United States
Department of
Agriculture

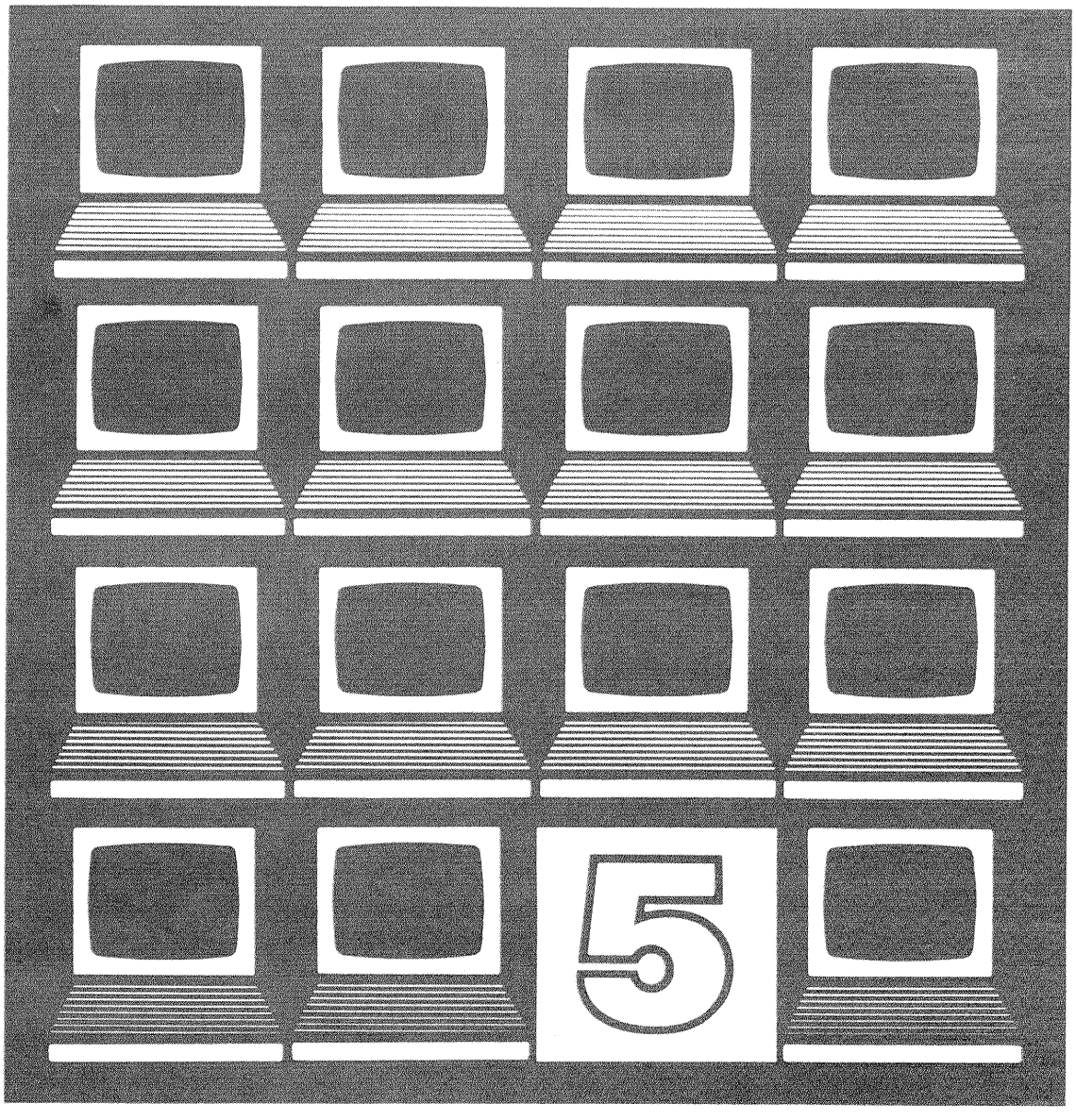
Forest
Service

North Central
Forest Experiment
Station

General Technical
Report NC-127

The Microcomputer Scientific Software Series 5

The BIOMASS User's Manual



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1992 Folwell Avenue
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Manuscript approved for publication March 24, 1989
1989

The Microcomputer Scientific Software Series 5: The BIOMASS User's Guide

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Introduction

The increased interest in complete tree utilization and the need for biomass estimates in ecological research have resulted in the development of species-specific biomass equations for most important tree species of the Lake States. BIOMASS is an interactive microcomputer program that calculates total aboveground biomass for major tree species of the Lake States using these published equations. Biomass equations use diameter or a combination of height and diameter to predict oven-dry weight of entire trees or tree components. The methods used to sample trees and develop biomass equations are reviewed in Hitchcock and McDonnell (1979), Tritton and Hornbeck (1982), and Crow and Schlaegel (1988).

