest types (40 $< =$ F__TYPE $= >$ 50), or the hardwood forest types (F__TYPE $>$ 50) were grouped together. When these groupings were not possible, either all the non-pine forest types (F__TYPE $>$ 40) were grouped together, all forest types were grouped together, or physiographic regions were combined. These species groupings attempted to combine forest types which exhibited similar growth patterns.

The procedure used to group SP__G's into clusters was a four-part process:

1. Stepwise regression, plotting of variables, a literature search, and "trial and error" were used to select variables which exhibited a strong linear relationship with the function (crown class, diameter increment, bole length, or mortality) being modeled. For each of the SP__G's, this simple linear model is fitted. The regression coefficients (B_0, B_1) for each of these models are then standardized and entered into the clustering algorithm.

2. Cluster analysis of SP__G's into 15, 10, and 5 clusters was then performed using the clustering algorithm from Proc FASTCLUS *(10)*. The simple linear relationship which produces the coefficients which minimized the mean square error was then chosen as the "clustering function."

3. Using a graph of the cubic clustering criterion, a graph of the clusters, and through some "trial and error," an "optimal" number of clusters was obtained.

4. Final adjustments were then made to insure SP__G's were intuitively correct, e.g., cedar is not assigned to the same cluster as loblolly pine.

CROWN RATIO

Crown ratio is strongly correlated with stand density, competition, and tree vigor. Therefore, it is an important variable in predicting tree growth. Southeastern Forest Survey defines crown ratio as "the percent of total tree height that supports green, live foliage that is effectively contributing to tree growth" *(12)*. This was measured for all live trees using 10 crown ratio classes, with each class representing different percents of live crown. These crown ratio classes were treated as "pseudo-continuous" variables. This was done by assigning the crown ratio (CROWN__R) to be the midpoint of the crown ratio class. Since CROWN__R only existed for trees at the second measurement, two sets of models were developed. One set predicted CROWN_R in the future as a function of initial conditions and the other predicted CROWN_R as a function of the current conditions. The first set of models was used in the prediction of growth and mortality. The latter was necessary for the prediction of bole length.

Clustering of species groups was done for the three major groups (pines, oaks, non-oaks) by the methodology presented previously. Crown ratio was viewed as being very species specific. Therefore, the primary goal in deriving SP_G's was to group a species together and avoid clumping of different species as much as possible. Final clusters were based on the relationship of CROWN_R = f(annual diameter increment). The "optimal" number of clusters was found to be 8 for pines, 13 for oaks, and 21 for the non-oaks. Multiple linear regression analysis was then used to predict CROWN_R. Clusters and models may be found in Appendix 3.

DIAMETER INCREMENT

In most tree simulation packages, basal area increment or diameter increment is typically used as the basic measure of growth. West *(16)* showed that little difference existed between the two types of models. Since diameter growth was the main focus of interest, more flexibility and versatility were foreseen in developing a diameter increment model. Efforts were therefore directed toward developing annual diameter increment (DINC) models.

The clustering technique used for diameter increment followed that mentioned previously. However, in assigning SP_G's, more attention was given to separating species by region. The following variables along with the "optimal" number of clusters were used to model DINC.

Group	*Function*	*Optimal no.*
Pine	DINC = ln(predicted CROWN_R)	12
Oak	DINC = sqrt(trees/acre larger)	23
Non-oak	DINC = ln(dbh)	18

These final clusters may be found in Appendix 3.

Initial attempts at modeling DINC involved the use of non-linear regression models similar to those developed in the Lake States for STEMS *(13)*. Such models are intellectually appealing. However, this approach did not produce satisfying results. Therefore, models for each cluster were constructed by simply using multiple linear regression.

Next, an iterative method of fitting a power transformation to DINC was used to improve these initial models. This approach to fitting a transformation follows that suggested by Draper and Smith *(5)*. The power transformation used was:

If lambda = 0 then W = ln(DINC)
else W = ((DINC**lambda) - 1.0)/lambda

This transformation assumes that DINC > 0. Within each group (pine, oak, non-oak), several clusters were identified for which transformations on the previously derived models had a marked impact on the analysis of the residuals. After comparing the maximum lambda value and its corresponding confidence interval for these select clusters, an acceptable value was chosen for lambda. The regressions were then estimated again using this value for lambda to calculate the power transformation. In all but a few cases, gains of 1-10 percent were noticed in the r-square. Furthermore, the analysis of the residuals showed marked improvement in every regression. The models, coefficients, and transformations for the final models are given in Appendix 3.

BOLE LENGTH

Equations were needed to predict some form of tree height, for use in calculating volumes. The preferred approach would have been to develop a height increment or bole increment equation, similar to that of DINC. However, the only measure of height in the data was bole length (BOLE) of trees at time 2 which had a dbh > = 5 inches. The Southeastern Forest Survey defined BOLE as "the distance on the main stem from a 1-foot stump to a 4-inch diameter outside bark." This definition set restrictions on the volume equations used in TWIGS.

The procedure used to develop the bole length models was the same as those used for DINC and CROWN_R. The cluster analysis resulted in clustering on the following equations and number of clusters:

Group	*Function*	*Optimal no.*
Pine	BOLE = (site index*dbh)/100.0	14
Oak	BOLE = site index*dbh	13
Non-oak	BOLE = dbh	20

Regression analysis was used to derive equations to predict BOLE as a function of current growing conditions. The resulting clusters, equations, and coefficients may be found in Appendix 3.

SURVIVAL/MORTALITY

Mortality is one of the most difficult tree characteristics to predict. The only aspect of mortality which these data could be used to model was natural mortality. Therefore, plots which exhibited heavy mortality due to infestations of insects, disease, or fire were identified and deleted. Additionally, the nature of survey data is such that it is not known when in the remeasurement period a tree died. This inadequacy in the data severely limited the scope of the analysis.

The clustering technique used for mortality differed from that used in the previous models. This technique was based on the principle that greater mortality is anticipated for trees which grow slowly than for trees which are growing vigorously. Therefore, vigor was defined by the predicted annual diameter increment, or PDINC. In deriving SP__G's upon which to perform cluster analysis, efforts were then made to group species in a region which had a distribution of dead trees across the range of PDINC. This follows recommendations by Buchman et al. *(4)*. In order to group species further, they were placed in the following categories:

RO (red oaks) - SP = 806, 812, 813, 817, 820, 827, 828, 830, 831, 833, 834, 837,838.

WO (white oaks) - SP = 802, 822, 823, 832, 835

RS (scrub oaks) - SP = 807, 819, 824, 825, 840, 841, 899.

SOFT (soft hardwoods) - SP = 221, 222, 313, 316, 460 555, 580, 611, 621, 651, 652, 653, 691, 693, 694, 721, 731, 740, 762, 920, 950, 970.

HARD (hard hardwoods) - SP = 311, 318, 370, 400, 491, 531, 540, 552, 591, 602, 680, 901.

Also, due to the enormous number of small trees which existed in the mortality dataset, only trees with a dbh > = 5.0 inches were used in deriving SP__G's and in the cluster analysis. Cluster analysis was then performed on the results of non-linear regression, by maximum likelihood method, to estimate a logistic function weighted by the initial dbh. Each group (pine, oak, non-oak) used coefficients for the function mortality = f(trees per acre larger) on which to cluster. The final number of clusters was selected by examining the graphical results of the cluster analysis and by minimizing the mean square error.

Logistic regression was then used to derive equations which predict the probability of survival. Initial attempts at modeling mortality utilized the full range of the data. However, the best results came from dividing the data into trees with dbh's > = 5.0 inches and trees with dbh's < 5.0 inches. The clusters, equations, and coefficients may be found in Appendix 3.

TWIGS

The growth and mortality models have been implemented into the TWIGS 2.0 framework. TWIGS was originally developed by the U.S. Forest Service North Central Forest Experiment Station *(1)*. It is a menu driven program which allows the user to explore several silvicultural and economic alternatives. The program is designed for IBM PC's and compatible machines. Little was changed in this program during model implementation. For more information on running this version of GATWIGS, refer to Bolton and Meldahl *(3)*, and for a more detailed description of TWIGS see Miner et al. *(9)*.

VOLUME EQUATIONS

Volume equations which represent the forest of Georgia were an essential requirement of the projection system. However, a scarcity of volume information, especially for southern pines, and the limitation of predicting bole length severely restricted the selection and implementation of volume equations into TWIGS.

In GATWIGS, volumes are calculated for the stem and product for all trees with a dbh > = 5 inches. The stem volume is measured by green weight of the bole, including bark, to a 4-inch top (d.o.b.). Volumes for sawtimber and pulpwood are also estimated. Sawtimber is defined as any stem with a bole length > = 16 feet, and for pines a dbh > = 9 inches, or for hardwoods a dbh > = 11 inches. Volume is estimated for sawtimber in cubic feet and board feet. Board foot volumes are calculated by the Scribner log rule for pines and by the Doyle log rule for hardwoods. Pulpwood is defined as any stem that does not meet the requirements for sawtimber. It is measured in cubic feet and in cords. Cubic foot volumes for both products are only predicted for solid wood.

Attempts were made to use the most recent and complete volume information for each species. Selection of a volume equation proceeded with the following steps until available equations were found in the literature.

