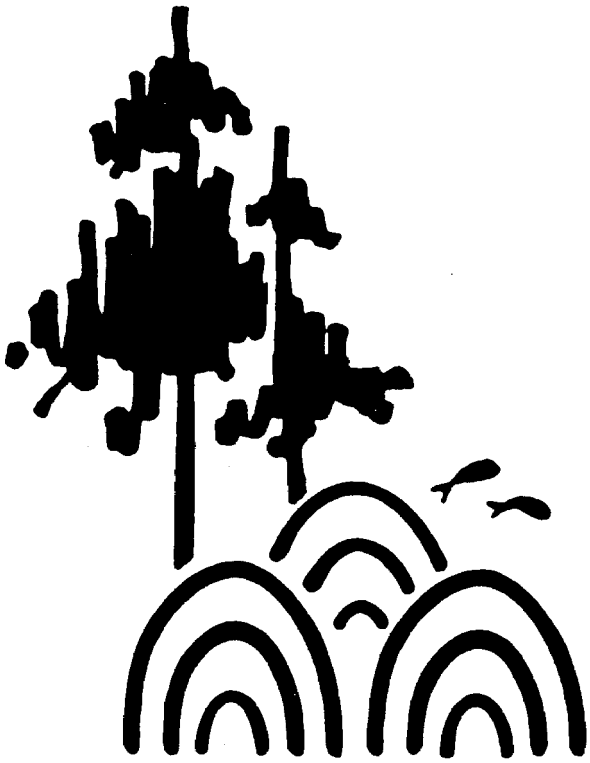
Growth and Yield of Appalachian Mixed Hardwoods After Thinning

Version 2.0



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School of Forestry and Wildlife Resources
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061
1986

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by

Wade C. Harrison
Harold E. Burkhart
Thomas E. Burk
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PREFACE

This paper presents an individual tree, distance independent growth and yield model, and software for implementing the model, for Appalachian mixed hardwoods after thinning. Research was funded by the USDA Forest Service Southeastern Forest Experiment Station under Cooperative Agreement 18-962. Those wishing to obtain copies of the software (GHAT2.0) should write to:

Harold E. Burkhart
College of Natural Resources and Environment
Virginia Tech
Blacksburg, Virginia 24061

A charge of $75.00 will be made for the Windows software. Checks should be made payable to ***Treasurer, Virginia Tech***.

Although the software has been extensively tested and checked for accuracy and, to the best of our knowledge, contains no errors, neither Virginia Tech, the Department of Forestry, the U. S. Forest Service, nor the authors claim any responsibility for errors that do arise.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Westvaco Corporation for allowing the use of its computer facilities in the completion of the original software development, and to Ernest H. Bowling for substantial contributions in the development of individual tree yield models. Appreciation is extended to Ralph L. Amateis for overseeing the development of the Windows software and the revision of the documentation.

ABSTRACT

G-HAT2.0 (Growth of Hardwoods After Thinning (Version 2.0)) is a computer program used to predict growth and yield of Appalachian mixed hardwoods after thinning. Given a tree list or stand table, along with inputs of stand age, site index, and stand basal area before thinning, G-HAT software uses species-specific individual tree equations to predict tree basal area increment and total height for the residual stand. Cubic foot volumes and bole biomass in tons, based on desired merchantability standards, may be obtained for thinned trees, the residual stand, and the projected stand. Biomass in non-merchantable tops and branches, in foliage, and the total aboveground biomass can also be obtained. G-HAT is available as a self-contained Windows application.

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GROWTH AND YIELD OF APPALACHIAN MIXED HARDWOODS AFTER THINNING Version 2.0

Wade C. Harrison, Harold E. Burkhart, Thomas E. Burk, Donald E. Beck, Charles O. Sabatia, and Thomas R. Fox

INTRODUCTION

Appalachian mixed hardwoods predominate on an estimated 26 million acres in the eastern United States. The high growth rates and high-value species found in these stands make this forest type more profitable for the management and production of timber than any other in the Appalachian region (Trimble, 1973; Smith and others, 1988). Sound management of Appalachian mixed hardwoods, including thinning for intermediate cash flows and stand improvement, must rely on growth and yield models for evaluating growth response and economic returns. The diverse mixture of species occurring in these stands creates a need for both species and size class resolution in model predictions.