Biomass Equations

In developing BIOMASS, we attempted to select the most appropriate equations available for important overstory species of the Lake States. Factors important in selecting the equations were (1) the independent variables used, (2) the geographic area in which the equations were developed, (3) the sample size and range of diameters used to develop the regression functions, and (4) the correlation coefficient or standard error of the estimate for the equation. Equations that use only diameter as an independent variable are generally reliable only in the local area in which they were developed. Equations using both diameter and height incorporate the effect of site quality into the function and are therefore applicable on a regional basis (Young 1976, Schmitt and Grigal 1981). Generalized biomass equations, which have been proven reliable over a wide geographic range, are acceptable even if height is not included (Grigal and Kernik 1984). Most of the equations used in BIOMASS are driven by height and diameter or are generalized equations, and should be applicable over most of the North Central region.

Equations developed using regression analysis are valid only within the diameter range of the trees used to construct the regression. Extrapolating beyond the range of the data used to develop the equation can result in substantial error. BIOMASS will calculate estimates outside the diameter range but will flag these values with an error code. The user must interpret these estimates cautiously.

General hardwood and softwood biomass equations (Monteith and Jacobs 1979) were included in the program to accommodate species for which biomass equations are currently unavailable, such as cottonwood, silver maple, black ash, and elm.

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Table 1.—*Biomass equations, regression coefficients, sources, and related information*

