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A User's Guide for On-Site Determinations of Stand Density and Growth with a Programmable Calculator

J. C. Tappeiner
J. C. Gourley
W. H. Emmingham

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The Authors

The authors are members of the College of Forestry, Oregon State University, Corvallis. John C. Tappeiner is associate professor and Jonna C. Gourley is senior research assistant, Department of Forest Management. William H. Emmingham is extension specialist and associate professor of silviculture, Department of Forest Science.

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Introduction

To help foresters quickly determine stand growth and density in the field, we have developed two programs, FIXP for fixed plots and VARP for variable-radius plots, to be run on a hand-held calculator convenient to use on site. We believe the programs will save both inventory and office-computation time. The necessary field data are relatively easy to obtain. You supply tree height, diameter, radial growth, and a measure of stand density. The appropriate program quickly summarizes the data, providing estimates of the current growth in cubic volume, basal area, and diameter, and of number of trees, basal area, and cubic volume per acre. Because estimates can be calculated in the field, questions they may raise can be immediately resolved by observation or additional measurement.

The programs apply to any species for which you have volume equations. We provide equations from Brackett (1973) for Douglas-fir, Sitka spruce, ponderosa pine, alder, big-leaf maple, and aspen, and from Chambers and Foltz (1979) for western hemlock. The programs allow insertion of local volume equations or those with merchantability standards.

We emphasize that the programs are designed for stand examination and analysis in the field. They do not replace powerful, computer-based stand simulators that estimate and project stand growth under different densities and treatments. However, they can be used with such simulators and with site-specific information to verify growth estimates, test thinning strategies, and calibrate growth models to specific stands.

How the Programs Work

Both VARP and FIXP are constructed in two parts: a tarif-tree section and a stand-table section. We have used the tarif-volume system (Chambers and Foltz 1980, Cole 1965) because it provides a compact method for estimating volume and volume growth from individual tree measurements and volume equations. Two types of data are needed: tarif-tree measurements and a tally of trees by 2-inch diameter class. The kinds of information needed to run the programs are listed in Table 1.

TABLE 1.

INFORMATION REQUIRED FOR THE PROGRAMS.

VARP	FIXP
PLOT DATA	
Basal-area factor of prism (1 to 100)	Plot area in acres (0.01 to 100+)
Number of plots (prism points)	Species
Species	Number of years (rings) for which radial growth is measured
Number of years (rings) for which radial growth is measured	
TARIF-TREE DATA	
DBH to the nearest 0.1 inch	DBH to the nearest 0.1 inch
Height to the nearest 2 feet	Height to the nearest 2 feet
Radial growth as counted in 1/20-inch increments	Radial growth as counted in 1/20-inch increments
STAND DATA	
DBH of each "in" tree to the nearest inch	DBH of each "in" tree to the nearest inch

Tarif-Tree Section

Tarif trees should be chosen to represent the stand as a whole or the set of components (species, crown class, tree class, diameter class) for which growth and volume are to be estimated. If there is more than one species, data for each are entered and computed separately. Tarif trees should be distributed throughout the population. In relatively uniform 40- to 50-year-old Douglas-fir stands, we have found that five to ten trees give consistent estimates of total stand growth. Chambers and Foltz (1980) recommend 20 tarif trees per species and provide a method for statistical checking of sample adequacy. If you are using the tarif system for the first time or in unfamiliar stands, we suggest that you make a "sensitivity analysis," varying the number of tarif trees by diameter or crown classes to determine how growth and volume estimates are affected. Measure the tarif trees carefully (see Table 1).

Estimation of volume growth from a tarif number is made with the assumption that the number does not change as the diameter grows. The average tarif number for a given stand is used for all diameter classes. Like other volume-to-basal area ratios (VBAR's), a tarif number implies a relationship between diameter and height. When diameter increases, height must increase correspondingly to ensure that the ratio remains constant. Because tarif number may change with age, and because growth rate changes appreciably, especially in young stands, use caution when projecting volume.

The purpose of the tarif-tree section is to compute the average tarif number, TN_{av}, and the average annual diameter growth, DG_{av}, of a stand. If these values have been previously calculated, they may be entered directly. The calculator performs calculations with as many digits to the right of the decimal as you provide, but the resulting tarif numbers are printed to the nearest tenth and values for diameter growth to the nearest hundredth.

If TN_{av} and DG_{av} have not been previously calculated, individual tarif-tree numbers, TN_t, and annual diameter growth, DG_t, are determined from individual tarif-tree data by means of Equations [1], [2], and [3].

TN_t is calculated in two steps. The first step requires a species-specific equation by which total-stem cubic-foot volume for an individual tree, $CVTS_t$, is computed from values for diameter at breast height, DBH, and height, HT. Equation [1], from Brackett (1973), is for Douglas-fir, DF:

$$CVTS_{DF} = (10^{B_1})(HT^{B_2 LogDBH})(DBH^{B_3 LogDBH})(DBH^{B_4})(HT^{B_5})(HT^{B_6 LogHT}) \quad [1]$$

where

$B_1 = -3.21809$ $\quad B_4 = 2.02132$
$B_2 = 0.04948$ $\quad B_5 = 1.63408$
$B_3 = -0.15664$ $\quad B_6 = -0.16185$

Log is the logarithm to the base 10.

Six other species-specific equations are given in Table 2.

The second step for computing TN_t requires a general equation for all species (see Appendix, p. 13) and values for $CVTS_t$ and DBH:

$$TN_t = \frac{B_1 \; CVTS_t}{B_2 \left[1 + B_3 \, e^{\left(B_4 \frac{DBH}{10}\right)}\right]\left[BA_t + B_5\right] - B_6} \quad [2]$$

where

$B_1 = 0.912733$ $\quad B_4 = -4.015292$
$B_2 = 1.0330$ $\quad B_5 = 0.087266$
$B_3 = 1.382937$ $\quad B_6 = 0.174533$
$e = 2.71828$

RG_t is the length of the increment core for the growth period measured in twentieths of an inch and entered in the calculator as a whole number. For example, if the increment core is 23/20 inches long, 23 is entered. RGY is the number of years in the growth period (the number of annual rings on the increment core), usually 5 or 10.

$$DG_t = \frac{RG_t}{10\,(RGY)}. \quad [3]$$

TABLE 2.
SPECIES-SPECIFIC EQUATIONS FOR TOTAL-STEM CUBIC-FOOT VOLUME (CVTS) INCLUDING TOP AND STUMP.