G-HAT (Growth of Hardwoods After Thinning) is a computer program implementing an individual tree, distance independent growth and yield model for Appalachian mixed hardwoods after thinning. Because it is an individual tree model, it provides both species and size class resolution. It operates in a distance independent mode and thus individual tree locations or inter-tree distances are not required. Given a tree list-or stand table, along with inputs of stand age and site index, G-HAT software applies the species-specific individual tree equations developed by Harrison and others (1986) to predict tree basal area increment and total tree height for the residual stand after thinning. Cubic foot volumes (Burk and others, 1986) based on desired merchantability standards, may be obtained for thinned trees, the residual stand, and the projected stand. GHAT2.0 (Growth of Hardwoods After Thinning Version 2.0) is an extension of GHAT that has a tree and stand biomass prediction capability. In addition to basal area and cubic volume, GHAT2.0 also predicts total aboveground, merchantable stem, branches and non-merchantable tops, and foliage biomass for the stands.

DATA

Data used in model development consisted of two measurements from 66 permanent sample plots. The plots lie within the Blue Ridge physiographic province (Braun, 1950) of Virginia, North Carolina, Tennessee, and Georgia, and are sizes 0.15, 0.20 and 0.25 acre. Criteria for plot selection required that they occur in unharvested, even-aged, mixed-species stands on productive sites such as coves and moist slopes. Smith and others (1983) place such stands in the Appalachian mixed hardwood type.

Site indices for the plots were determined from selected dominants and codominants, and standardized to that of white oak using Doolittle's (1958) species conversions. Site indices for all oaks were computed with the following equation (after Olson, 1959):

$$\ln(S) = \ln(Hd) + 22.0217 \ (1/As - 1/50)$$

where: S = site index (feet), base age 50
Hd = average height of dominants and codominants (feet)
As = stand age (years), assumed to be breast height age plus four years.
1n denotes natural logarithm.

During the first measurement, 62 of the 66 plots were thinned in order to concentrate growth on high-value species and large, high--quality stems, and to improve spacing. Apart from the removal of wolf trees, these objectives generally resulted in low thinnings. Yields from thinnings were merchantable, but commercial feasibility was not a requirement. Remeasurement of all plots occurred after five growing seasons. Individual tree data recorded at each measurement included species, dbh, and total height for trees of all crown classes competing in the main canopy. Stem profile data (heights and diameters at approximate four--foot intervals along the stem) were determined with a Barr and Stroud dendrometer at the first measurement. More complete descriptions of the data are given by Harrison and others (1986) and Burk and others (1986). A data summary for the 62 thinned plots appears in Table 1.

The biomass prediction components of the model were developed using information from biomass equations of Clark III and Schroeder (1986) and Clark III et al. (1986) and from wood and bark percentage and specific gravity information in Miles and Smith (2009).

Table 2 presents the nomenclature and relative importance of all species present in the data, as well as the G-HAT abbreviation and numeric code for each species group.

Table 1. Data summary for 62 thinned plots in stands of Appalachian mixed hardwoods.

VARIABLE	MEAN	MINUMUM	MAXIMUM
Site index, base age 50 (feet)	80	62	96
Breast height age (years)			
at first measurement	40	19	58
at remeasurement	45	24	63
Dominant/codominant height			
at first measurement	72	45	93
at remeasurement	77	53	96
Stand basal area (square feet per acre)			
before thinning	113	83	193
removed in thinning	47	11	74
at first measurement	60	28	107
at remeasurement	71	34	127
net growth	11	-12	26
Trees per acre			
before thinning	407	151	1517
removed in thinning	277	51	1167
at first measurement	130	40	384
at remeasurement	125	40	384
mortality	5	0	45
Quadratic mean dbh			
before thinning	7.8	3.4	12.6
at first measurement	10.0	4.7	14.9
at remeasurement	11.0	5.9	15.9

Table 2. Species present in Appalachian mixed hardwood data. Number in parentheses is the mean percentage of plot basal area after thinning.