Species	Equation	r^2	Diameter range (cm)	Location	Units (Y,D,H)[1]	Source
Balsam fir (*Abies balsamea* (L.) Mill.)	Y =0.018308*D^2*H+0.000717*D^2*H (whole tree + dead branches)	0.98	5.7 - 27.4	ONTARIO	kg,cm,m	Alemdag 1982
Tamarack (*Larix laricina* (Du Roi) K. Koch)	log Y = 0.4065+2.298*log D	.98	7.6 - 30.2	MN	lb,in	Carpenter 1983
White spruce (*Picea glauca* (Moench) Voss)	Y = 0.018219*D^2*H+0.001012*D^2*H (whole tree + dead branches)	.97	6.3 - 35.8	ONTARIO	kg,cm,m	Alemdag 1982
Black spruce (*Picea mariana* (Mill.) B. S. P.)	Y = 0.153*D^2.248	.98	3.0 - 30.0	MN	kg,cm	Grigal & Kernik 1984
Jack pine (*Pinus banksiana* Lamb.)	Y = 0.0726*D^2.091*H^0.435	.99	2.8 - 32.8	Lake States	kg,cm,m	Green & Grigal 1978
Red pine (*Pinus resinosa* Ait.)	Y = 0.03556*D^1.8869*H^0.8693	.99	10.4 - 27.2	MN,MI,WI	kg,cm,m	Alban & Laidly 1982
Eastern white pine (*Pinus strobus* L.)	Y = 0.5209+0.07434*D-0.5439*H + 0.0001516*D^2*H	.98	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
Northern white-cedar (*Thuja occidentalis* L.)	ln Y = -2.3939+1.8187*ln D+0.4796*ln H	.99	2.2 - 30.2	New Brunswick	kg,cm,m	Ker 1980
Eastern hemlock (*Tsuga canadensis* (L.) Carr.)	Y = 1.4081+0.1824*D-1.4563*H+ 0.0001842*D^2*H	.99	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
Red maple (*Acer rubrum* L.)	ln Y = -1.545+0.923*ln (D^2*H)	.97	10.0 - 52.2	Lake States	lb,in,ft	Crow & Erdmann 1983
Sugar maple (*Acer saccharum* Marsh.)	Y = 0.06116+0.1752*D-0.8988*H+ 0.0002761*D^2*H	.99	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
Yellow birch (*Betula alleghaniensis* Britton)	Y = -4.9178+0.02462*D+0.5461*H+ 0.0002773*D^2*H	.98	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
Paper birch (*Betula papyrifera* Marsh.))	Y = 0.0501*D^2.301*H^0.417	.99	0.0 - 29.5	Lake States	kg,cm,m	Schmitt & Grigal 1981
Hickory (all) (*Carya* spp. Nutt.)	Y = 0.10308*(D^2*H)^1.01605	.99	5.1 - 40.6	WV	lb,in,ft	Wiant *et al.* 1979
American beech (*Fagus grandifolia* Ehrh.)	Y = 0.78331+0.08899*D-0.529705*H+ 0.0002996*D^2*H	.97	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
White ash (*Fraxinus americana* L.)	Y = -4.17764+0.21947*D-0.44212*H+ 0.000204*D^2*H	.99	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
Yellow-poplar (*Liriodendron tulipifera* L.)	Y = 0.07599*(D^2*H)^0.99425	.99	5.1 - 40.6	WV	lb,in,ft	Wiant *et al.* 1979
Quaking aspen[2] (*P. tremuloides* Michx.)	ln Y = 0.98996(ln D^2*0.00545*H)+2.7422	.99	5.1 - 33.0	MN	lb,in,ft	Schlaegel 1975
Black cherry (*Prunus serotina* Ehrh.)	Y = 0.12968*(D^2*H)^0.97028	.99	5.1 - 40.6	WV	lb,in,ft	Wiant *et al.* 1979
White oak (*Quercus alba* L.)	Y = 0.08782*(D^2*H)^1.0206	.99	5.1 - 40.6	WV	lb,in,ft	Wiant *et al.* 1979
Northern red oak (*Quercus rubra* L.)	Y = 9.68288+0.42137*D-4.16579*H+ 0.000265*D^2*H	.99	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
Black oak[3] (*Quercus velutina* Lam.)	Y = 0.14206*(D^2*H)^0.97268	.99	5.1 - 40.6	WV	lb,in,ft	Wiant *et al.* 1979
American basswood (*Tilia americana* L.)	Y = 1.4416*D^2.5328	.96	6.3 - 50.8	WV	lb,in	Brenneman *et al.* 1978
General hardwood	Y = 0.31666+0.04666*D-0.2082455*H+ 0.0002549*D^2*H	.96	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979
General softwood	Y = 1.57734+0.13039*D-1.21916*H+ 0.0001774*D^2*H	.90	2.5 - 55.0	NY	kg,mm,m	Monteith & Jacobs 1979

[1] Y = oven-dry mass, D = diameter at breast height, and H = height.
[2] equation also used for Bigtooth aspen, (*Populus grandidentata* Michx.)
[3] equation also used for Northern pin oak, *Quercus ellipsoidalis* E. J. Hill

Outputs from the general equations are flagged. New biomass equations may be added to the program as they become available.

Most of the equations used in BIOMASS were developed in the Lake States area. In some cases, equations from this region were not available, so biomass equations developed in other parts of the eastern United States and Canada were used. Efforts were made to ensure that these equations included height as an independent variable. The equations used by BIOMASS, their regression coefficients, diameter ranges, correlation coefficients, and sources are presented in table 1. Nomenclature for overstory species follows Little (1979).

Field Sampling

BIOMASS is designed to handle standard timber cruise data collected from fixed area or variable radius (point) sample plots. Average plot heights and diameters may also be used. BIOMASS operates at the stand level, and assumes that one or more plots/points have been sampled per stand. The program uses English units for data input: diameter at breast height in inches and total height in feet. Species are coded using the standard Forest Service three digit coding system (USDA Forest Service 1972). BIOMASS will generate tree, plot, and stand level summaries, in either English or metric units.

Program Overview

The BIOMASS program comprises three major sections: an input routine that controls data entry and file organization, a calculation routine that processes the input data, and an output routine that expands the data to an areal basis and controls the screen and printer outputs. Data may be entered from the keyboard or read from an existing disk file. The program is interactive and menu-driven, consisting of BIOMASS INPUT and OUTPUT Menus and several data entry screens. In addition to screen and printer output, BIOMASS can create disk files that summarize the input data at the individual tree, species, or plot level. The disk files are compatible with most statistical and report-generating software.