Program symbol	Species	Equation[a]
HM	Western hemlock (Tsuga heterophylla)	$CVTS = (10^{-2.72170})(DBH^{2.00857})(HT^{1.08620})(10^{-.00568DBH})$
ALD	Alder (Alnus rubra)	$CVTS = (10^{-2.672775})(DBH^{1.920617})(HT^{1.074024})$
ASP	Aspen (Populus tremuloides)	$CVTS = (10^{-2.635360})(DBH^{1.946034})(HT^{1.024793})$
MAP	Big-leaf maple (Acer macrophyllum)	$CVTS = (10^{-2.770324})(DBH^{1.885813})(HT^{1.119043})$
PP	Ponderosa pine (Pinus ponderosa)	$CVTS = (10^{-2.729937})(DBH^{1.909478})(HT^{1.085681})$
SS	Sitka spruce (Picea sitchensis)[b]	$CVTS = (10^{-2.550299})(DBH^{1.835678})(HT^{1.042599})$

[a] Source for the western hemlock equation is Chambers and Foltz (1979). All other equations are from the British Columbia Forest Inventory (Brackett 1973).

[b] This equation applies only to trees less than 140 years old.

Stand-Table Section

The purpose of the stand-table section is to calculate values per acre (number of trees, basal area, volume, basal-area growth, and volume growth) for each 2-inch diameter class. VARP and FIXP differ chiefly in the way they compute number of trees per acre and basal area per acre for a class. In the VARP program, basal area per acre is computed by multiplying the total number of "in" trees by the basal area factor of the prism. The number of trees per acre in a diameter class is then computed by dividing basal area per acre by average basal area per tree of the class. Average basal area per tree corresponds to the basal area of a tree at the diameter-class midpoint. In the FIXP program, the number of trees per acre in a diameter class is computed by dividing the total number of "in" trees by the plot area. Basal area per acre of a diameter class is then computed by multiplying number of trees per acre by average basal area per tree of the diameter class.

The remaining calculations of diameter class are the same for VARP and FIXP. Volume per tree, basal area growth per tree, and volume growth per tree are computed for a tree at class midpoint. Diameter-class values are obtained by multiplying midpoint values by the number of trees in the class. The sum of diameter-class values comprises the totals per acre.

Tree Volume

Total-stem cubic-foot volume of a tree at the diameter-class midpoint, $CVTS_d$, is computed by means of a species-independent equation (see Appendix, p. 13).

[4]

$$CVTS_d = \frac{TN_{av}\left\{\left[B_2\left[1 + B_3\, e^{(B_4 \frac{D}{10})}\right]\right]\left[BA_d + B_5\right] - B_6\right\}}{B_1}$$

where
B values are the same as in Equation [2],
D is the midpoint DBH of the class, and
BA_d is the basal area, $D^2 * 0.005454154$.

Basal-Area Growth

Basal-area growth of a tree at the diameter-class midpoint (BAG_d) is computed:

[5]

$$BAG_d = \left[(D + DG_{av})^2 - D^2\right] * 0.005454154.$$

Computations are made for each diameter class with the same value for DG_{av}. Differences in growth by diameter class depend on the diameter midpoint; that is, a larger starting diameter means a larger ring of growth, even though the ring width is constant.

Volume Growth

Volume growth per tree in a given diameter class is found by computing the rate of volume growth per unit of DBH growth for a 0.01-inch increment on each side of the class midpoint diameter [Equation 6] and by multiplying that value, called the growth multiplier, GM_d (Brackett 1973), by the average diameter growth rate for the stand [Equation 7]:

[6]

$$GM_d = \frac{(CVTS_{D+0.01}) - (CVTS_{D-0.01})}{0.02}$$

where
$CVTS_{D+0.01}$ is the cubic volume of a tree with a diameter 0.01 greater than the class midpoint diameter, and
$CVTS_{D-0.01}$ is the cubic volume of a tree with a diameter 0.01 less than the class midpoint diameter.