SPECIES	G-HAT ABBREVIATION	G-HAT NUMERIC CODE
Black Cherry Prunus serotina Ehrh. (4.3)	bc	1
Northern red oak Quercus rubra L. (16.9)	no	2
White oak Quercus alba L. (11.9)	wo	3
Yellow-poplar Liriodendron t li ifera L. (14.2)	yp	4
Black oak Quercus velutina Lam. (6.1)	bo	5
Magnolia Magnolia acuminata L. (3.3) Magnolia fraseri Walt. (0.4)	ma	6
Black Locust Robinia pseudoacacia L. (2.3)	lo	7
Basswood Tilia heterophylla Vent. (< 0.1)	bw	8
Birch Betula lenta L. (6.0) Betula allegheniensis Britton (1.1)	bi	9
Chestnut oak Quercus prinus L. (13.8)	co	10
Scarlet Oak Quercus coccinea Muenchh. (4.8)	so	11
Red Maple Acer rubrum L. (5.8)	rm	12
Miscellaneous Carya spp. (1.2) Halesia monticolp Sarg. (0.4) Fraxinus americans L. (0.3) Fagus grandifolia Ehrh. (0.2) Oxyrdendrum arboreum L. (0.2) Acer sacharrum Marsh. (0.1) Sassafrass albidum (Nutt.) Nees (0.1) Nyssa sylvatica Marsh. (< 0.1)	xx	13

MODEL COMPONENTS

G-HAT2.0 uses individual tree equations to compute growth and yield estimates. The equations include basal area increment equations, a survival equation, total height equations, volume prediction equations, and tree biomass equations. The model uses proportional constants to estimate individual tree foliage biomass from the biomass of stems and branches and it uses volume-to-biomass conversion factors to estimate merchantable stem biomass from merchantable volume.

Basal area increment equations

Species-specific multiple linear regression equations were developed to predict individual tree periodic annual basal area increment over a five--year period as a function of original tree basal area, breast height age, and stand basal area. The equations are based on individual tree growth data from the 62 thinned plots. The model form and the coefficients for each species group appear in Appendix 1. Harrison and others (1986) give more information on the development of these equations.

G-HAT2.0 software projects tree size by predicting the periodic annual basal area increment for each tree (or dbh class) in the input data and multiplying this predicted annual increment by a desired projection period of one to ten years. (Predicted tree growth is therefore linear with respect to time and will be most accurate for five-year projection periods.)

Survival equation

A single nonlinear regression equation was developed, expressing the five--year probability of survival (S) for a tree of any species as a function of predicted annual basal area increment (G) in square inches. The equation is:

$$S = .90477 + .09523 \; [\; 1 - \exp(\; -.7247\, G \;)\;]$$

The regression model was constrained so that S would lie between some threshold value and 1. The resulting equation specifies the threshold as .90477, implying that at least 9 out of 10 trees will survive over the five-year period. To develop this equation, the individual tree data from the thinned plots (excluding trees that were cut or knocked down) were ranked in terms of G and then grouped into 15 classes, 14 classes of 100 trees each and 1 class (that containing the largest values of G) of 46 trees. S was computed for each class as the proportion of trees in the class surviving over the five-year period. A mean value of G was computed for each class. Weighted least squares was used in the nonlinear regression, since each of the 15 samples were assumed to be from a binomial population, with variance given by S (1 - S).

For a desired projection period (t) of one to ten years, G-HAT2.0 software computes the predicted survival probability (St) with the following convention:

$$St = S^{t/5}$$

This convention implies that the survival probability over any number of years is the product of independent annual survival probabilities. All G-HAT2.0 software treats the predicted survival probability as a proportion. The number of trees represented by each item in a tree list or stand table is multiplied by this proportion, giving the surviving number of trees.

Total height equations

Species-specific nonlinear regression equations were developed to predict total tree height as a function of diameter at breast height (dbh) and average height of dominant and codominant oaks. These equations are based on all dbh and total height data from both measurements of the 66 plots. The model form and the coefficients for each species group appear in Appendix 1. Harrison and others (1986) give more information on the development of these equations.

Volume prediction equations

A species-specific volume prediction system was developed, expressing (1) total volume as a function of dbh and total height, (2) merchantable volume as a function of total volume, total height and merchantable height, and (3) diameter outside bark at any height on the stem as a function of total height and height on the stem. Coefficients for this system of equations were estimated simultaneously for each of nine species groups, using individual tree stem profile data available from the initial measurement of the 66 plots. The model forms and the coefficients for these species groups appear in Appendix 1. Burk and others (1986) give more information on the development of these equations.