1. If an equation existed for that species in that physiographic region which calculated volume = f(dbh, bole).
2. If an equation existed for that species in an adjacent physiographic region which calculated volume = f(dbh, bole).
3. If an equation existed for that species in Georgia which calculated volume = f(dbh, bole).
4. If an equation existed for that species which calculated volume = f(dbh, total height). Where total height is predicted using unpublished Forest Survey equations.[3]
5. A miscellaneous category for that particular physiographic region. The equations finally selected and implemented into TWIGS are detailed further in Appendix 4.

CONCLUSIONS AND RECOMMENDATIONS

Georgia contains a large land base and a diverse forest resource. This diversity made the modeling of forest growth a complicated task. To capture and control this diversity, cluster analysis was used frequently in the modeling process. Four sets of models were calibrated to predict growth: crown ratio, diameter increment, bole length, and mortality. In deriving these equations, statistical techniques such as multiple linear regression, non-linear regression, power transformations, and logistic regression were used. These models will generally predict growth and mortality on the "average" very well. However, the forest ecosystem is a very complex system that is difficult to mathematically model. Therefore, these models have limits and may at times appear to behave illogically. At this time, these limits have not been fully investigated or defined. Users should be careful with the inputs to the model, and use their forestry background to assess the final results. Properly used, these models should allow many different aspects of forest growth and management to be investigated and studied.

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[3] Personal communication, December 1987, J.P. McClure, FIA, Southeastern Forest Experiment Station, Asheville, North Carolina 28804.

ACKNOWLEDGMENTS

Many people assisted in the development of this projection system. However, several individuals have made major contributions. Marian Eriksson developed much of the theory and methodology of the clustering analysis; and Chuck Warlick developed many of the programs used in data manipulation and variable selection. Mike Watson and Joseph Yu spent many hours making the needed computer programming modifications to TWIGS. Appreciation is also expressed to the Georgia Forestry Commission and Forest Resource Systems Institute for their funding and support of this project.

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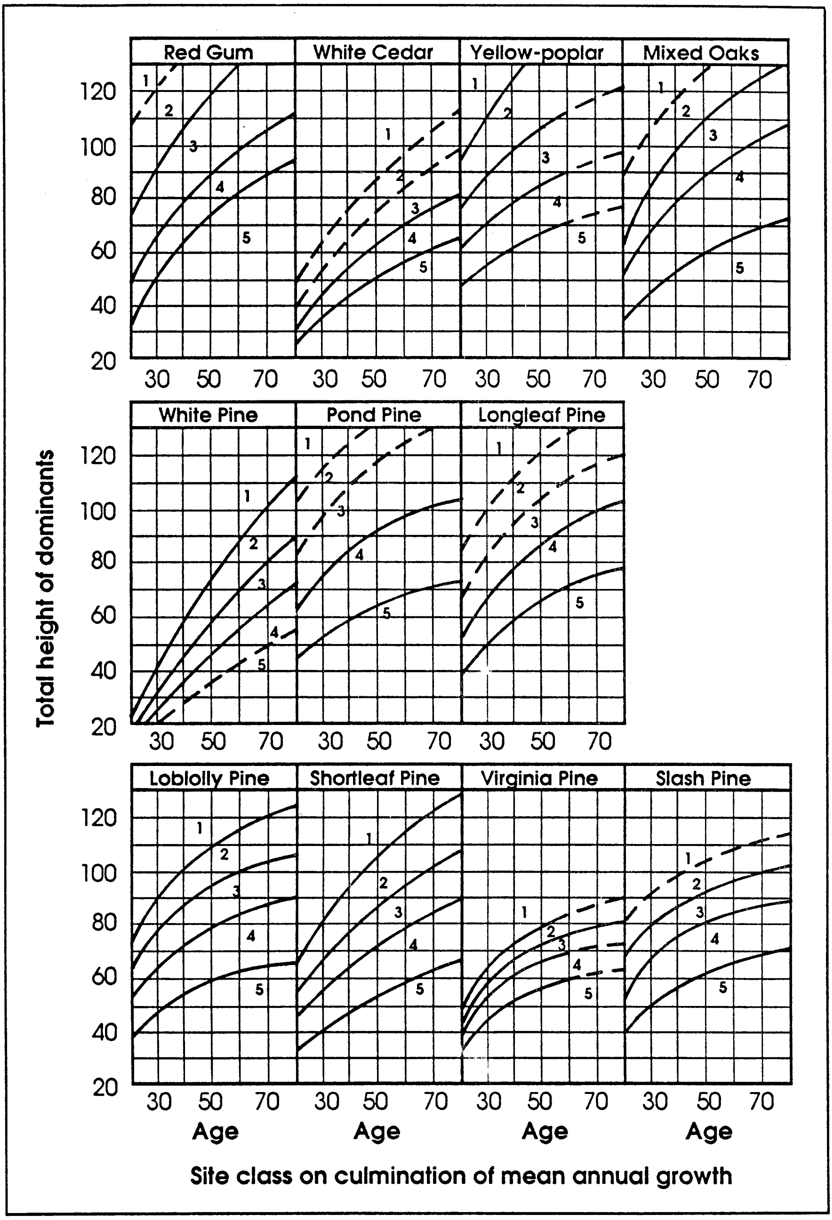
APPENDIX 1. RELATIONSHIP AMONG SITE CLASS, AGE, AND HEIGHT

TABLE 1. RELATIONSHIP BETWEEN SITE CLASS AND SITE INDEX[1]

Species	Site index range[2], by site class				
	1	2	3	4	5
White pine	74+	58 - 73	44 - 57	35 - 43	34 -
Longleaf pine	123+	106 - 122	89 - 105	68 - 88	67 -
Slash pine	103+	93 - 102	80 - 92	62 - 79	61 -
Loblolly pine	110+	95 - 109	80 - 94	60 - 79	59 -
Shortleaf pine	104+	86 - 103	72 - 85	54 - 71	53 -
Virginia pine	79+	74 - 78	67 - 73	57 - 66	56 -
Pond pine	133+	118 - 132	93 - 117	66 - 92	65 -
Sweetgum	---	119+	90 - 118	75 - 89	75 -
Yellow-poplar	135+	108 - 134	87 - 107	68 - 86	67 -
Mixed oaks	128+	109 - 127	89 - 108	60 - 88	59 -

[1] Personal communication, July 1986, J.P. McClure, FIA, Southeast Forest Experiment Station, Asheville, North Carolina, 28804.

[2] Height in feet at age 50.



Site class based on culmination of mean annual growth *(14)*.

APPENDIX 2. LIST OF COUNTIES BY PHYSIOGRAPHIC REGIONS AS USED IN GATWIGS

Blue Ridge

Fannin
Gilmer
Rabun
Towns
Union

Lower Coastal Plain

Appling
Atkinson
Bacon
Ben Hill
Berrien
Brantley
Brooks
Bryan
Bulloch
Burke
Camden
Candler
Charlton
Chatman
Clinch
Coffee
Colquitt
Cook
Dodge
Echols
Effingham
Emanuel
Evans
Glynn
Grady
Irwin
Jeff Davis
Jenkins
Johnson
Lanier
Laurens
Liberty
Long
Lowndes
McIntosh
Montgomery
Pierce
Screven
Tattnall
Telfair
Thomas
Tift
Toombes
Treutlen
Turner
Ware
Wayne
Wheeler
Wilcox
Worth

Piedmont

Baldwin
Banks
Barrow
Butts
Carroll
Cherokee
Clarke
Clayton
Cobb
Columbia
Coweta
Dawson
Dekalb
Douglas
Elbert
Fayette
Forsyth
Franklin
Fulton
Greene
Gwinnett
Habersham
Hall
Hancock
Haralson
Harris
Hart
Heard
Henry
Jackson
Jasper
Jones
Lamar
Lincoln
Lumpkin
Madison
McDuffie
Meriweather
Monroe
Morgan
Newton
Oconee
Olgethorpe
Paulding
Pickens
Pike
Putnam
Rockdale
Spalding
Stephens
Talbot
Taliaferro
Troup
Upson
Walton
Warren
White
Wilkes

Upper Coastal Plain

Baker
Bibb
Bleckley
Calhoun
Chattahoochee
Clay
Crawford
Crisp
Decatur
Dooly
Dougherty
Early
Glascock
Houston
Jefferson
Lee
Macon
Marion
Miller
Mitchell
Muscogee
Peach
Pulaski
Quitman
Randolph
Richmond
Schley
Seminole
Stewart
Sumter
Taylor
Terrell
Twiggs
Washington
Webster
Wilkerson

Ridge and Valley

Bartow
Catoosa
Chatooga
Dade
Floyd
Gordon
Murray
Polk
Walker
Whitfield

APPENDIX 3. SPECIES GROUPS, CLUSTERS, AND MODELS

Species groups (SP_G) were assigned names based on a three part naming convention. The first part of the name identifies the physiographic region, the second part the species, and the third part the forest type. A typical SP_G name is then L611F60. The first character(s) of a SP_G name represents one of the following regions:

L = Lower Coastal Plain
U = Upper Coastal Plain
P = Piedmont
V = Ridge and Valley
B = Blue Ridge
A = all regions

All but the last code may be combined to represent several regions. The next 3 digits are simply the Forest Service's species codes, Appendix 5. The rest of the SP_G name represents the forest type by one of the following codes:

FXX = forest type XX,
where XX is forest type (Appendix 6)
A = all forest types
OP = oak - pine forest types (F_TYPE < = 50)
H = hardwood forest types (F_TYPE > 50)
O = oak forest types (F_TYPE = 40 or 50)
PH = mixed forest types
M = miscellaneous, all forest types excluding those assigned to other groups

All species not assigned to a SP_G are placed into a category called OTHER. Therefore, the SP_G name L611F60 represents sp = 611 (sweetgum) found in the Lower Coastal Plain, and located in Forest Type = 60 (oak-gum-cypress).