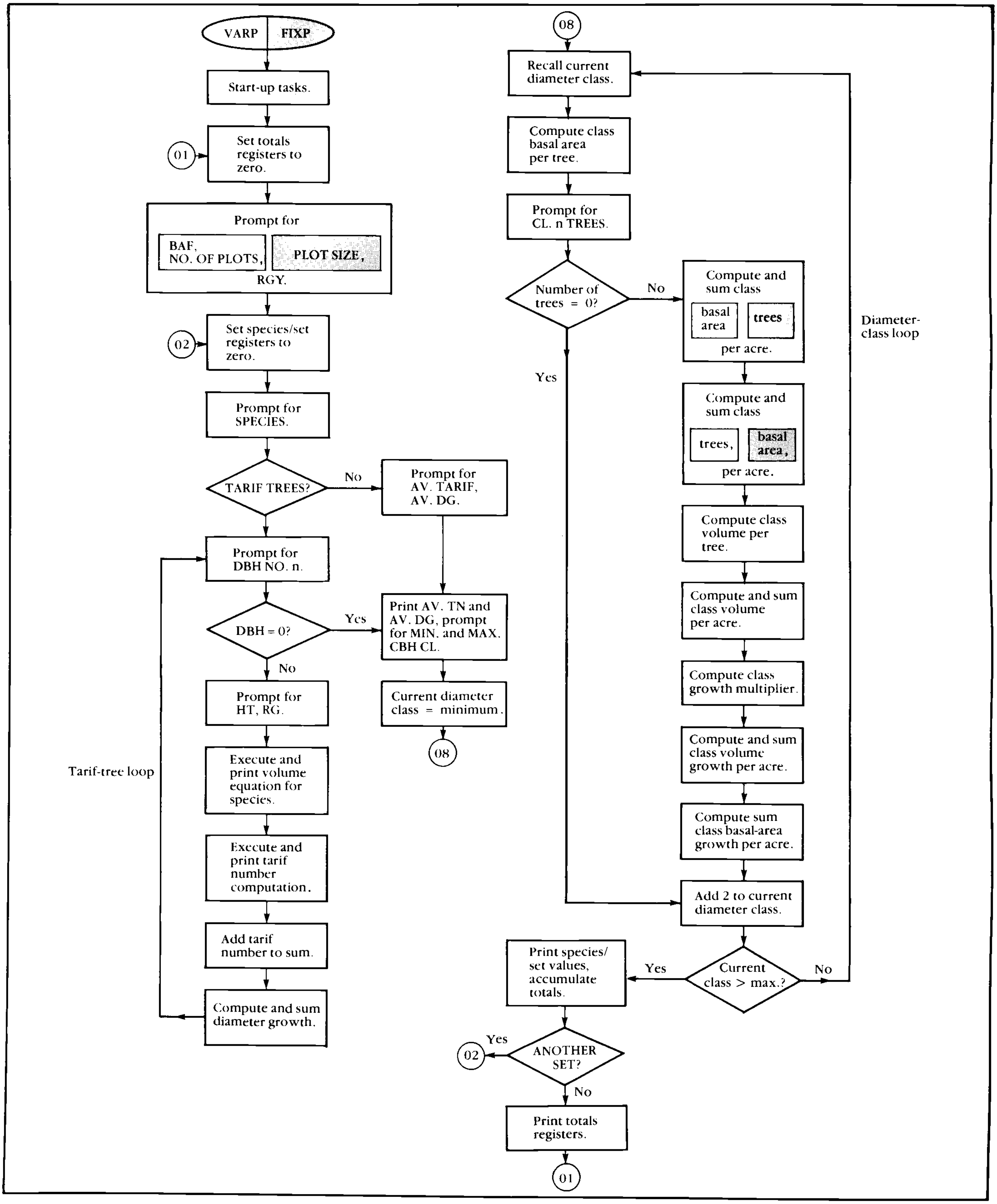
[7]

$$VOLGRO_d = GM_d * DG_d.$$

Summation by Species or Sets

The summation over diameter classes of values per acre for the number of trees, basal area, basal-area growth, volume, and volume growth gives totals per acre for species or other sets. VARP and FIXP will also sum values for several species or sets. For example, if a stand contains Douglas-fir and hemlock, the tarif-tree and plot data may be entered separately for each species, the average tarif number for Douglas-fir tarif trees applied to data for the Douglas-fir plot and the average tarif number for hemlock tarif trees to data for the hemlock plot. After completing both sets of calculations, the programs print a sum that represents full per-acre values for basal area and volume. Similarly, in thinning computations, "cut" trees and "leave" trees can be entered and computed separately, then summed; as can dominant, codominant, intermediate, and suppressed trees. The advantage of using an average tarif number is that it best represents the form of the trees of a particular species or diameter class.

VARP / FIXP Flowchart



Getting Started

The calculator

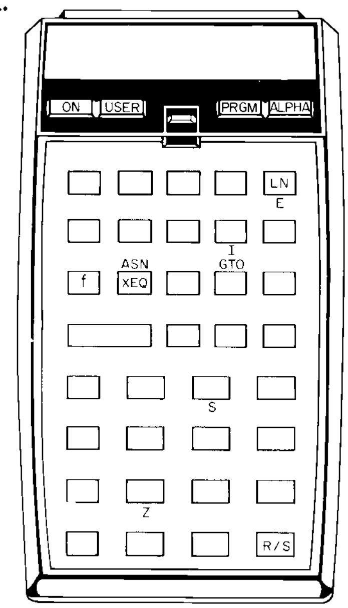
The programmable calculator we used was a Hewlett-Packard 41-C with a quad memory module (equivalent to four standard memory modules). The newer HP-41CV has the same amount of memory built in. Three standard memory modules in an HP-41C can also be used.

A printer is helpful for changing programs or for extensive data sets. A card reader is generally used for program entry.

Both VARP and FIXP are video-enabled, providing correct flag settings for duplicating the calculator display on a television screen.

Key reference

f	Gold shift key (selects alternate function)
XEQ	Execute key
LN	Natural logarithm key
f ASN	Shift and assign keys
S I Z E	Function controlling size of data storage (spelled letter by letter in alpha mode)
f GTO	Shift and go to keys
R/S	Run/stop key
ALPHA	Alpha mode toggle switch
PRGM	Program mode toggle switch



Program requirements

The main programs, VARP or FIXP, perform most of the calculations. They require 1) one or more species-specific volume equations; 2) the tarif program to compute the tarif number for each tarif tree; and 3) the cubic-volume program to compute total-stem cubic-foot volume for the typical tree in each diameter class.

Loading the programs

CAUTION: Do not connect or remove equipment from the calculator unless both pieces are turned off. Joining equipment that is turned on produces a current arc that may ruin both pieces.

Turn off the calculator. Attach the card reader. Turn on the calculator.

Adjust the data storage size to at least 26 data registers.

Key XEQ ALPHA S I Z E ALPHA. Key 026.

Be sure the calculator is not in program mode. If PRGM appears in the display, press the PRGM toggle switch. When PRGM disappears, the calculator is out of program mode.

Key f GTO.. (two periods) to place a termination mark after the last program in the calculator.

Repeat procedure

Repeat the two following steps for all programs:
Put cards in the reader. (The calculator prompts for each side of the required cards.)
Press f GTO.. after each program.

Practice runs

The following example of data analysis is for a 42-year-old Douglas-fir stand. We suggest that you follow each step in the running procedure and use the data in the sample runs to teach yourself how the programs work.