With this volume prediction system, G-HAT2.0 software can accept merchantability standards in the form of any desired top limit (upper stem diameter, outside bark, or height to any point on the stem) and any desired stump height. When a top diameter limit is desired, G-HAT2.0 solves the taper equation (3) with a bisection algorithm to determine the height on the stem where the specified diameter occurs. Volumes may be computed as either inside or outside bark. Inside bark volumes are computed by using the species-specific ratios of diameter inside bark to diameter outside bark (as observed in the data), taken at breast height. If the ratio is assumed constant throughout the stem, inside bark volume may be computed by multiplying the squared ratio by outside bark volume.

Biomass prediction

G-HAT2.0 predicts the biomass in the stem (from 0.6 ft stump height) and branches of an individual hardwood tree using biomass equations of Clark III and Schroeder (1986). The equation form and the coefficients are given in Appendix 1. Total aboveground (stem + branches + foliage) biomass of an individual tree is estimated by scaling the stem + branches biomass estimates by a foliage proportion factor of each species. The foliage proportion factor is also used to estimate foliage biomass as a proportion of the total biomass of the tree. Foliage proportion factors for the different species were computed from the stem + branches and the total tree (stem + branches + foliage) biomass equations of Clark III et al. (1986). Biomass of the merchantable stem or of the whole stem is estimated by converting the corresponding stem volume to biomass using volume-to-biomass conversion factors of the different species. The volume-to-biomass conversion factors used in G-HAT2.0 were computed from wood and bark specific gravity information in Miles and Smith (2009). Outside or inside bark stem biomass may be obtained depending whether the volume converted to biomass is outside bark or inside bark volume. The foliage proportion factors and the biomass-to-volume conversion constants are given in Appendix 2. GHAT2.0 also estimates the biomass in branches and any non-merchantable stem tops as the positive difference between stem + branches biomass and stem biomass (to any merchantability top limit).

MODEL APPLICATION

G-HAT2.0 software was designed to facilitate the use of the equations described above. G-HAT2.0 is a Windows application for personal computers which will project a stand table and compute stock and biomass tables for thinned stands. Stand, stock, and biomass tables can be copied to the Windows clipboard for pasting into other Windows applications such as spreadsheet and graphics programs.

Applying the equations to data in which stand conditions lie beyond the range of data used for model development (Table 1) may yield illogical results, particularly in projecting growth and survival. The biomass functions in the model were developed using information from trees that were at least 5 inches in dbh. Biomass predictions for trees less than 5 inches in dbh may therefore be unreliable. The equations are intended only for even-aged stands of Appalachian mixed hardwoods in which no single species constitutes more than 60 percent of the basal area. Projections should occur immediately after thinning and should not be attempted for stands which have been thinned from above, thinned more than once, or high-graded.

G-HAT2.0 SOFTWARE

G-HAT for Windows

G-HAT2.0 is a Windows application compatible with Windows operating systems. It has been designed in a stand table format for foresters and land managers who wish to predict growth and yield after thinning. It is also useful for computing stock tables and biomass tables, as well as yields produced by various thinning methods. Given an existing stand table (numbers of trees per acre, by dbh class and species), G-HAT2.0 computes the corresponding stock table in terms of cubic foot volume to any merchantability limit and, optionally, biomass tables for the whole tree (foliage inclusive) to 0.6 ft stump, the merchantable stem, foliage, and branches and non-merchantable stem tops. If the stand table represents an unthinned stand, the user may specify which trees to thin or G-HAT2.0 can perform a low thinning automatically. Merchantable cubic foot volumes for the thinned trees and the stand, stock, and optional biomass tables for the residual stand are then displayed. After thinning, G-HAT2.0 will project the stand table for a period of one to ten years, displaying the stand's projected basal area, volume, and stand, stock, and optional biomass tables. Stand, stock, and biomass table output can be copied to the Windows clipboard for pasting into other applications such as spreadsheet, graphic, and word processing software.

User-supplied inputs to G-HAT2.0 are volume specifications (merchantability limits), breast height age of the stand (years), oak site index (feet at age 50) or height of dominant and codominant oaks (feet), stand basal area before thinning (square feet per acre) if input data represent a thinned stand or thinning criteria if the input data represent an unthinned stand, a stand table (trees per acre by species and dbh. class), and projection period length. The user may choose to have the biomass tables displayed by making the selection the “View” menu of G-HAT2.0. The user has considerable freedom in the nature of input data. However, extrapolation beyond the range of the data used in model development may generate warning messages. Such extrapolation is not recommended and may produce illogical results. Note that once a stand table has been entered, it can be saved under any filename and recalled later. Existing stand tables may be saved and recalled, so that numerous thinning trials or projection period lengths can be tested without manually re-entering the stand table.