The following is a listing of the variables and their computer symbols, which are used throughout the appendices.

BAL_T1	basal area larger - time 1
BAL_T2	basal area larger - time 2
DBHT1	dbh - time 1
DBHT2	dbh - time 2
PLCR	predicted live crown
SITE	site index
STAND_A	stand age - time 1
STAND_AT2	stand age - time 2
TAL_T1	trees/acre larger - time 1
TAL_T2	trees/acre larger - time 2
TO_BA1	total basal area - time 1
TO_BA2	total basal area - time 2
TO_TA1	total number of trees/acre - time 1
TO_TA2	total number of trees/acre - time 2

Table 1. Crown Ratio Clusters

Cluster	Pine	Oak	Non-oak
1.	B110A A121A	P832A V832A V833A	AMAGA[1] VLMAPELA[2]
2.	B132A P110A	B832A BVSREDA[3] PU806A V837A V806A	B400A AHACKA[4] P694A U691A V611A
3.	L131A P131A P131P1 U131A U111A V131A	L835A PVSCRUBA[2] A831A	A531A
4.	L131P1 U110A U111PL V110A	B833A B806A P833A PU837A V802A	L222A A692 U221A V711A
5.	L110A	B802A L802A L827A P824A P835A	B621A L221A L653A L694A P540A V612A A902A
6.	L111A L111PL V131P1	LSREDA[3] U807A U835A	B316A L721A P316A V400A U970A
7.	A128A A129A	L807A PU819A	B491A B711A PUL711A U521A V316A
8.	P132A U131P1 V132A	L820A PSREDA[3] PVB827A P802A U802A U827A	B693A L316A AOTHERA PVB762A U653A U694A
9.		U838A V835A	A060A
10.		B837A AOTHERA PUL825A	P391A P400A P611A PVBMAPLE[2] U400A

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[1] SP = 651, 652.

[2] SP = 310-318, not including 316.

[3] SP = 812, 813, 834.

[4] SP = 460, 461, 462.

Table 1 (continued). Crown Ratio Clusters

11.		L819A		A519A	
12.		PUL822A L838A P820A	U820A USREDA[3] VULB824A	L512A P512A V491A	
13.		USCRUBA[4] LSCRUBA[4]		V693A	
14.				L391A L400A U491A	U316A U611A
15.				L762A	U693A
16.				L693A P693A	P491A
17.				PV970A	U391A
18.				A701A	L491A
19.				ABIRCHA[5] L970A L611A L621A A680A	P653A P621A U762A U540A U621A
20.				L540A L691A	U222A
21.				A555A A931A	VB521A

Table 2 . Coefficients for Crown Ratio Equations - Pines

Cluster	B0	B1	B2	B3	B4
CROWN_R = B0 + B1*([SITE*STAND_A]/100.00) + B2*([SITE*TO_BA1]/100.00) + B3*(SITE*DBHT1) + B4*(ln(TAL_T1))					
1	0.58671978	-0.00154260	-0.00085430	0.00002096	-0.01003733
2	0.43379111	-0.00166059	-0.00101115	0.00013397	-0.00476772
3	0.59532667	-0.00158220	-0.00035415	0.00000780	-0.03170961
4	0.57858310	-0.00136857	-0.00049365	0.00000614	-0.02745300
5	0.16596777	0.00076801	0.00348249	0.00042025	-0.01397368
6	0.61825820	-0.00187729	-0.00006025	-0.00004120	-0.03936502
7	0.68482619	-0.00080745	-0.00095414	-0.00002616	-0.02442492
8	0.57962489	-0.00277728	-0.00025979	0.00000336	-0.02539228

Table 3. Coefficients for Crown Ratio Equations- Oaks

Cluster	B0	B1	B2	B3	B4
CROWN_R = B0 + B1*(ln[TAL_T1]) + B2(ln[STAND_A]) + B3*(ln([O_BA1])					
1	0.61787371	-0.01616234	-0.02508335	0.00143028	
2	0.63921987	-0.01587070	-0.03338825	0.00395124	
5	0.75320210	-0.01145295	-0.05660677	0.00736719	
6	0.90442649	-0.01194511	-0.05587069	-0.02159680	
8	0.66325143	-0.01179819	-0.03593225	0.00884265	
9	1.22163682	-0.01510610	-0.20061924	0.02520893	
10	0.76361118	-0.01896173	-0.07481344	0.02180847	
12	0.73126488	-0.00515414	-0.02007368	-0.02522286	
CROWN_R = B0 + B1*(SITE) + B2*(TO_TA1) + B3*(ln[STAND_A]) + B4(TO_TA1/SITE)					
3	0.71492827	0.00292671	-0.00030155	-0.09198565	0.01886271
4	0.79028349	-0.00169732	0.00007943	-0.04394815	-0.00790070
99[*]	0.68471313	0.00068135	-0.00000720	-0.02487705	-0.00100139

[*] Clusters - 7, 11, & 13 were combined into this cluster.

Table 4. Coefficients for Crown Ratio Equations - Non-Oaks

Cluster	B0	B1	B2	B3	B4	B5
CROWN_R = B0 + B1*(TO_TA1/DBHT1) + B2(ln[STAND_A]) + B3*(ln[TO_TA1]) + B4*(ln[TO_BA1])						
2	0.65077629	0.00001585	-0.06493664	0.00035677	0.01390576	
4	0.61681247	-0.00001136	-0.00146183	-0.00685707	-0.04407853	
5	0.71433569	-0.00001321	-0.01624137	-0.02497831	-0.01476367	
6	0.80922492	-0.00004175	-0.02685701	-0.01903849	-0.02114446	
7	0.36802397	-0.00004038	-0.01651700	0.00352634	0.02700426	
8	0.73074453	-0.00000718	-0.01850771	-0.03381165	0.00237704	
10	0.73121784	-0.00003639	-0.04010656	-0.01568840	0.00741302	
11	1.24474979	-0.00004749	0.01095073	-0.03023905	-0.10812156	
12	0.30301827	-0.00011489	-0.02768460	0.04824427	-0.00873382	
14	0.80801309	-0.00001988	-0.06217830	-0.01391437	0.00153530	
16	0.58024327	-0.00006634	-0.04430699	-0.00931027	0.03935074	
19	0.65440445	0.00000699	-0.02788155	-0.00657313	-0.01117683	
20	0.58497571	-0.00000792	-0.00971895	-0.00728645	-0.02832546	
21	1.03782183	0.00001797	-0.04827582	-0.10125023	0.05461962	
CROWN_R = B0 + B1*(STAND_A) + B2*((SITE*STAND_A)/100.00) + B3*(ln(TO_BA1)) + B4*(sqrt(TAL_T1)) + B5*(SQRT(BAL_T1))						
15	0.75079723	0.00266222	-0.00748811	-0.06161525	-0.00626863	0.03579465
17	0.75718235	-0.00269809	0.00153455	-0.08382437	-0.00172909	0.02772736
99*	0.66378006	-0.00166099	0.00007289	0.01325696	-0.00308951	-0.00178924

* Clusters - 1, 3, 9, 13, & 18 were combined into this cluster.