Running Procedure

When using a printer, turn off both calculator and printer, then connect them and turn the printer on. Put the printer in NORM mode. When not using a printer, R/S must be keyed after each line to program displays. Put the calculator in USER mode with or without the printer. VARP and FIXP run identically except where separate instructions are bracketed.

		Display	Response
Beginning			Key XEQ ALPHA V A R P (or F I X P) ALPHA, or key the assigned function.
Plot data	VARP	VAR PLOT	With no printer, key R/S.
	VARP	BAF?	Key the basal area factor of the prism, then R/S.
	VARP	NO. OF PLOTS?	Key the number of plots, then R/S.
	FIXP	FIX PLOT	With no printer, key R/S.
	FIXP	PLOT SIZE	Key the size of the plot, then R/S.
		RGY?	Key the number of radial growth years, then R/S.
		SPECIES?	Key the alphabetic species code, then R/S. Note that the calculator is automatically in ALPHA mode for this entry.
		DO YOU HAVE TARIF TREES?	With no printer, key R/S. Key YES to enter tarif tree data or NO to enter average tarif number and average diameter growth, then R/S.

Tarif information	DBH NO. n?	Key diameter at breast height for tarif tree "n," then R/S.
	HT?	Key total height, then R/S.
	RG?	Key radial growth, then R/S.
	CVTS=	(Digits are displayed for total-stem cubic-foot volume for tarif tree "n.") With no printer, key R/S.
	TN=	(Digits are displayed for the tarif number of tarif tree "n.") With no printer, key R/S.
	DBH FOR NO. n?	Key a zero, then R/S.
	AV. TARIF?	Key the average tarif number, then R/S.
	AV. DG?	Key average annual diameter growth, then R/S.
	AV. TN=	(Digits are displayed for the average tarif number.) With no printer, key R/S.
	AV.DG=	(Digits are displayed for average annual diameter growth.) With no printer, key R/S.
Stand table	MIN. DBH CL.?	Key minimum diameter class, then R/S.
	MAX. DBH CL.?	Key maximum diameter class, then R/S.
	CL. n TREES?	Key number of "in" trees tallied for diameter class "n," then R/S.
Species/set results	T/A= BA/A= BAG/A= D GRO= VOL/A= VG/A= VG%=	(The values displayed with the seven output items are available only once.) If you are not using a printer, record the values, then key R/S.
Repetition/ completion	ANOTHER SET?	(Select the appropriate response.) Key YES, then R/S. (The program will return to the plot data section that asks for species. The same species code can be used for more than one category; for example, "cut" and "leave" trees of the same species.) Key NO, then R/S.
	TOTALS	(The seven output items will be summed over species or sets. For VARP, the program will return to the plot-data section that asks for the basal area factor. For FIXP, the program will return to the plot-data section that asks for plot size.)

Sample Run: VARP

The sample run of VARP is for a 42-year-old Douglas-fir stand.

Calculator Display	User Input
	XEQ "VARP"
VAR PLOT BAF?	20 RUN
NO. OF PLOTS?	7 RUN
RGY?	10 RUN
SPECIES?	DF RUN
DO YOU HAVE TARIF TREES?	YES RUN
DBH NO. 1 ?	14.5 RUN
HT?	100 RUN
RG?	20 RUN
CVTS=45.1 TN=37.2 DBH NO. 2 ?	20.3 RUN
HT?	118 RUN
RG?	24 RUN
CVTS=95.9 TN=39.1 DBH NO. 3 ?	12.1 RUN
HT?	96 RUN
RG?	14 RUN
CVTS=31.4 TN=38.1 DBH NO. 4 ?	10.4 RUN
HT?	98 RUN
RG?	12 RUN
CVTS=24.4 TN=41.3 DBH NO. 5 ?	18.9 RUN
HT?	114 RUN
RG?	

Calculator Display cont.	User Input cont.
	20 RUN
CVTS=81.9 TN=38.7 DBH NO. 6 ?	0.0 RUN
AV. TN=38.9 AV. DG=0.18 MIN. DBH CL.?	10 RUN
MAX. DBH CL.?	22 RUN
CL. 10 TREES?	5 RUN
CL. 12 TREES?	12 RUN
CL. 14 TREES?	20 RUN
CL. 16 TREES?	24 RUN
CL. 18 TREES?	18 RUN
CL. 20 TREES?	6 RUN
CL. 22 TREES?	2 RUN

Stand Summary

SPECIES DF T/A= 212 BA/A= 249 BAG/A= 6.0 D GRO= 0.18 VOL/A= 10243 VG/A= 261 VG%= 2.5 ANOTHER SET?	NO RUN
TOTALS T/A= 212 BA/A= 249 BAG/A= 6.0 D GRO= 0.18 VOL/A= 10243 VG/A= 261 VG%= 2.5 BAF?	

Sample Run: FIXP

The sample run of FIXP is for a 15-year-old thinned alder stand.

Calculator Display	User Input	
	XEQ "FIXP"	
FIX PLOT		
PLOT SIZE	.20	RUN
RGY?	10	RUN
SPECIES?	ALD	RUN
DO YOU HAVE TARIF TREES?	YES	RUN
DBH NO. 1 ?	8.3	RUN
HT?	48	RUN
RG?	45	RUN
CVTS=7.9		
TN=22.1		
DBH NO. 2 ?	6.6	RUN
HT?	50	RUN
RG?	35	RUN
CVTS=5.3		
TN=25.1		
DBH NO. 3 ?	6.5	RUN
HT?	48	RUN
RG?	34	RUN
CVTS=4.9		
TN=24.1		
DBH NO. 4 ?	6.5	RUN
HT?	50	RUN
RG?	37	RUN
CVTS=5.2		
TN=25.2		
DBH NO. 5 ?	6.3	RUN
HT?	54	RUN
RG?	40	RUN