Output from G-HAT2.0 includes displays of stand, stock, and optional biomass tables after input and after projection. If input data represent an unthinned stand, the program displays merchantable cubic foot volumes removed in the simulated thinning (total and from each cell of the stand table) as well as the residual basal area and the new stand, stock, and biomass tables. After projection, total stand basal area, basal area growth, merchantable cubic foot volume, total standing (stem + branches + foliage) biomass, merchantable biomass, foliage biomass, branches and non-merchantable tops biomass, and volume growth are displayed.

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Appendix la. Model form and species-specific coefficients for the individual tree periodic annual basal area increment equations.

MODEL: $G = a + b\ X_1 + c\ X_2 + d\ X_3$

where: G = periodic annual basal area increment over five years (square inches)
X_1 = original tree basal area, or original tree basal area divided by breast height age (square inches, or square inches/year)
X_2 = stand basal area after thinning (square feet/acre)
X_3 = stand basal area before thinning (square feet/acre)
a,b,c species-specific coefficients.

Note: If $G < 0$, then G should be set equal to 0.

G-HAT ABBREVIATION[a]	a	b	c	d
bc	1.844	1.396	-.0376	.0130
no	1.8I8	0.034[b]	-.0163	--
wo	1.311	1.124	-.0169	--
yp	1.332	1.386	-.0402	.0197
bo	1.874	1.299	-.0290	--
ma	0.320	1.441	-.0288	.0187
lo	1.991	1.020	-.0128	.0221
bi	0.305	0.965	-.0137	.0114
co	1.017	1.203	-.0151	--
so	2.155	0.041[b]	-.0313	-
rm	2.305	0.035[b]	-.0345	.0095
xx,bw	0.331	0.950	-.0293	.0188

[a]See Table 2.

[b]X_1 is original tree basal area (square inches).

Appendix lb. Model form and species-specific coefficients for the individual tree total height equations.

MODEL: $H = 4.5 + Hd [1 + a \exp(b \ Hd)] \ [1 - \exp(c \ D \ / \ Hd)]$

where: H = total height (feet)
Hd = height of dominants and codominant oaks (feet)
D = dbh (inches)
a,b,c = species-specific coefficients
exp denotes the base of the natural logarithm.

G- -HAT ABBREVIATION[a]	a	b	c
bc	.0001	.07590	-17.528
no	.1967	-.00107	-10.530
wo	.0026	.04002	-14.601
yp	.1711	.00346	-13.123
bo	.0719	.00029	-16.562
ma	.1254	.00948	- 9.630
lo	.0074	.03738	-15.932
bi	-.0992	-.00930	-17.966
co	.2046	-.00957	-13.621
so	.0021	.04569	-16.322
rm	-.1587	-.04386	-17.833
bw,xx	.3197	-.00066	-9.761

[a]See Table 2.

Appendix 1c. Model forms and species-specific coefficients for the individual tree volume prediction system.

MODELS:

(1) $V = (.1104435 / -a\ b\ ) (D^2 / H) [(H - 4.5) / 4.5]^{b+1}$
$\exp\{-a [4.5 / (H - 4.5)]^b \}$

(2) $Vm/V = 1 - \exp\{ a [h / (H - h)]^b \}$

(3) $d^2/D^2 = (h / 4.5) b-1 [(H - 4.5) / (H - h)]b+1$
$\exp< a \{ [h / (H - h)]^b - [4.5 / (H - 4.5)]^b \} >$

where: V = total volume (cubic feet, outside bark)
D = dbh (inches)
H = total height (feet)
V_m = merchantable volume (cubic feet, outside bark)
h = upper stem height (feet)
d = upper stem diameter (inches, outside bark)
a,b = species-specific coefficients
exp denotes the base of the natural logarithm.

G-HAT ABBREVIATION[a]	a	b	dib/dob[b]
bc	-1.9213	.8750	.939
no	-1.7320	.7989	.929
wo	-1.7139	.7489	.937
yp,lo,ma,bw	-1.7427	.8540	.902
bo	-1.8988	.7965	.925
rm,bi	-1.8285	.8416	.934
co	-1.6334	.7959	.909
so	-1.7901	.7993	.939
xx	-1.7854	.8304	.927

[a] See Table 2.