Table 5. Coefficients for Crown Ratio Equations - Pines

<table>
<tr><th>Cluster</th><th>B0</th><th>B1</th><th>B2</th><th>B3</th><th>B4</th></tr>
<tr><td colspan="6">CROWN_R = B0 + B1*([SITE*STAND_A]/100.00) + B2*([SITE*TO_BA2]/100.00)
+ B3*(SITE*DBHT2) + B4*(ln[TAL_T2])</td></tr>
<tr><td>1</td><td>0.58671978</td><td>-0.00154260</td><td>-0.00085430</td><td>0.00002096</td><td>-0.01003733</td></tr>
<tr><td>2</td><td>0.43379111</td><td>-0.00166059</td><td>-0.00101115</td><td>0.00013397</td><td>-0.00476772</td></tr>
<tr><td>3</td><td>0.59532667</td><td>-0.00158220</td><td>-0.00035415</td><td>0.00000780</td><td>-0.03170961</td></tr>
<tr><td>4</td><td>0.57858310</td><td>-0.00136857</td><td>-0.00049365</td><td>0.00000614</td><td>-0.02745300</td></tr>
<tr><td>5</td><td>0.16596777</td><td>0.00076801</td><td>0.00348249</td><td>0.00042025</td><td>-0.01397368</td></tr>
<tr><td>6</td><td>0.61825820</td><td>-0.00187729</td><td>-0.00006025</td><td>-0.00004120</td><td>-0.03936502</td></tr>
<tr><td>7</td><td>0.68482619</td><td>-0.00080745</td><td>-0.00095414</td><td>-0.00002616</td><td>-0.02442492</td></tr>
<tr><td>8</td><td>0.57962489</td><td>-0.00277728</td><td>-0.00025979</td><td>0.00000336</td><td>-0.02539228</td></tr>
</table>

Table 6. Coefficients for Crown Ratio Equations - Oaks

<table>
<tr><th>Cluster</th><th>B0</th><th>B1</th><th>B2</th><th>B3</th></tr>
<tr><td colspan="5">CROWN_R = B0 + B1*(ln[TAL_T2]) + B2(ln[STAND_AT2]) + B3*(ln[TO_BA2])</td></tr>
<tr><td>1</td><td>0.67857626</td><td>-0.01999881</td><td>-0.02430130</td><td>-0.00980732</td></tr>
<tr><td>2</td><td>0.63670670</td><td>-0.01611040</td><td>-0.03112951</td><td>0.00177135</td></tr>
<tr><td>4</td><td>0.62617555</td><td>-0.00291208</td><td>-0.03639119</td><td>-0.00273879</td></tr>
<tr><td>5</td><td>0.77268513</td><td>-0.01482497</td><td>-0.05702860</td><td>0.00613392</td></tr>
<tr><td>6</td><td>0.92013974</td><td>-0.01566130</td><td>-0.07268841</td><td>-0.00602839</td></tr>
<tr><td>8</td><td>0.70257374</td><td>-0.01414789</td><td>-0.03335369</td><td>-0.00073750</td></tr>
<tr><td>9</td><td>1.32784652</td><td>-0.01992882</td><td>-0.18582340</td><td>-0.00994076</td></tr>
<tr><td>10</td><td>0.85902067</td><td>-0.02427357</td><td>-0.06895190</td><td>-0.00054510</td></tr>
<tr><td>12</td><td>0.80082060</td><td>-0.00657727</td><td>-0.01523777</td><td>-0.04261648</td></tr>
<tr><td>99[*]</td><td>0.77501650</td><td>0.00170704</td><td>-0.04043025</td><td>-0.00997731</td></tr>
</table>

[*] Clusters - 7, 11, & 13 were combined into this cluster.

Table 7. Coefficients for Crown Ratio Equations - Non-Oaks

Cluster	B0	B1	B2	B3	B4	B5
CROWN_R = B0 + B1*(TO_TA2/DBHT2) + B2(ln[STAND_AT2]) + B3*(ln[TO_TA2]) + B4*(ln[TO_BA2])						
2	0.62180129	0.00000346	-0.05969193	0.01126605	0.00090678	
4	0.55825051	-0.00004113	-0.01687799	0.00384287	-0.03175050	
5	0.69794133	-0.00002532	-0.01454281	-0.01830821	-0.02131153	
6	0.79805477	-0.00007935	-0.02719698	-0.01107934	-0.02819772	
7	0.18518734	-0.00008614	-0.01481022	0.02665836	0.03298846	
8	0.69166192	-0.00003365	-0.01234013	-0.01990346	-0.01304923	
10	0.66045308	-0.00008336	-0.04168485	-0.00322262	0.00756447	
11	0.88998435	-0.00019138	0.02014112	0.02409889	-0.10489869	
12	0.13047278	-0.00023119	-0.02430671	0.08510241	-0.01991285	
14	0.81262402	-0.00005201	-0.05911250	-0.00796262	-0.00937431	
16	0.49861277	-0.00014914	-0.04452100	0.00633516	0.03774567	
19	0.67675808	-0.00002296	-0.03494872	-0.00236557	-0.01444909	
20	0.60469732	-0.00001528	0.00668729	-0.00205668	-0.05084870	
21	1.08977746	-0.00000372	-0.02741897	-0.09396750	0.01343640	
CROWN_R = B0 + B1*(STAND_A) + B2*([SITE*STAND_AT2]/100.00) + B3*(ln[TO_BA2]) + B4*(sqrt[TAL_T2]) + B5*(sqrt[BAL_T2])						
15	0.45496672	0.00570173	-0.01193936	0.03163636	-0.00755879	0.02580512
17	0.83950888	-0.00247987	0.00116878	-0.09304467	-0.00317068	0.02653958
99[*]	0.55713463	-0.00163836	-0.00004506	0.04333391	-0.00307408	-0.00572902

[*] Clusters - 1, 3, 9, 13, & 18 were combined into this cluster.

Table 8. Diameter Increment Clusters

Cluster	Pine		Oak		Non-oak	
1.	P131PL U131F40		L827F60 P812F40 U812H V832F50	P812F32 P827F50 U827F50 V833A	BOTHERA L540F60A P316F70 U611F40 U970H	B316MPH POTHERF70 U540MOH U693A V400P
2.	B132A P132A U131F32	P131F50 U131F31 U110F30	B802A L838A P832A	B806A P802MPO P835F50	P621F31	P621F50
3.	L131A L111F22 P110F32 U110F40	L121F22 P131F32 U121F21	B812A		L621F60	
4.	L131PL L111PL P131F31	L131F31 L111F21 V131MPO	POTHERA U831A	UOTHERA	L653MOP	U621067
5.	U121H		B833A		B400A	
6.	P132F33 V132F33	U131PL A129A	B837A U807A	P835F40	P316F60	U200A
7.	L121MPH L110F32 P110F50	L128MPH L111F40	V802A	V8320	L611F22 UOTHERMP U611F60 U621MO	P540F70 U611F31 U611F70 V621A
8.	U111PL		L807A	L819A	POTHERP	P316F40
9.	B110A P110MP P110F40 V132MPH	L111F60 P110F31 V110H	L812A	P820A	B316F50 L611F31 POTHERF50 P611F32 U400F50 V316A	B621A L611F50 P491MPO UOTHERF70 VOTHERP V611A
10.	L131F20 U111F22	P132MP	L840P	V824A	B711A L316MPO L721F60 POTHERF31 P491F50 U391A V491	L222F22 L591A POTHERMH P491F40 P970P U491F50

Table 8 (continued). Diameter Increment Clusters

11.	L128F22	U131F50	L820F40	U820F60	LOTHERF40	LOTHERF60
	V131PL				LOTHERF70	L316F60
					L611F40	L970A
					POTHERF60	P316F50
					P316MPO	P611F50
					P711F50	UOTHERO
					UOTHERF60	U316HP
					U540F60	U611F50
					VOTHERMH	V711A
12.	L121F21	L128F36	L820F50		B491A	B711F50
	L111F31	P131F40			LOTHERF50	L222F40
	P121A	U110F32			L316F40	L391H
	V110P	V131F31			L653F60	L692H
					L694F22	L694F40
					L694F60	P491F31
					P540MPH	P693H
					P693P	P762H
					P970H	U491MH
					U491P	U521A
					U694F40	U694F50
					U694F60	V693A
13.			L820F60	V806A	P621H	
14.			L820P	P827P	L221A	L316F22
					L400A	L694F31
					L721MPO	P711P
15.			L822A	U802A	L621MO	P621F40
16.			L827F40	P802F31	U691A	
			U812P	VOTHERA		
17.			L827F50	L827P	LOTHERP	L316F50
			P812F31	P812F50	L611F60	L693A
			P827F40	U827F40	P060A	P611F60
					P762P	U762A
18.			B832A	P835P	B693A	L222F60
			U835A	V837A	L491A	L691F60
					L694F50	P391A
					P400F40	P400MPO
					P521A	P694A
					P711F40	U316F60
					U400MPH	U653A
					V400H	
19.			LOTHERA	P802F50		
			P802F40	0837A		
			V832F40			

Table 8 (continued). Diameter Increment Clusters

20.		L831A	
21.		L835A P824A U840A V835A	
22.		P833A U827F60	
23.		L840H U819045	

Table 9. Coefficients for Diameter Increment Equations - Pines

W = B0 + B1*([SITE*PLCR]/100.00) + B2*(STAND_A) + B3*(DBHT1) + B4*(TO_BA1/SITE) +
B5*(sqrt[TAL_T1])

Cluster	B0	B1	B2	B3	B4	B5
1	-0.75175908	0.00806429	-0.01132985	0.00157051	-0.03988400	-0.02323115
2	-0.97690793	0.00815043	-0.00771632	-0.00608998	-0.03898688	-0.02174645
3	-1.06206566	0.00307892	-0.00567702	0.00252820	-0.06665636	-0.01834552
4	-0.43816368	0.00059790	-0.01077181	-0.00714177	-0.12640480	-0.02635387
5	1.07195724	-0.03956717	0.00250204	-0.03600948	-0.38184447	-0.04487584
6	-1.23278964	0.00563915	-0.00617363	0.01967963	0.03314018	-0.01863985
7	-1.42595380	0.01619828	0.00009209	-0.03658446	-0.03647473	-0.01811980
8	0.12738235	-0.00218810	-0.02551635	0.00407352	-0.15176792	-0.03106088
9	-1.10464488	-0.00657847	-0.00473796	0.01464383	-0.08749770	-0.01382970
10	-0.22525604	-0.00367436	-0.01156928	-0.00900284	0.05211989	-0.03895463
11	0.03288369	-0.02243265	0.00086374	-0.01263540	-0.14762841	-0.02612898
12	-0.86071304	0.00397704	-0.00560024	-0.01168674	-0.06934679	-0.02732836