Calculator Display cont.	User Input cont.	
CVTS=5.3		
TN=27.8		
DBH NO. 6 ?	5.4	RUN
HT?	50	RUN
RG?	25	RUN
CVTS=3.6		
TN=27.5		
DBH NO. 7 ?	7.0	RUN
HT?	48	RUN
RG?	41	RUN
CVTS=5.7		
TN=23.4		
DBH NO. 8 ?	7.1	RUN
HT?	54	RUN
RG?	42	RUN
CVTS=6.6		
TN=26.4		
DBH NO. 9 ?	6.9	RUN
HT?	54	RUN
RG?	38	RUN
CVTS=6.3		
TN=26.7		
DBH NO. 10 ?	6.5	RUN
HT?	52	RUN
RG?	32	RUN
CVTS=5.4		
TN=26.3		
DBH NO. 11 ?	5.0	RUN
HT?	42	RUN
RG?	20	RUN

Calculator Display cont.	User Input cont.	
CVTS=2.6		
TN=23.8		
DBH NO. 12 ?	5.8	RUN
HT?	48	RUN
RG?	30	RUN
CVTS=4.0		
TN=25.4		
DBH NO. 13 ?	0.0	RUN
AV. TN=25.3		
AV. DG=0.35		
MIN. DBH CL.?	6	RUN
MAX. DBH CL.?	10	RUN
CL. 6 TREES?	11	RUN
CL. 8 TREES?	12	RUN
CL. 10 TREES?	2	RUN

Stand Summary

Calculator Display	User Input
SPECIES ALD	
T/A= 125	
BA/A= 37	
BAG/A= 3.5	
D GRO= 0.35	
VOL/A= 875	
VG/A= 93	
VG%= 10.6	
ANOTHER SET?	NO RUN
TOTALS	
T/A= 125	
BA/A= 37	
BAG/A= 3.5	
D GRO= 0.35	
VOL/A= 875	
VG/A= 93	
VG%= 10.6	
PLOT SIZE	

Using Stand Estimates in Prescriptions for Silviculture

Contrasting Diameter, Basal-Area, and Cubic-Volume Growth

Estimates of current stand diameter and diameter growth can be used to evaluate changes in merchantability and in logging costs and log value. For example, if the current average diameter is 14 inches and the average growth rate is 0.2 inches per year, the average diameter in 10 years (if we assume a constant growth rate) would be 16 inches; therefore log value would have increased and logging cost probably would have decreased.

Current basal area and basal-area growth are measures of stand density that can be used to evaluate the need for present or future thinning. Estimates of cubic volume and volume growth are important because they are direct measures of wood production. However, volume growth is not always directly related to diameter growth (Figure 1).

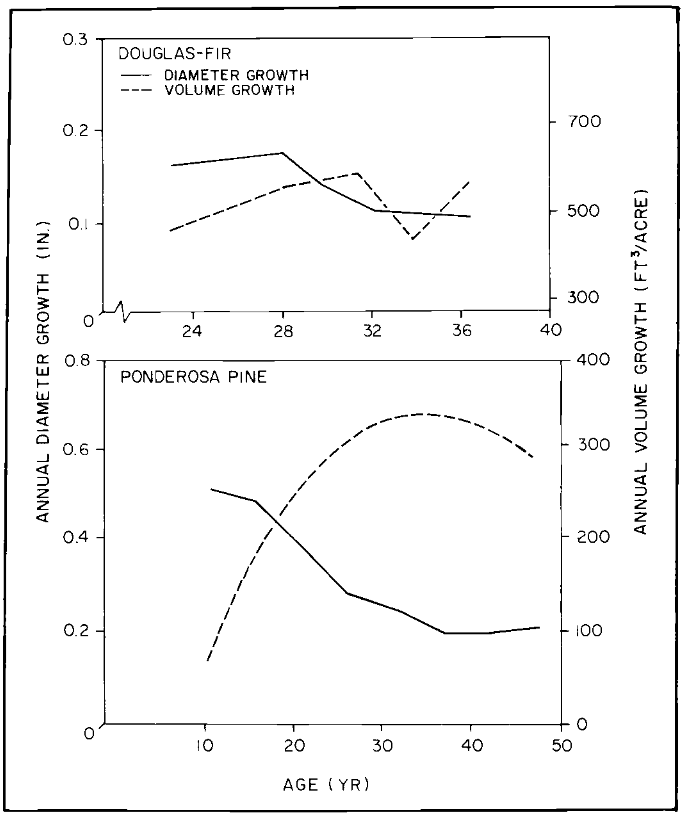


FIGURE 1.

TRENDS IN VOLUME GROWTH DO NOT CORRESPOND TO TRENDS IN DIAMETER GROWTH. (DOUGLAS-FIR DATA ARE FROM BERG AND BELL, 1979, PONDEROSA PINE DATA FROM OLIVER AND POWERS, 1978.)

Volume growth is a useful measure of stand performance because it integrates radial growth, change in stand density, and height growth; moreover, it is a measure of increase in merchantable material. Evert (1964) has shown that two stands with the same rate of basal-area growth may have very different rates of volume growth if they differ in basal area and in height growth. This was true in two young Douglas-fir stands (Tappeiner et al. 1982), both growing annually about 8 ft^2/acre in basal area but about 450 ft^3/acre and 340 ft^3/acre in volume.

Determining When to Harvest

Volume growth can be used to help select young stands for harvest. Among stands having similar sites and ages, those with high volume growth can be left to grow while poorer stands can be harvested and replaced with more vigorous ones. With estimates of current volume and volume increment, mean annual increment (MAI) and periodic annual increment (PAI) of each stand can also be compared. For example, PAI of the 50-year-old stand in Table 3 is well above MAI, which has not yet culminated. By that criterion, the stand is still vigorous. However, PAI of the 55-year-old stand is less than MAI, therefore MAI has probably culminated. Caution should be exercised in using these volume-growth estimates, as tree mortality or volume loss, due to pathogens, for example, is not part of growth calculations but can substantially affect values for net stand growth.

TABLE 3.