Program Setup and File Structures

Hardware Requirements

BIOMASS has been written and compiled using Microsoft QuickBASIC V 4.0. The program runs under MS-DOS on both floppy disk and hard disk-based systems. Both color and monochrome monitors are supported. A printer is needed for printer reports but not for program operation.

Installation

To install BIOMASS on a hard disk, simply copy the four BIOMASS program files (BMASS.EXE, BIOMASS.LIB, VIDPOP.COM, and BIOMASS.BAT) to a subdirectory on the hard disk. We recommend storing all program and data files in a single subdirectory.

File Structures

BIOMASS creates two disk files to store the input data and stand description information, and generates up to three summary files. These files may be stored on the program disk or written to a separate disk. All files associated with a given stand use the same filename but with different extensions (table 2). The user supplies a single filename (up to eight characters in standard DOS format); BIOMASS adds the appropriate extensions. The DOS user's manual includes further information on naming files.

Table 2.--Example input and output files created by BIOMASS

REDCEDAR.DES	the stand description file (input)
REDCEDAR.INP	the input data file (input)
REDCEDAR.SUM	the individual tree biomass file (output)
REDCEDAR.SP	the species-level summary file (output)
REDCEDAR.PL	the plot-level summary file (output)

Caution: If the user specifies a filename that already exists, **the previously stored files will be erased !**

The BIOMASS files are described below:

The Stand Description File

The stand description file stores the basic sampling information, and is created when new stand data are entered. Information stored in this file includes the stand name and location, sampling method (fixed or variable plots), plot size or basal area factor (BAF), crew, date, number of plots sampled, and maximum number of trees on a plot. The stand description file has the filename extension **DES**.

A typical stand description file is as follows:
"Red Cedar 1","T4N R1W Sec. 22","F",.1,"Cole, Zak","4/1/85",3,9

This stand was sampled using three fixed area plots, each 0.1 acre in size, with a maximum of nine trees on any plot.

The Input Data File

The input data file contains the information associated with individual sample trees. Input data files have the file extension **INP**. Sample data may be entered through the BIOMASS data input routine, or read into the program from an external data file (see below). Each line of the file contains data for one sample tree; these data are the plot number, the numeric species code, diameter at breast height (d.b.h.) in inches, and total tree height in feet. Plots are stored in sequential order.

An input data file may be created by a text editor, word processor, or a previous run of BIOMASS. The file must have the filename extension **INP**, e.g. REDCEDAR.INP. The file must be in comma or space-delimited ASCII format, with no special formatting or control characters. Each line must consist of individual tree data in the following order:

plot number, species code, d.b.h. in inches, total height in feet.

The file must be sorted by increasing plot numbers. The following are two example input data files:

COMMA-DELIMITED FORMAT	SPACE-DELIMITED FORMAT			
1,316,12.5,56	1	316	12.5	56
1,743,15,71	1	743	15.0	71
2,837,8,38	2	837	8.0	38
2,802,10.8,54	2	802	10.8	54
2,802,7,38	2	802	7.0	38
3,125,6.0,32	3	125	6.0	32
3,129,12.0,41	3	129	12.0	41
3,12,14.0,61	3	12	14.0	61
3,74,8.0,42	3	74	8.0	42

The Output Files

The input data files are read into the calculation routine of BIOMASS. The species codes are used to transfer the height and diameter data to the appropriate biomass equations. The calculated biomass values are then written to a summary file, which has the extension **SUM**.

The summary file is a fixed-format ASCII file containing the raw input data and the calculated biomass values in metric and English units. The columns of the summary file are as follows: plot number, species code, diameter in inches, diameter in centimeters, height in feet, height in meters, aboveground dry weight in pounds, aboveground dry weight in kilograms, and an error code. An example of the summary data file is shown below:

1	316	12.5	31.8	56	17	928	421	0
1	743	15.0	38.1	71	22	1291	586	1
2	837	8.0	20.3	38	12	279	127	0
2	802	10.8	27.4	54	16	662	300	0
2	802	7.0	17.8	38	12	191	87	0
3	125	6.0	15.2	32	10	97	44	0
3	129	12.0	30.5	41	12	424	192	0
3	12	14.0	35.6	61	19	986	447	1
3	74	8.0	20.3	42	13	303	138	0

The error codes denote biomass values that have been extrapolated beyond the range of diameters used to develop the equation or that have been calculated from the general hardwood or softwood equations. The error codes are interpreted as follows:

1 —Diameter beyond range of equation
2 —General hardwoods equation used
3 —General softwoods equation used
4 —Diameter beyond range of a general equation
5 —Unknown species code, general hardwood equation has been used

The user should again be cautioned that interpretation of data from beyond the range of the regression or from general equations may be subject to error. The magnitude of the error depends on the extent of extrapolation and the reliability of the equations.