Where,

DINC = ([W*0.35] + 1.0) ** (1.0/0.35)

Table 10. Coefficients for Diameter Increment Equations - Oaks

W = INTERCEPT + B1*(PLCR) + B2*(STAND_A) + B3*(DBHT1) + B4*(TO_BA1/SITE) + B5*(sqrt[TAL_T1])

Cluster	B0	B1	B2	B3	B4	B5
1	-1.32501399	0.62536478	-0.00298999	-0.00477197	0.00368176	-0.03132648
2	-0.69893090	-1.39469354	-0.00301444	0.00127903	-0.01642658	-0.02274301
3	-1.19931070	-0.01793073	-0.00594414	-0.00590567	0.08348777	-0.03582079
4	-0.79577436	-0.81901111	-0.00544189	0.01762343	0.02547589	-0.02125517
5	-2.11679538	2.05830852	-0.00296299	0.02138262	-0.44587966	-0.02055009
6	-1.67882541	0.32125481	-0.00383395	0.00840340	-0.07240059	-0.01829927
7	-2.30140428	1.85481096	-0.00027839	0.00562756	0.00766738	-0.02627102
8	-1.97872530	0.21271929	-0.00146257	0.02108047	-0.07086816	-0.00636795
9	-2.70774893	2.56578690	-0.00571508	0.02487778	0.09385432	-0.02360776
10	-1.91939813	0.48722724	-0.00605506	-0.00849574	0.05257516	-0.01028813
11	1.20203445	-3.70715547	-0.00785543	0.01748542	0.02500008	-0.03934875
12	-2.72672523	3.30930023	-0.00207102	-0.00657351	0.09670765	-0.03632951
13	-1.33399377	0.65613847	-0.00142158	-0.00394879	-0.07111605	-0.02428226
14	19.57062466	-38.18846567	-0.04068608	0.06684565	0.20128000	-0.05169545
15	-2.44590566	2.67112625	-0.00164263	-0.00248346	0.02445698	-0.03628908
16	-1.91519010	1.64066979	-0.00085211	-0.00821890	-0.17291823	-0.02346719
17	-0.87210940	-0.58765289	-0.00472228	0.01006620	-0.01738612	-0.02144100
18	-0.96932027	-1.06529334	-0.00532527	0.00847158	0.08144186	-0.02260131
19	-0.74987418	-0.57021006	-0.00578678	-0.00310797	0.10140864	-0.03554657
20	-14.99731693	22.09654205	0.03816865	-0.01793224	0.58597100	-0.05525150
21	-2.12058687	0.61202956	-0.00008411	0.00202469	0.00710054	-0.01818277
22	-0.57903963	-0.06720399	-0.00850916	-0.00237341	0.01434030	-0.03577062
23	-2.57541306	1.21281405	0.00080182	-0.01050180	0.02289566	-0.01699124

Where,

DINC = ([W*0.25] + 1.0) ** (1.0/0.25)

Table 11. Coefficients for Diameter Increment Equations - Non-Oaks

W = B0 + B1*(PLCR) + B2*(STAND_A) + B3*(DBHT1) + B4*(TO_BA1/SITE) + B5*(sqrt[TAL_T1])

Cluster	B0	B1	B2	B3	B4	B5
1	-2.13947221	0.21118800	-0.00071122	0.04339527	0.01381083	-0.01397865
2	-1.42372883	1.94210085	-0.00626071	-0.01925349	0.04625379	-0.03884221
3	7.76276114	-16.42481019	-0.01039097	-0.00526574	-0.40325556	-0.03398598
4	-0.01147462	-1.71999703	-0.00478461	0.01041694	-0.15415411	-0.03744622
5	0.82591182	-5.05852615	-0.01529672	0.04818579	0.01617225	-0.01474917
6	-1.63291141	-0.70216262	-0.00008131	0.03768434	-0.02364058	-0.01524475
7	-1.20482426	-0.06903728	-0.00481095	0.01214267	0.01873088	-0.02619186
8	-0.41299856	-2.27238536	-0.00631562	0.04564528	-0.10769231	-0.01291362
9	-1.52526289	0.03120181	-0.00417812	0.01428138	0.05235534	-0.02391424
10	-2.20095830	0.57091372	-0.00250353	-0.02521788	0.07363077	-0.01035861
11	-1.41045273	-0.60352128	-0.00404528	0.01640188	0.02463621	-0.01652395
12	-2.28900036	0.55564419	-0.00153230	0.00991791	0.00154364	-0.00861532
13	-8.20024938	13.90509111	0.01443199	0.00986969	-0.00153866	0.00161674
14	-1.34449583	-0.06537910	-0.00559050	0.00635124	0.00256852	-0.01967158
15	-0.61982843	-0.04823953	-0.00475800	-0.02121113	0.21382103	-0.04967325
16	-5.45943363	10.37694935	0.02879308	-0.07875779	-0.20439142	-0.10490343
17	-1.75875152	0.52192240	-0.00309983	0.01508418	-0.09567373	-0.01377002
18	-2.39501254	0.36726507	-0.00084662	0.02627356	0.04581283	-0.01024107

Where,

DINC = ([W*0.20] + 1.0) ** (1.0/0.20)

Table 12. BOLE Length Clusters

Cluster	Pine		Oak		Non-oak	
1.	B110A	L128F36	POTHERH	P802MPH	BOTHERA	L316MPH
	P131F31	U131F31	U802A		POTHERF50	UOTHERF50
	U131F40					
2.	B132A	L111F22	POTHERA	POTHERF50	P611F60	U611MPH
	L111F40	POTHERA	B812P	U827F50		
	U110F32					
3.	L121MPH	L131F40	P837A		L611MPH	L694F40
	U131F50				L694H	P693A
					V400A	
4.	V110H		UOTHERF50		B621A	
5.	L131F31	L131MH	B833A	B837A	P612H	U621F60
	P131F40	P131F50	P832A			
6.	U131PL	U121A	B832A	LOTHERF50	LOTHERMPH	L316F60
	U131MPO		L820F50	L820F60	L691A	L694F60
			L838A	P802F60	POTHERF70	P316F50
			U820F50	U820MPH	P316F70	UOTHERMPH
7.	L11F60	L121F21	L812A	UOTHERA	P621F50	P621P
			U812A		U621MPH	
8.	L131PL	L111PL	B802A	B806A	B316A	L222F40
	L111MPO	V110P	L827F60	P802F50	P400F50	P611F40
	V131A		P812F50	P820A	U400F50	
			P827MPH	P833A		
			P835F50	P835MPH		
9.	P132A	U1100MPH	V802A		P491MPH	
	V132A					
10.	L121F22		L820MPH	P827F50	L222MPH	U653A
			U827MPH			

Table 12 (continued). BOLE Length Clusters

11.	U111A	L822A V837A	LOTHERF60 L400A POTHERMPH
12.	A129A	L827F50 L827MPH POTHERMPH U835A VOTHERA	P400MPH P611F31 P711A
13.	L128MPO	P812F40 V832F50 V832MPH	L611F40 P611MPH
14.	L131MPO P131PL P131F32		L540A U400MPH U611F40 V621A
15.			L555A UOTHERF60 U694MPH
16.			L222F60 P694A U619A
17.			B400A L221A L611F50 L611F60 L653A P611F50 U540A U970A
18.			P540A P621F40 U611F50 U611F60 U694F60
19.			L694P L970A P316MPH P970A U316A VOTHERA
20.			L621A U200A

Table 13. Coefficients for Bole Length Equations - Pines

BOLE LENGTH = B0 + B1*((SITE*DBHT2)/100.00) + B2*(SITE*PLCR) +
B3*(BAL_T2/SITE) + B4*(TO_TA2)

Cluster	B0	B1	B2	B3	B4
1	39.01972153	3.99180016	-0.79875633	-0.95269580	-0.00067370
2	30.97143318	4.99140557	-0.67914014	0.18485098	-0.00101922
3	37.99074464	3.39231491	-0.60857461	1.21033063	0.00064769
4	14.26990172	6.91213481	-0.73296781	1.86129142	0.00036666
5	37.05009096	3.70222923	-0.65346276	1.34585696	-0.00168459
6	28.38612923	4.45845522	-0.64896485	3.60397469	-0.00303813
7	55.80657728	4.35174239	-1.13738949	-0.53589665	-0.00239366
8	24.29234475	5.38883660	-0.68540608	-0.63120150	-0.00000337
9	11.15604203	6.06818162	-0.49167233	3.80768963	0.00159825
10	63.10088950	2.45991418	-0.87090472	-3.73184530	-0.00347381
11	34.39236033	5.84085188	-1.24383871	1.35982669	0.00405467
12	72.16468006	5.53988509	-1.89621549	-1.94637422	-0.00848680
13	66.38969504	2.61791743	-0.94309257	-11.95175404	-0.00374410
14	43.68922243	4.95560908	-1.32360432	-2.21564176	-0.00051928