VALUES DERIVED FROM VARP ESTIMATES AND DFSIM[a] SIMULATIONS OF TWO DOUGLAS-FIR STANDS.

	55-yr-old stand, site index 115/50, 125 ft^2/acre		50-yr-old stand, site index 128/50, 161 ft^2/acre	
Variable	VARP	DFSIM	VARP	DFSIM
Total stem volume (ft^3/acre)	5580	4630	6695	6724
MAI[b] (ft^3/acre)	101	84	134	134
PAI[c] (ft^3/acre)	80	209	259	234
Diameter growth (in/yr)	0.14	0.2	0.23	0.21

[a] Curtis et al. (1981).

[b] Mean annual increment: total volume (no thinning or mortality) divided by stand age.

[c] Periodic annual increment: average annual growth for previous 10 years.

Evaluating the Effects of Cutting

Stand examination may be made with the purpose of evaluating whether or not a particular treatment will be profitable. A proposed level of stocking or basal area can be tested, first, by tallying "cut" and "leave" trees on each plot and choosing tarif trees to represent each class. Entering the data for all trees in an untreated stand will give growth and volume estimates that can then be compared with estimates made with an assumed treatment. In the example in Table 4, almost 2,900 ft^3/acre would be harvested. Basal area would be reduced from 266 to 190 ft^2/acre, and it is estimated that annual volume growth would be reduced 22% (from 317 to 250 ft^3/acre). If the remaining trees were vigorous and could respond to the thinning, the reduction might be only temporary.

VARP or FIXP may also analyze data plot by plot. Note that stocking in the Douglas-fir stand in Table 4 varies from 134 to 526 trees/acre and volume growth from 180 to 500 ft^3/acre annually. Analysis of individual plots may be important in such stands where great variation in growth warrants different prescriptions. The basal area of this stand appears to be increasing rapidly—from 4.5 to more than 12.0 ft^2/acre annually. In 10 years, if we assume no mortality, the basal area is expected to range from 225 ft^2/acre (Plot 1) to more than 480 ft^2/acre (Plot 2). If a thinning prescription is being considered, marking guidelines might vary with stand density.

Calibrating Growth Models

Growth estimates made with VARP or FIXP can also be used in calibrating growth models to a particular stand. For example, comparison of results of an examination in 50- and 55-year-old Douglas-fir stands with estimates from a growth model (Table 3) show that, until about 50 years of age, the 55-year-old stand produced somewhat more volume than that estimated by the stand simulator. However, in the last 5 to 10 years, diameter growth decreased sharply, and PAI and diameter growth are much less than that estimated by the simulator. Also, VARP indicates that MAI has culminated; the stand simulator indicates that it has not. The stand examination shows that estimates from the simulator should be adjusted to give more accurate projections of future stand volumes.

In the 50-year-old stand (Table 3), total volume estimated by VARP agrees with the estimate of the stand simulator, and periodic volume and diameter growth are comparable. Thus stand growth projected by the simulator can be accepted with greater confidence. Because PAI may increase or decrease rapidly with stand age or other factors, VARP or FIXP growth estimates probably should not be projected beyond 10 years.

TABLE 4.

CURRENT VALUES AND ESTIMATES OF GROWTH ON SIX PLOTS IN A 45-YEAR-OLD DOUGLAS-FIR STAND.

Plot	Trees per acre	Annual diameter growth	Basal area	Annual basal-area growth	Volume	Annual volume growth	
		in.	---- ft^2/acre	----	ft^3/acre	ft^3/acre	%
1	134	0.2	180	4.5	6,900	180	2.6
2	214	0.2	220	6.2	8,300	250	3.0
3	526	0.2	360	12.7	13,200	500	3.8
4	326	0.2	320	9.4	12,000	370	3.1
5	210	0.2	260	6.9	9,900	270	2.8
6	335	0.2	260	8.4	9,600	330	3.4
Average	290	0.2	266	8.0	9,983	317	3.1
Average after thinning[a]	160	0.25	190	6.3	7,100	250	3.5

[a] Estimates of the density and growth of trees after a hypothetical thinning of 130 trees and 76 ft^2 basal area per acre. Trees were designated on variable plots and measurements were summarized in VARP.

Literature Cited

BERG, A.B. and J.B. BELL. 1979. Levels-of-growing-stock cooperative study on Douglas-fir. Report No. 5--The Hoskins study 1963-1975. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Paper PNW 257.

BRACKETT, M. 1973. Notes on tarif tree volume computation. State of Washington, Department of Natural Resources, Olympia. Resource Management Report 24.

CHAMBERS, C.J., and B.W. FOLTZ. 1979. The tarif system--revisions and additions. State of Washington, Department of Natural Resources, Olympia. DNR Note Number 27.

CHAMBERS, C.J., and B.W. FOLTZ. 1980. Comprehensive tree-volume tarif tables. 3rd edition, State of Washington, Department of Natural Resources, Olympia.

COLE, B.L. 1965. Construction and analysis of comprehensive tree-volume tarif tables. State of Washington, Department of Natural Resources, Resource Management Report 8.

CURTIS, R.O., G.W. CLENDENEN and D.J. DeMARS. 1981. A new stand simulator for coast Douglas-fir: DFSIM users guide. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. General Technical Report PNW-128.

EVERT, F. 1964. Components of stand volume and its increment. Journal of Forestry 62:810-813.

OLIVER, W.W. and R.F. POWERS. 1978. Growth models for ponderosa pine: I. Yield of unthinned ponderosa pine plantations in northern California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Paper PSW-133.

TAPPEINER, J.C., J.F. BELL and J.D. BRODIE. 1982. Response of young Douglas-fir to 16 years of intensive thinning. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 36.