In addition to the summary file, two other output files may be written to disk. These files are created by choosing Option 2 (View Plot-level Expansion) from the BIOMASS OUTPUT MENU. The species-level output file summarizes biomass data by plot and species. This file has the extension **SP**. The four columns of the species-level summary are plot number, species code, biomass in lb/ac, and kg/ha, respectively:

1	316	9280	10440
1	743	14120	15885
2	802	8530	9596
2	837	2790	3139
3	125	4450	5006
3	129	8230	9259
3	12	950	1069
3	74	3030	3409

The plot-level output file (extension **PL**) summarizes total biomass by plot. The three columns of this file are the plot number, and biomass in lb/ac, and kg/ha, respectively:

1	23400	26325
2	11320	12735
3	16660	18743

Using the Program

Starting the Program

BIOMASS is started by typing **BIOMASS** at the DOS prompt. The BIOMASS batch file installs the screen management utility and runs the BIOMASS program. An opening screen is displayed and after a few seconds the BIOMASS INPUT MENU appears.

Entering Biomass Data - The BIOMASS INPUT MENU

The BIOMASS INPUT MENU controls data entry and disk file management. The options for this menu are as follows:

1) Enter New Individual Tree Data For Variable Radius Plots
2) Enter New Individual Tree Data For Fixed Area Plots
3) Enter Average Plot Heights and Diameters - Variable Radius Plots
4) Enter Average Plot Heights and Diameters - Fixed Area Plots
5) Use an Existing File / List Files
6) Exit BIOMASS

An option is selected by typing the number of the option or by pointing to the option with the highlight and pressing the return (Enter) key.

Entering Data from the Keyboard - Options 1-4

Options 1 to 4 allow the user to enter data from the keyboard. The user will be asked to specify a disk drive (A-E) and a file name (up to eight letters; e.g. REDCEDAR). BIOMASS will append the appropriate file extensions to this name. The user is then presented with a screen for entering the stand description data. The screen contains the following fields:

Stand name
Stand location
Plotsize / BAF
Number of plots
Crew names
Sampling date

The Number of plots and Plotsize / BAF fields *must* be completed; the other entries are optional. When all the stand description information has been entered, the user presses the <F1> key; this writes the stand description data to disk (filename.DES) and transfers the user to the data entry screen.

Entering Individual Tree Data (Options 1, 2).—The Data Entry Screen displays the species codes and allows the user to enter the codes, heights, and diameters of up to 100 tree species/plot (fig. 1). The screen has a spreadsheet format: the user can move about the screen using the cursor arrows, <ESC>, and Return keys. Each line of the spreadsheet contains data for a single tree: the three digit species code, d.b.h. in inches, and total height in feet. All rows of data must be adjacent, i.e. there should be no blank lines within the block of data. When all data for a plot have been entered, the user presses the <F1> key; this writes the data from this plot to a disk file and begins data entry for the next plot. When the last plot has been entered, biomass values are calculated and the BIOMASS OUTPUT MENU is displayed.

Entering Average Plot Data (Options 3, 4).—Options 3 and 4 allow the user to enter average plot data. Data are entered as the *number* of trees of a given species found in a particular diameter/height class. These options simplify keyboard input of large amounts of data and allow input of data collected as stand averages. The Data Entry Screen for average data is identical to that for individual tree data, with an added column for the number of trees in a diameter-height class.

Using an Existing Data File - (Option 5).—Option 5 is used to select an existing input data file. The user is asked to specify the disk drive, and is presented with a list of the input data files on that drive. A file is selected by moving the cursor to the desired file and pressing the return (Enter) key. If needed, a stand description file may be created; otherwise the biomass values are calculated and the BIOMASS OUTPUT MENU is displayed.