Table 14. Coefficients for Bole Length Equations - Oaks

BOLE LENGTH = B0 + B1*(DBHT2) + B2*(SITE) + B3*(BAL_T2) + B4*(TO_TA2) + B5*(PLCR)

Cluster	B0	B1	B2	B3	B4	B5
1	52.50031126	3.03489054	0.02492904	-0.02899222	-0.00309185	-80.85865588
2	22.90544722	2.83122631	0.20490537	0.04241212	0.00073246	-67.34047230
3	127.87164288	2.25017585	0.23182976	-0.01714174	0.00130502	-279.35981767
4	-12.57362366	2.39940996	0.27974278	-0.02918460	0.00618849	-2.42709816
5	-10.00665124	1.97965551	0.38253461	-0.00118635	-0.00304441	7.24451735
6	51.98035344	1.87333317	0.08563130	0.00525169	-0.00193369	-74.32969075
7	7.14536603	2.65281021	0.23369684	0.05243512	0.00075709	-41.17305582
8	33.35573057	2.48614798	0.06312505	0.01031642	-0.00212752	-47.09514635
9	-13.03859804	2.29443313	-0.07599553	0.04990657	-0.00214860	81.91910065
10	58.56993240	2.46374607	0.02821655	0.00041211	-0.00248301	-87.60492903
11	-23.42788398	1.54099988	0.18778656	0.07939821	0.00337934	52.86717459
12	17.36207348	3.06505208	0.12817259	-0.00918845	0.00170556	-48.44069205
13	-2.06073224	2.54503349	0.16854654	0.00487251	-0.00070350	-1.63304060

Table 15. Coefficients for Bole Length Equations - Non-Oaks

Cluster	B0	B1	B2	B3	B4	B5
BOLE LENGTH = B0 + B1*(DBHT2) + B2*(SITE) + B3*(BAL_T2) + B4*(TO_TA2) + B5*(PLCR)						
1	11.99805585	2.57071598	0.10239446	-0.01745911	-0.00026888	-22.33659577
2	-26.78619372	4.27470285	0.31258576	0.01320519	-0.00768636	6.98078503
3	11.17414893	3.45302253	0.06477151	0.00325131	-0.00099061	-28.42163995
4	218.49703327	4.08658564	0.07997534	0.01959178	-0.00893186	-518.20492317
5	127.17798701	1.08279686	0.18646014	-0.15632181	-0.00746105	-185.78633161
6	31.60793374	2.70940679	0.03503347	-0.00613777	-0.00276892	-47.16795576
7	90.32717505	2.62105177	0.15874811	-0.02722459	-0.00432662	-169.77069085
8	3.82422509	3.48634683	0.09442930	0.00060728	0.00086728	-14.90279471
9	46.31748394	5.27646110	-0.16147069	0.02861530	0.00154920	-98.80151689
10	-32.53252352	4.94947841	0.03150258	0.10328971	0.00084069	29.83539272
11	-13.69411907	3.40863928	0.20786327	-0.00447535	0.00184714	-10.45425679
12	-10.23490666	3.86878981	0.02961025	0.01115720	0.00176952	8.28936818
13	-23.04574406	3.00995490	0.18539977	-0.07156718	0.00043494	45.17757611
14	10.05131164	2.80981692	0.07122914	-0.01969680	-0.00053119	-0.88981247
15	8.56475765	2.30095453	0.10073394	-0.02510794	-0.00050817	-4.08671585
16	36.56004163	2.55226587	0.02471245	-0.02196641	-0.00160741	-40.20323175
17	13.13006481	2.73827305	0.06880837	-0.00712913	-0.00050708	-7.02088284
18	9.05231430	3.17035443	0.07022516	-0.00520148	-0.00196615	-4.09345350
19	7.07211337	3.06648069	0.08620558	-0.00615299	-0.00117936	-18.50935393
20	8.12592218	2.58756776	0.12749414	0.01032247	-0.00244715	4.55908838

Table 16. Mortality Clusters

Cluster	Pine	Oak	Non-oak
1.	P131MH U131MPH	BROA LROF50 PROF50	BOTHERMPH P611F31 V400A
2.	P110F32	BWOA PWOA ULWOA	BSOFTA L691A P611F50
3.	L131F31 L131MPH P110F40 P131MP P132A V110A	LROF40 PROMPH	U400A
4.	L111F40 POTHERA U111F22	P812F50	P400A
5.	P110F50	P802F50	LSOFTA LUPOTHERA L316A L611F60 PHARDA UDARDA
6.	L121F21	LROF60 LROMPH UROF50 UROMPH	P611MPH USOFTF60 USOFTMPH U611MPH
7.	L111F22 L121MPH U121A	L820F50 VWOA	L200MPH L222F60
8.	B132A L128A U110A U131F31	L820F60	U611F60
9.	LUOTHERA L11MPH P110F31 V132A	U827F50	LHARDA L653A L694MPH U694A VOTHERA
10.	VBOTHERA V131A	RS UROF60 VROA	L611MPH U611MPH
11.			L621A
12.			U316A
13.			P621A
14.			L694F40 PSOFTA P316A
15.			L694F60

Table 17. Coefficients for Mortality Equations - Pines

$$X = B0 + B1*(TAL\_T1) + B2*(TO\_TA1) + B3*(PLCR) + B4*(DBHT1) + B5*(SITE) + B6*(BAL\_T1)$$

Cluster	B0	B1	B2	B3	B4	B5	B6
DBHT1 > = 5.0							
1	9.17194811	-0.00573346	-0.00016929	-13.4916	-0.03196000	-0.00314735	-0.02076203
2	-0.78041095	-0.00466196	-0.00001475	2.98230661	0.17228982	0.00540931	0.01340063
3	8.53440500	-0.00113172	0.00014907	-11.8552	0.03491021	-0.01246882	-0.01759301
4	5.80978614	-0.00100925	0.00092069	-8.25446	0.04367029	-0.01022889	-0.01095206
5	13.16736467	-0.01278102	0.00046394	-24.9957	-0.02969901	-0.00161554	-0.03760419
7[•]	5.51188474	-0.00436770	0.00012803	6.76269	0.02424753	0.00636203	-0.00618504
8	3.84942026	0.00044416	-0.00002004	-2.06575	0.14475845	-0.01412170	-0.01325697
9	0.14503691	-0.00520571	0.00028770	0.97895478	-0.10301292	0.03546311	-0.00209673
10	4.10658452	0.00270978	0.00185630	-7.24557	0.35603640	-0.03159388	-0.01583754
DBHT1 < 5.0							
1	-4.82795624	-0.00053386	-0.00018473	12.9987	0.27407612	0.00686293	-0.00560184
2	-4.22323488	0.00113204	-0.00060606	15.9906	0.74043693	-0.04388052	-0.01016036
3	-6.10969109	-0.00040948	0.00039518	14.3948	0.41438918	0.01152417	-0.01153440
4	-6.73120578	-0.00050135	-0.00011996	17.531	0.50903846	0.01406976	-0.00721299
5	28.67379618	-0.00228464	0.00210310	71.2498	-0.16246518	-0.01241976	0.03520507
7[•]	1.06453275	-0.00122383	0.00031542	9.761442	0.27397747	-0.03263240	-0.00748562
8	-2.74390748	-0.00091103	-0.00009472	13.5042	0.40923931	-0.01659749	-0.00237869
9	0.82525051	-0.00126769	0.00019524	3.491764	0.39636065	-0.02809345	-0.00566541
10	9.23707964	-0.00190108	-0.00010767	-3.73246	0.57870286	-0.11775905	0.00110457

Where,

$$PMORT = \frac{1.0}{1.0 + \exp(X)}$$

[•] Cluster 6 combined with Cluster 7.

Table 18. Coefficients for Mortality Equations - Oaks

X = INTERCEPT + B1*(TAL_T1) + B2*(TO_TA1) + B3*(PLCR) + B4*(DBHT1) + B5*(SITE)

Cluster	B0	B1	B2	B3	B4	B5
DBHT1 >= 5.0						
1	2.66936794	-0.00258932	-0.00036896	-0.64893593	-0.06867221	0.00814298
2	2.55396818	-0.00151891	-0.00034787	2.11597262	-0.05036853	0.00446648
3	3.97679002	-0.00356568	0.00012581	-2.07787545	-0.06960713	0.00108828
4	-48.18904781	0.00208279	0.00139744	87.08852827	-0.03961656	0.07226881
5	10.01225107	-0.00668616	0.00085341	4.05546436	-0.08388281	-0.08536477
6	7.39530461	-0.00142417	-0.00042258	-9.59791605	-0.08285416	0.01169516
7	12.63471990	-0.00255722	-0.00033127	-13.82405997	-0.15986485	-0.00262834
8	2.17917154	-0.00819368	-0.00021723	2.82336598	-0.16705102	0.01518120
9	15.35134699	0.00480380	-0.00005074	-33.41383007	0.13909130	0.02858400
10	4.81208046	-0.00017567	-0.00015810	-6.14094769	-0.04979528	0.00237904
DBHT1 < 5.0						
1	-1.05072284	-0.00149959	0.00039873	5.47045772	0.08607928	-0.01258862
2	-2.07158146	-0.00108736	0.00035022	6.00604069	0.24231681	-0.00504600
3	-0.94729026	-0.00199005	0.00135980	3.41293074	0.09162208	-0.00310951
4	-12.46268269	-0.00223315	0.00246556	17.74409086	0.80306420	0.0101013
5	-0.18656351	-0.00162776	0.00111065	-0.60628083	0.59732820	-0.00441235
6	0.00440130	-0.00106971	0.00054342	0.28191582	0.17824063	0.00072588
7	2.43853865	-0.00112802	0.00057549	-3.20578424	0.46917434	-0.00927278
8	-4.12711915	-0.00184693	0.00234250	14.79079526	0.36799232	-0.04704037
9	-1.48608659	-0.00177910	0.00074931	1.98237548	0.40730093	-0.00067373
10	1.19924067	-0.00098588	0.00079832	0.30136686	-0.03605216	-0.01509243