Appendices

Tarif-Number (TN) Equation

TN computes the tarif number for each tarif tree by means of Equation [2], p. 2. The program assumes that data register R_{16} contains tarif-tree diameter at breast height, DBH; R_{20} contains total-stem cubic-foot volume of the individual tarif tree, $CVTS_t$; and R_{25} contains the basal-area constant (0.005454154). Intermediate results are stored in R_{19}. The X register contains the result.

```
01♦LBL "TN"
02 RCL 16
03 10
04 /
05 -4.015292
06 *
07 E↑X
08 1.382937
09 *
10 1
11 +
12 1.0330
13 *
14 STO 19
15 RCL 16
16 X↑2
17 RCL 25
18 *
19 .087266
20 +
21 RCL 19
22 *
23 .174533
24 -
25 STO 19
26 RCL 20
27 .912733
28 *
29 RCL 19
30 /
31 RTN
32 END
```

Cubic-Volume Total-Stem (CVTS) Equation

CVTS computes the species-independent total stem cubic-foot volume by means of Equation [4], p. 3. The program assumes that data register R_{21} contains diameter, D, R_{22} contains basal area, BA, and R_{11} contains the average tarif number, TN_{av}. D may be the midpoint diameter of the class or the midpoint diameter plus or minus a small increment. BA is the basal area corresponding to D. The X register contains the result.

```
01♦LBL "CVTS"
02 RCL 21
03 10
04 /
05 -4.015292
06 *
07 E↑X
08 1.382937
09 *
10 1
11 +
12 1.0330
13 *
14 RCL 22
15 .087266
16 +
17 *
18 .174533
19 -
20 RCL 11
21 *
22 .912733
23 /
24 RTN
25 END
```

How to Change Volume Equations

The programs were written in sections in order to facilitate independent checking and easy adaptation, such as substitution of species-specific volume equations. You may wish to use local volume equations or equations that include merchantability standards.

To enter a species-specific volume equation, start by selecting an equation that uses diameter at breast height, DBH, and total tree height, HT, for calculating total-stem cubic-foot volume, CVTS. The example given here is for ponderosa pine (Brackett 1973):

$$CVTS_{PP} = (10^{-2.729937})(DBH^{1.909478})(HT^{1.085681}).$$

DBH for each tarif tree is stored in data register R_{16}, and HT in R_{17}. The main program, either VARP or FIXP, expects the answer CVTS to be stored in R_{20}. The common species code for ponderosa pine is PP. The following is the HP-41C program for ponderosa pine volume.

Step No.	Instruction	Explanation
01	LBL 'PP'	Links species code and program
02	-2.729937	Exponent of 10
03	10 ↑ X	Computes $10^{-2.729937}$
04	RCL 16	Recalls DBH
05	1.909478	Exponent of DBH
06	Y ↑ X	Computes $DBH^{1.909478}$
07	*	Multiplies $DBH^{1.909478}$ times $10^{-2.729937}$
08	RCL 17	Recalls HT
09	1.085681	Exponent of HT
10	Y ↑ X	Computes $HT^{1.085681}$
11	*	Multiplies $HT^{1.085681}$ times $(DBH^{1.090478})$ $(10^{-2.729937})$
12	STO 20	Stores result (CVTS) in register 20
13	RTN	Returns to main programs (VARP or FIXP)
14	END	Ends the program

Intermediate results in this program are stored in the "stack", a series of registers used during computations.

Species-Specific Equations

Species codes and volume equations are listed in Table 2, p. 2. The following programs assume that data register R_{16} contains tarif–tree diameter at breast height, DBH, and that R_{17} contains tarif–tree height, HT. R_{19} is available for storing intermediate results if you wish. R_{20} contains the results.

Alder

```
01♦LBL "ALD"
02 -2.672775
03 10↑X
04 RCL 16
05 1.920617
06 Y↑X
07 *
08 RCL 17
09 1.074024
10 Y↑X
11 *
12 STO 20
13 RTN
14 END
```

Aspen

```
01♦LBL "ASP"
02 -2.635360
03 10↑X
04 RCL 16
05 1.946034
06 Y↑X
07 *
08 RCL 17
09 1.024793
10 Y↑X
11 *
12 STO 20
13 RTN
14 END
```

Douglas-fir

```
01♦LBL "DF"
02 RCL 16
03 LOG
04 STO 19
05 -3.21809
06 10↑X
07 RCL 17
08 .04948
09 RCL 19
10 *
11 Y↑X
12 *
13 RCL 16
14 RCL 19
15 -.15664
16 *
17 Y↑X
18 *
19 RCL 16
20 2.02132
21 Y↑X
22 *
23 RCL 17
24 1.63408
25 Y↑X
26 *
27 RCL 17
28 ENTER↑
29 LOG
30 -.16185
31 *
32 Y↑X
33 *
34 STO 20
35 RTN
36 END
```

Western Hemlock

```
01♦LBL "HM"
02 -2.72170
03 10↑X
04 RCL 16
05 2.00857
06 Y↑X
07 *
08 RCL 17
09 1.08620
10 Y↑X
11 *
12 RCL 16
13 -.00568
14 *
15 10↑X
16 *
17 STO 20
18 RTN
19 END
```

Big-leaf Maple

```
01♦LBL "MAP"
02 -2.770324
03 10↑X
04 RCL 16
05 1.885813
06 Y↑X
07 *
08 RCL 17
09 1.119043
10 Y↑X
11 *
12 STO 20
13 RTN
14 END
```

Ponderosa Pine

```
01♦LBL "PP"
02 -2.729937
03 10↑X
04 RCL 16
05 1.909478
06 Y↑X
07 *
08 RCL 17
09 1.085681
10 Y↑X
11 *
12 STO 20
13 RTN
14 END
```

Sitka Spruce

```
01♦LBL "SS"
02 -2.550299
03 10↑X
04 RCL 16
05 1.835678
06 Y↑X
07 *
08 RCL 17
09 1.042599
10 Y↑X
11 *
12 STO 20
13 RTN
14 END
```