[b] Average of observed ratio of dbh inside bark to dbh outside bark for each species group. If the ratio is assumed constant throughout the stem, inside bark volume may be computed by squaring this ratio and multiplying it by the outside bark volume.

Appendix 1d. Model forms and species-specific coefficients for the individual tree stem + branches biomass prediction equations.

MODELS:

(1) $Biomass = a \times (D^2)^b$; for trees less than 11 inches dbh

(2) $Biomass = c \times (D^2)^d$; for trees 11 inches dbh or larger

where: *Biomass* is the oven dry weight of the tree in lbs.,
D is the dbh in inches
a, *b*, *c*, and *d* are species-specific coefficients

Table of species-specific coefficients

Species	*a*	*b*	*c*	*d*
Black Cherry (bc)*	2.02338	1.27612	5.28790	1.07581
Nothern Red Oak (no)	3.06739	1.22338	3.28071	1.20936
White Oak (wo)	1.73738	1.33404	1.69511	1.33917
Yellow-poplar (yp),	0.87948	1.40401	1.65215	1.27254
Black Oak (bo)	1.29270	1.36723	2.54650	1.22586
Magnolia (ma)†	0.87948	1.40401	1.65215	1.27254
Black locust (lo)	4.13741	1.08876	1.04649	1.37539
Basswood (bw)	1.94274	1.21008	1.47600	1.26737
Birch (bi)	4.29408	1.14203	3.80734	1.16711
Chestnut Oak (co)	0.86674	1.47585	3.40602	1.19049
Scarlet Oak (so)	1.62952	1.34103	2.94915	1.21733
Red Maple (rm)	2.02338	1.27612	5.28790	1.07581
Miscellaneous (xx)	1.73023	1.33323	3.09465	1.20063

Note: The coefficients were adopted from Clark III and Schroeder (1986). The species in the "Miscellaneous" category are given in Table 1. The coefficients for the species in the "Miscellaneous" category are the average of the individual coefficients for Blackgum, White Ash, and Hickory.

*Biomass equations not available. Red maple coefficients used due to species similarity of wood characteristics

† Biomass equations not available. Yellow-poplar coefficients due to species similarity of wood characteristics

Appendix 2a. Species-specific stem volume-to-biomass conversion factors

Species	*Conversion Factor (k)*	
	Inside Bark	Outside Bark
Black Cherry (bc)	29.328	30.509
Nothern Red Oak (no)	34.944	35.970
White Oak (wo)	37.440	37.135
Yellow-poplar (yp),	29.960	24.727
Black Oak (bo)	34.944	35.304
Magnolia (ma)	26.832	26.948
Black locust (lo)	41.184	36.881
Basswood (bw)	19.968	21.829
Birch (bi)	31.824	32.382
Chestnut Oak (co)	35.568	35.243
Scarlet Oak (so)	37.440	38.252
Red Maple (rm)	30.576	31.452
Miscellaneous (xx)	29.952	30.391

Note: The conversion factors were computed using wood and bark specific gravity information from Miles and Smith (2009) and bark proportion information from Appendix 1c. The species in the "Miscellaneous" category are given in Table 1. The conversion constants for the species in the "Miscellaneous" category are the average of the individual values for the species in this category. Stem dry weight in tons is computed as $k \times$ stem volume/2000.

Appendix 2b. Species-specific foliage biomass proportions

Species	Foliage biomass proportion (%)
White Oak,	2.7
Yellow-poplar, Magnolia	1.9
Chestnut Oak	3.2
Scarlet Oak, Northern red oak, Black oak	4.7
Red Maple, Black cherry, Birch, Basswood, Black locust	5.3
Miscellaneous	3.6

Note: The proportions were computed from stem + branch and stem + branch + foliage biomass equations of Clark III et al. (1986). The species in the "Miscellaneous" are given in Table 1. The proportion value for the species in the "Miscellaneous" category is the average of the individual values for the other species in the table. The species in bold are those whose biomass equations were available. The rest of the species have foliage biomass proportions assigned by grouping with a similar species.

Appendix 3. Input parameters, thinning and output options for G-HAT2.0.

The following paragraphs summarize input parameters, thinning options and output options for G-HAT2.0.

1. Volume specifications. These specifications are applied to every tree in the input data. Stump height (ft) must be specified. Merchantable volume can be specified inside bark or outside bark to a top diameter merchantability limit or to a merchantable height limit on the stem. Total stem volume may be specified by indicating a 0-inch top diameter above a 0-foot stump. Stump height may be set as high as desired if upper stem volumes are of interest. If G-HAT2.0 were to encounter a tree in which the specified top diameter was larger than 1.3 times dbh, or whose total height or specified top height was less than or equal to stump height, zero volume would be computed for that tree.