Where,

$$PMORT = \frac{1.0}{1.0 + exp(X)}$$

Table 19. Coefficients for Mortality Equations - Non-Oaks

X = INTERCEPT + B1*(TAL_T1) + B2*(TO_TA1) + B3*(PLCR) + B4*(DBHT1) + B5*(SITE)

Cluster	B0	B1	B2	B3	B4	B5
DBHT1 >= 5.0						
1	3.52714453	-0.00251632	0.00010350	-3.08200601	-0.06434783	0.01785795
2	1.98549664	0.00091330	-0.00000318	0.37657831	0.03534203	-0.00358113
3	4.72968692	0.00291256	-0.00098240	-8.58074263	-0.15716321	0.04763157
4	-16.81088533	-0.00265292	-0.00020498	38.48862230	-0.01891203	0.01586478
5	2.43497118	-0.00052694	-0.00002434	-0.70263276	-0.08255141	0.00429476
6	5.90065766	-0.00351118	-0.00021588	-6.31924092	-0.07992003	0.00799488
7	4.99455867	-0.00281550	-0.00057050	3.99864451	-0.00297943	-0.02459980
8	3.69710630	0.00513631	-0.00007706	-9.43457523	0.10318536	0.01038003
9	4.10017365	-0.00397938	-0.00014222	-4.50631308	-0.10533885	0.02215372
10	1.93475993	-0.00459870	0.00050530	-3.64710591	-0.11436720	0.02830042
11	40.53076008	-0.00239376	-0.00045265	-75.06607936	-0.36238716	0.00833487
12	9.47821152	-0.00565973	-0.00007703	-18.52463026	-0.11335788	0.03130244
13	20.58806257	0.01493787	-0.00001509	-47.37625847	0.13138042	0.02200683
14	2.49851174	-0.00186261	0.00097740	-0.29686558	-0.06398131	-0.00527276
15	7.15691228	-0.00136685	-0.00054068	-7.77034764	-0.14743483	0.01537900
DBHT1 < 5.0						
1	-0.04951055	-0.00126790	0.00107019	1.12726578	0.25511728	-0.00032126
2	0.86486933	-0.00065551	0.00029503	-0.60844971	0.23001919	0.00115650
3	-1.07471291	-0.00165916	0.00250079	2.96416697	0.15472986	-0.00443655
4	-1.69016462	-0.00195444	0.00111207	8.40329369	-0.01019835	-0.00881217
5	0.22335370	-0.00053517	0.00031428	0.99304544	0.15787323	0.00016156
6	-0.68939650	-0.00013888	0.00012862	2.99308524	0.37004638	-0.01016140
7	10.97160998	-0.00158603	0.00084213	-12.79533900	0.03692028	-0.04966315
8	-14.55606230	0.00018918	-0.00063616	43.48443703	0.01971491	-0.05281810
9	1.13206962	-0.00093940	0.00074221	0.96427222	0.09311962	-0.00853496
10	-5.02564235	-0.00090392	0.00038980	11.60855380	0.21544756	-0.00083931
11	1.44205600	-0.00220658	0.00085730	10.06941333	-0.18526511	-0.04363228
12	-2.12424916	-0.00221794	0.00133600	1.03715421	0.01621064	0.02848830
13	2.25726841	-0.00065776	0.00020831	-0.86208585	0.38325174	-0.01896380
14	-2.61098182	-0.00045306	0.00085802	7.34648851	0.19918127	-0.00835737
15	7.52002453	-0.00084789	0.00041461	-13.06963919	0.27919167	-0.01480949

Where,

$$\text{PMORT} = \frac{1.0}{1.0 + \exp(X)}$$

APPENDIX 4. VOLUME EQUATIONS

This appendix documents the publications from which the various volume equations were selected.

Board foot equations were selected from the set presented by Parker *(J)*. For the pines, the equation for Scribner log rule with a form class = 78 is used. The hardwoods use the equation for the Doyle log rule with a form class = 78. Sawtimber height is calculated for these equations, by utilizing a set of equations from the Southeastern Forest Survey Unit, which predicted sawlog length = f(dbh)[1].

The number of rough cords per tree is predicted using an equation presented by Merrifield and Foil *(I)*. The equation selected estimates rough cords for form class 77. These equations were designed for estimation of Southern Pine pulpwood to a 3-inch top (d.o.b.). However, the projection system uses the equation for both pines and hardwoods. Bole length (which is to a 4-inch top) is used as the merchantable height in these equations. Therefore, caution should be exercised with these figures until more appropriate volume equations can be found.

Considerably more information was available to predict both weight and cubic foot volumes. The equations selected are presented in table 1 and table 2. The capital letter in the table refers to the publication in the Literature Cited section which is being used for the species and region combination. A small s or h symbolizes that the equations for miscellaneous soft hardwoods or hard hardwoods are respectively being utilized. For those equations which require total height, a set of equations is again used from the Southeastern Forest Survey Unit, which predicts total height = f(dbh^2).

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[1] Personal communications, December 1987, J.P. McClure, FIA, Southeastern Forest Experiment Station, Asheville, North Carolina, 28804.

Table 1. Green Weight Equations for Wood and Bark of Stem to a 4-inch Top Used in GA-TWIGS

Species code	Lcp, Ucp	Pie	Val	Blu	Equivalent species
Hard hardwoods	E h	C h	B h	D h	311, 491, 591, 680
318	A	A	A	A	
370	D	D	D	D	
400	E	C	B	D	601, 602
531	A	A	A	A	
591	D	D	D	D	
802	E	C	B	D	
806	C	C	B	B	
812	C	C	B	B	813
820	E	E	E	E	
822	K	K	K	K	804, 823, 825
827	E	E	E	E	826
831	N	N	N	N	
832	C	C	C	C	
833	D	D	D	D	
834	G	G	G	G	830, 828, 838
835	B	B	B	B	807, 816, 819, 824 840, 841, 899
837	D	D	D	D	
901	D	D	D	D	
540	L	L	L	L	
Soft hardwoods	E s	C s	B s	D s	313, 555, 651, 652, 653, 691, 740, 920, 970
221	F	F	F	F	220
316	E	C	D	D	
460	M	M	M	M	
611	E	C	B	B	
621	E	C	B	D	
693	D	D	D	D	
694	E	E	D	D	
731	C	C	C	C	
950	D	D	D	D	
Pines					
110	F	F	F	F	
111	F	F	F	F	
121	F	F	F	F	
129	F	F	F	F	
131	F	F	F	F	
132	F	F	F	F	
260	F	F	F	F	

Table 2. Cubic Foot Equations for Wood Only of Stem to a 4-inch Top Used in GA-TWIGS

Species code	Lcp, Ucp	Pie	Val	Blu	Equivalent species
Hard hardwoods	E h	C h	B h	D h	311, 318 491, 531, 591, 680
370	D	D	D	D	
400	E	C	B	D	601, 602
540	L	L	L	L	
802	E	C	B	D	
806	C	C	B	B	
812	C	C	B	B	813, 828, 830, 834
820	E	E	E	E	
822	K	K	K	K	804, 823, 825
827	E	E	E	E	826
831	N	N	N	N	
832	C	C	C	C	
833	D	D	D	D	
835	B	B	B	B	807, 816, 819, 824, 840, 841, 899
837	D	D	D	D	
901	D	D	D	D	
Soft hardwoods	E s	C s	B s	D s	313, 554, 651, 652, 653, 691, 740, 762, 920, 970
221	F	F	F	F	220
316	E	C	D	D	
460	M	M	M	M	
611	E	C	B	B	
621	E	C	B	D	
691	E	E	E	E	
693	D	D	D	D	
694	E	E	D	D	
731	C	C	C	C	
950	D	D	D	D	
970	C	C	C	C	
Pines					
110	F	F	F	F	
111	F	F	F	F	
121	F	F	F	F	
129	F	F	F	F	
131	F	F	F	F	
132	F	F	F	F	
260	F	F	F	F	

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APPENDIX 5. SPECIES CODE, COMMERCIAL TREES