Option 6 will save any open files to the designated disk and return the user to DOS.

```
                                SPECIES CODES                          Plot #  1
-------------------------------------------------------------------------------------
012= BALSAM FIR      261= E. HEMLOCK     541= WHITE ASH        809= N. PIN OAK
074= TAMARACK        316= RED MAPLE      543= BLACK ASH        833= N. RED OAK
094= WHITE SPRUCE    317= SILVER MAPLE   621= YELLOW-POPLAR    837= BLACK OAK
095= BLACK SPRUCE    318= SUGAR MAPLE    742= E. COTTONWOOD    951= AM. BASSWOOD
105= JACK PINE       371= YELLOW BIRCH   743= BIGTOOTH ASPEN   972= AM. ELM
125= RED PINE        375= PAPER BIRCH    746= QUAKING ASPEN
129= E. WHITE PINE   402= HICKORY        762= BLACK CHERRY     998= GEN. HARDWOOD
241= N. W. CEDAR     531= AM. BEECH      802= WHITE OAK        999= GEN. SOFTWOOD
-------------------------------------------------------------------------------------

TREE #                SPECIES CODE          DBH (in)       TOTAL HEIGHT (ft)
-------                -------------          --------       -----------------
  1                        ▒▒▒▒
  2
  3
  4
  5
  6
  7
  8

  <ESC> for previous column   <RETURN> for next column   <F1> when finished
```

Figure 1.--*Data entry screen.*

Calculating Biomass

After the input data have been entered or read from an external file, control of the program passes to the BIOMASS CALCULATION subroutine. A running tally appears on the screen as these values are processed. When the calculations are complete, the results are written to a summary file (e.g. REDCEDAR.SUM) and the BIOMASS OUTPUT MENU is displayed.

Viewing Biomass Output - The BIOMASS OUTPUT MENU

The BIOMASS OUTPUT MENU presents reports of the output data in individual tree or expanded format. The user may choose English or metric units for the output and may send reports to a printer. The options of this menu are:

1) View Individual Tree Biomass
2) View Plot-level Expansion (lb/ac - kg/ha)
3) View Stand Description Data
4) Change Unit Type
5) Change Output Destination
6) Return to BIOMASS INPUT MENU
7) Exit BIOMASS

Option 1 allows the user to view the individual tree biomass values. Screen display of biomass values is presented plot by plot beginning with Plot 1. The plot number is displayed in the upper left corner of the screen. A maximum of 15 trees can be displayed on the screen at one time; remaining trees are displayed on the next screen. Trees are sorted by species code and diameter.

Option 2 of the OUTPUT MENU will expand biomass estimates from the individual tree level to an areal (lb/ac or kg/ha) basis. Selecting this option will also cause the areal estimates for species and plots to be written to disk files (file extensions **SP** and **PL**, respectively). The expansion factors are calculated from the basal area factor or fixed plot size specified in the stand description file.

Option 3 displays or prints the stand description data.

Option 4 allows the user to toggle between English and metric units for the individual tree summaries.

Option 5 allows the user to produce printed reports of the stand description data, individual tree, and plot expansion biomass values. The option toggles between screen-only and screen+printer outputs.

Option 6 returns the user to the MAIN INPUT MENU; this allows data from another stand to be be entered.

Option 7 closes all files and returns the user to the operating system.

Program Availability

To obtain copies of the BIOMASS program files contact:

Forestry Sciences Laboratory
North Central Forest Experiment Station
1831 HWY 169 E.
Grand Rapids, MN 55744

A list of registered users will be maintained and users will be notified as new biomass equations are added to the program. Comments and suggestions for this program are welcome and should be sent to the above address.

The computer program is available on request with the understanding that the U.S. Department of Agriculture cannot assure the accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program.

The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

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BIOMASS is an interactive microcomputer program that uses allometric regression equations to calculate aboveground biomass of common tree species of the Lake States. The equations are species-specific and most use both diameter and height as independent variables. The program accommodates fixed area and variable radius sample designs and produces both individual tree and areal estimates of whole tree oven-dry weights.

KEY WORDS: Aboveground oven-dry weight, whole tree weight, allometric regression equations, dimension analysis.

Our job at the North Central Forest Experiment Station is discovering and creating new knowledge and technology in the field of natural resources and conveying this information to the people who can use it. As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

NORTH CENTRAL FOREST EXPERIMENT STATION