2. Input options. The first time G-HAT2.0 is run for any stand, the input data should be entered interactively at the keyboard. Later runs can utilize data previously saved on disk.

3. Thinned or unthinned. If the stand table to be projected represents an unthinned stand, it must be thinned prior to projection.

4. Stand-level inputs., Necessary inputs are stand age (years at breast height) and oak site index (feet at age 50). The user may enter height of dominant and codominant oaks if site index is unknown. If a thinned stand had been specified, stand basal area before thinning (square feet per acre) should be entered. This information is required for projecting tree growth for non-oak species. If the thinned stand table to be projected were predominantly oak, this information would be of little importance and the word "unknown" could be entered in response to this item.
(CAUTION: if stand basal area before thinning is omitted prior to entering a thinned stand table, predictions of individual tree growth for non-oak species are computed using an alternate set of coefficients, estimated with a model form which lacks this predictor variable. Such predictions are likely to be biased.)

5. Stand table entry. As indicated on the stand table entry side of the initialize screen, the user selects a species code, a dbh class (inches), and the number of such trees per acre. Then click the Add entry button. Dbh classes should not exceed 30 inches and trees per acre should not exceed 999. The “Remove entry” button allows the user to correct entry errors. Any number of stand table entries will be accepted. A cumulative running total of basal area and trees/ac is displayed in upper right corner of the initialize screen.

6. Summary of input data. After the stand table data are entered, the stand table may be viewed. The stock table has been computed and may also be viewed. Biomass tables may also be viewed if the option “Show Biomass (in subsequent operations)” is selected in the “View” menu of GHAT2.0.

7. Thinning options - automatic thinning. With "automatic thinning", the user inputs a desired residual basal area and the thinning algorithm effectively removes one tree (per acre) at a time until the desired residual basal area is achieved. G-HAT2.0 assumes that the red maple and "miscellaneous" species groups are undesirable; it removes all undesirables before the other species are considered for removal. Apart from this species criterion, thinning is from below. The thinning algorithm begins with the lowest dbh class in the stand table and first removes undesirables until this dbh class has been removed. Then the next higher dbh class is considered and the process is repeated. The algorithm continues through all dbh classes containing undesirables, lowest to highest. If the desired basal area has not been reached, the algorithm then returns to the lowest dbh class and begins removing desirable species (in reverse order of the species list in Table 2). Again, the dbh classes are thinned lowest to highest. Whenever the stand's residual basal area is computed as equal to or below the

desired residual basal area, the thinning procedure stops, and a list of thinned trees by species and dbh class, with associated cubic foot volumes, is displayed.

8. Projection period. Projection periods may vary from one to ten years, but dbh class projections are linear with respect to the predicted periodic annual increment. Hence, a one-year projection will indicate one-fifth of the tree growth in a five-year projection, and a ten-year projection will indicate twice the tree growth in a five-year projection. Mortality projections are compounded annually.

9. Options after projection. After projection, the user may examine the projected stand and stock tables, recall a previously saved stand table for another projection, restart the program, or stop the program. Note that further projections are not allowed for a stand that has already been projected. The growth equations are inappropriate for this purpose. In this example, the user examines the stand and stock tables, then recalls the unthinned stand table for an alternative thinning and projection. Recalling the unthinned stand table from disk involves a short delay.

10. Thinning options - selection. The idealized thinning carried out above may not be appropriate for many stands, particularly if the user has information on stem quality, spacing, or species-specific market values unique to the area. Should this be the case, the second thinning option would be more appropriate. (CAUTION: Thinning criteria which differ drastically from those of a low thinning with some selection for species and stem quality constitute an extrapolation and may yield unreliable results.) This option begins by allowing re-examination of the current (unthinned) stand table. At this point the user should make decisions on which trees to thin. This thinning algorithm simply loops through the stand table, beginning with the least desirable species and the lowest dbh class. The user enters the number of such trees that should remain. A running total of the stand's residual basal area is displayed as each stand table entry is thinned. The user may alter the stand table as many times as necessary until the desired stand structure is achieved. After the thinning, the list of thinned trees is displayed and the session continues as before with projection of the thinned stand.