Yellow Pines

107	Sand pine	*Pinus clausa*
110	Shortleaf pine	*Pinus echinata*
111	Slash pine	*Pinus elliottii*
115	Spruce pine	*Pinus glabra*
121	Longleaf pine	*Pinus palustris*
123	Table-Mt. pine	*Pinus pungens*
126	Pitch pine	*Pinus rigida*
128	Pond pine	*Pinus serotina*
131	Loblolly pine	*Pinus taeda*
132	Virginia pine	*Pinus virginiana*

Other Softwoods

010	Fraser fir	*Abies fraseri*
043	Atlantic white-cedar	*Chamaecyparis thyoides*
060	Eastern redcedar	*Juniperus virginiana*
090	Red spruce	*Picea rubens*
129	White pine	*Pinus strobus*
221	Baldcypress	*Taxodium distichum* var. *distichum*
222	Pondcypress	*Taxodium distichum* var. *nutans*
241	Northern white-cedar	*Thuja occidentalis*
260	Eastern hemlock	*Tsuga canadensis*

Soft Hardwoods

313	Boxelder	*Acer negundo*
316	Red maple	*Acer rubrum*
317	Silver maple	*Acer saccharinum*
330	Buckeye	*Aesculus* spp.
460	Hackberry	*Celtis occidentalis*
555	Loblolly-bay	*Gordonia lasianthus*
580	Silverbell (in mts.)	*Halesia* spp.
601	Butternut	*Juglans cinerea*
611	Sweetgum	*Liquidambar styraciflua*
621	Yellow-poplar	*Liriodendron tulipifera*
651	Cucumbertree	*Magnolia acuminata*
652	Magnolia	*Magnolia* spp.
653	Sweetbay	*Magnolia virginiana*
691	Water tupelo	*Nyssa aquatica*
693	Blackgum (upland)	*Nyssa sylvatica*
694	Blackgum (lowland)	*Nyssa sylvatica*
731	American sycamore	*Platanus occidentalis*
740	Cottonwood	*Populus* spp.
762	Black cherry	*Prunus serotina*
920	Willow	*Salix* spp.
950	American basswood	*Tilia americana*
970	Elm	*Ulmus* spp.

Hard Hardwoods

311	Florida maple	*Acer barbatum*
318	Sugar maple	*Acer saccharum*
370	Birch (except yellow)	*Betula* spp.
371	Yellow birch	*Betula alleghaniensis*
400	Hickory	*Carya* spp.
491	Flowering dogwood	*Cornus florida*
521	Persimmon (forest grown)	*Diospyros virginiana*
531	American beech	*Fagus grandifolia*
540	Ash	*Fraxinus* spp.
552	Honeylocust	*Gleditsia triacanthos*
591	American holly	*Ilex opaca*
602	Black walnut	*Juglans nigra*
680	Red mulberry	*Morus rubra*
802	White oak	*Quercus alba*
804	Swamp white oak	*Quercus bicolor*
806	Scarlet oak	*Quercus coccinea*
812	Southern red oak	*Quercus falcata*
813	Cherrybark oak	*Quercus falcata* var. *pagodaefolia*
817	Shingle oak	*Quercus imbricaria*
820	Laurel oak	*Quercus laurifolia*
822	Overcup oak	*Quercus lyrata*
823	Bur oak	*Quercus macrocarpa*
825	Swamp chestnut oak	*Quercus michauxii*
826	Chinkapin oak	*Quercus muehlenbergii*
827	Water oak	*Quercus nigra*
830	Pin oak	*Quercus palustris*
831	Willow oak	*Quercus phellos*
832	Chestnut oak	*Quercus prinus*
833	Northern red oak	*Quercus rubra*
834	Shumard oak	*Quercus shumardii*
835	Post oak	*Quercus stellata*
837	Black oak	*Quercus velutina*
838	Live oak	*Quercus virginiana*
901	Black locust	*Robinia pseudoacacia*

Miscellaneous Species

310	Chalk maple	*Acer saccharum* var. *leucoderme*
315	Striped maple	*Acer pensylvanicum*
319	Mountain maple	*Acer spicatum*
341	Ailanthus	*Ailanthus* spp.
352	Serviceberry	*Amelanchier* spp.
391	Blue beech	*Carpinus caroliniana*
421	American chestnut	*Castanea dentata*
451	Catalpa	*Catalpa* spp.
471	Eastern redbud	*Cercis canadensis*
521	Persimmon (field grown)	*Diospyros virginiana*
548	American mt. ash	*Pyrus americana*
581	Carolina silverbell (except mts.)	*Halesia carolina*
641	Osage-orange	*Maclura pomifera*
660	Domestic fruit (apple etc.)	*Malus* spp.
661	Chinaberry	*Melia azedarach*
692	Ogeechee gum	*Nyssa ogeche*
701	Eastern hophornbeam	*Ostrya virginiana*
711	Sourwood	*Oxydendrum arboreum*
712	Royal paulownia	*Paulownia tomentosa*
721	Redbay	*Persea borbonia*
722	Planer-tree (water elm)	*Planera aquatica*
760	Fire cherry	*Prunus pennsylvanica*
807	Bluejack oak	*Quercus incana*
816	Bear oak	*Quercus ilicifolia*
819	Turkey oak	*Quercus laevis*
824	Blackjack oak	*Quercus marilandica*
840	Dwarf post oak	*Quercus stellata* spp.
841	Dwarf live oak	*Quercus virginiana* spp.
899	Other scrub oaks	*Quercus* spp.
931	Sassafras	*Sassafras albidum*
999	Other miscellaneous trees	------

APPENDIX 6. FOREST TYPE DEFINITIONS

White Pine - Hemlock (Code 4) - Forests in which eastern white pine and hemlock, singly or in combination, comprise a majority of the stocking.

Loblolly Pine Plantation (Code 5) - Forests in which loblolly pine was artificially regenerated with acceptable survival and comprises a plurality of the stocking.

Shortleaf Pine Plantation (Code 6) - Forests in which shortleaf pine was artificially regenerated with acceptable survival and comprises a plurality of the stocking.

Longleaf Pine Plantation (Code 7) - Forests in which longleaf pine was artificially regenerated with acceptable survival and comprises a plurality of the stocking.

Longleaf Pine (Code 21) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which longleaf pine contributes the most stocking of the pines.

Slash Pine (Code 22) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which slash pine contributes the most stocking of the pines.

Loblolly Pine (Code 31) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which loblolly pine contributes the most stocking of the pines.

Shortleaf Pine (Code 32) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which shortleaf pine contributes the most stocking of the pines.

Virginia Pine (Code 33) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which virginia pine contributes the most stocking of the pines.

Redcedar (Code 35) - Forests in which redcedar comprises a plurality of the stocking.

Pond Pine (Code 36) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which pond pine contributes the most stocking of the pines.

Pitch Pine (Code 38) - Forests in which southern yellow pines, singly or in combination, comprise a plurality of the stocking, and in which pitch pine contributes the most stocking of the pines.

Oak-Pine (Code 40) - Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking but in which pines comprise 25 to 50 percent of the stocking. (Common associates include gum, hickory, and yellow-poplar.)

Oak-Hickory (Code 50) - Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking, except where pines comprise 25 to 50 percent, in which case the stand would be classified oak-pine. (Common associates include yellow-poplar, elm, maple, and black walnut.)

Chestnut Oak (Code 52) - Forests in which chestnut oak *(Quercus prinus)* comprises a plurality of the stocking.

Southern Scrub Oak (Code 57) - Forests in which blackjack, bluejack, turkey, dwarf post, and bear oak, singly or in combination, comprise a plurality of the stocking.

Oak-Gum-Cypress (Code 60) - Bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination, comprise a plurality of the stocking, except where pines comprise 25 to 50 percent, in which case the stand would be classified oak-pine. (Common associates include cottonwood, willow, ash, elm, hackberry, and maple.)

Elm-Ash-Cottonwood (Code 70) - Forests in which elm, ash, or cottonwood, singly or in combination, comprise a plurality of the stocking. (Common associates include willow, sycamore, beech, and maple.)

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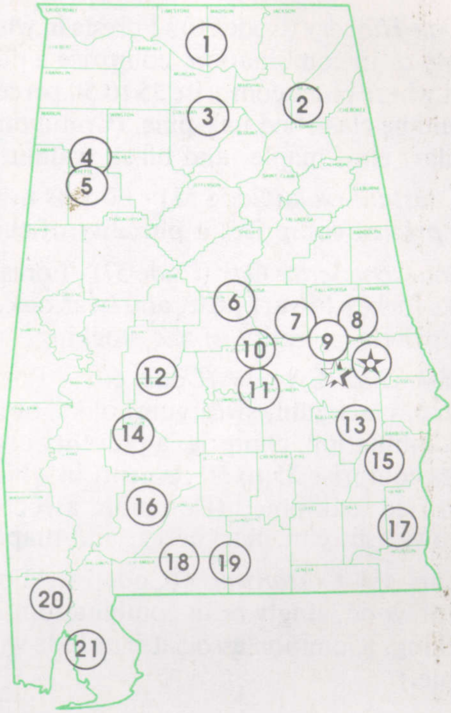

Research Unit Identification

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2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
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19. Solon Dixon Forestry Education Center, Covington and Escambia counties.
20. Ornamental Horticulture Substation, Spring Hill.
21. Gulf Coast Substation, Fairhope.