Data Register Assignments for VARP and FIXP

R	
00	Total weighted annual diameter growth
01	Total number of trees per acre
02	Total basal area per acre
03	Total basal area growth per acre
04	Total volume per acre
05	Total annual volume growth per acre
06	Species/set number of trees per acre
07	Species/set basal area per acre
08	Species/set annual basal-area growth per acre
09	Species/set volume per acre
10	Species/set annual volume growth per acre
11	Average tarif number
12	Average annual diameter growth
13	Basal area factor of prism
14	Years of radial growth measured
15	Species code name
16	Tarif-tree diameter
17	Tarif-tree height; current diameter class
18	Tarif-tree radial growth; maximum diameter class
19	Temporary storage
20	Tarif-tree volume; number of trees per acre in current diameter class
21	Tarif-tree count; D for CVTS
22	BA for CVTS
23	Volume for (D-.01)
24	Number of plots
25	Basal-area constant (0.005454154)

Program Listing: VARP

```
01♦LBL "VARP"
02 "VAR PLOT"
03 AVIEW
04 "COPYRIGHT 1984"
05 "OREGON STATE"
06 "UNIVERSITY"
07 "FOREST RESEARCH"
08 "LABORATORY"
09 CF 15
10 SF 16
11 SF 21
12 CF 29
13 .005454154
14 STO 25
15♦LBL 01
16 0
17 STO 00
18 STO 01
19 STO 02
20 STO 03
21 STO 04
22 STO 05
23 FIX 0
24 "BAF?"
25 PROMPT
26 STO 13
27 "NO. OF PLOTS?"
28 PROMPT
29 STO 24
30 "RGY?"
31 PROMPT
32 STO 14
33♦LBL 02
34 0
35 STO 06
36 STO 07
37 STO 08
38 STO 09
39 STO 10
40 STO 11
41 STO 12
42 STO 21
43 "SPECIES?"
44 AON
45 PROMPT
46 AOFF
47 ASTO 15
48 "DO YOU HAVE"
49 AVIEW
50 "TARIF TREES?"
51 AON
52 PROMPT
53 AOFF
54 ASTO Y
55 "NO"
56 ASTO X
57 X=Y?
58 GTO 05
59♦LBL 03
60 RCL 21
61 1
62 +
63 FIX 0
64 "DBH NO. "
65 ARCL X
66 "⊦ ?"
67 FIX 1
68 PROMPT
69 X<=0?
70 GTO 06
71 STO 16
72 FIX 0
73 "HT?"
74 PROMPT
75 STO 17
76 "RG?"
77 PROMPT
78 STO 18
79 XEQ IND 15
80 FIX 1
81 "CVTS="
82 ARCL X
83 AVIEW
84 XEQ "TN"
85 "TN="
86 ARCL X
87 AVIEW
88 ST+ 11
89♦LBL 04
90 RCL 18
91 10
92 /
93 RCL 14
94 /
95 ST+ 12
96 1
97 ST+ 21
98 GTO 03
99♦LBL 05
100 "AV. TARIF?"
101 FIX 1
102 PROMPT
103 STO 11
104 "AV. DG?"
105 FIX 2
106 PROMPT
107 STO 12
108 GTO 07
109♦LBL 06
110 RCL 21
111 ST/ 11
112 ST/ 12
113♦LBL 07
114 FIX 1
115 "AV. TN="
116 ARCL 11
117 AVIEW
118 "AV. DG="
119 FIX 2
120 ARCL 12
121 AVIEW
122 FIX 0
123 "MIN. DBH CL.?"
124 PROMPT
125 STO 17
126 "MAX. DBH CL.?"
127 PROMPT
128 STO 18
129♦LBL 08
130 RCL 17
131 STO 21
132 X↑2
133 RCL 25
134 *
135 STO 22
136 "CL. "
137 ARCL 17
138 "⊦ TREES?"
139 PROMPT
140 X<=0?
141 GTO 09
142 RCL 13
143 *
144 RCL 24
145 /
146 ST+ 07
147 RCL 22
148 /
149 STO 20
150 ST+ 06
151 XEQ "CVTS"
152 RCL 20
```

```
153 *
154 ST+ 09
155 RCL 17
156 .01
157 -
158 STO 21
159 X↑2
160 RCL 25
161 *
162 STO 22
163 XEQ "CVTS"
164 STO 23
165 RCL 17
166 .01
167 +
168 STO 21
169 X↑2
170 RCL 25
171 *
172 STO 22
173 XEQ "CVTS"
174 RCL 23
175 -
176 .02
177 /
178 RCL 12
179 *
180 RCL 20
181 *
182 ST+ 10
183 RCL 12
184 RCL 17
185 2
186 *
187 +
188 RCL 12
189 *
190 RCL 25
191 *
192 RCL 20
193 *
194 ST+ 08
195♦LBL 09
196 RCL 18
197 RCL 17
§198 2
199 +
200 STO 17
201 X<=Y?
202 GTO 08
203 "SPECIES "
204 ARCL 15
205 AVIEW
206 FIX 0
207 "T/A= "
208 ARCL 06
209 AVIEW
210 "BA/A= "
211 ARCL 07
212 AVIEW
213 FIX 1
214 "BAG/A= "
215 ARCL 08
216 AVIEW
217 FIX 2
218 "D GRO= "
219 ARCL 12
220 AVIEW
221 FIX 0
222 "VOL/A= "
223 ARCL 09
224 AVIEW
225 "VG/A= "
226 ARCL 10
227 AVIEW
228 FIX 1
229 RCL 10
230 ST+ 05
231 RCL 09
232 ST+ 04
233 /
234 100
235 *
236 "VG%= "
237 ARCL X
238 AVIEW
239 RCL 06
240 ST+ 01
241 RCL 12
242 *
243 ST+ 00
244 RCL 07
245 ST+ 02
246 RCL 08
247 ST+ 03
248 "ANOTHER SET?"
249 AON
250 PROMPT
251 AOFF
252 ASTO Y
253 "NO"
254 ASTO X
255 X≠Y?
256 GTO 02
257♦LBL 10
258 "TOTALS"
259 AVIEW
260 FIX 0
261 "T/A= "
262 ARCL 01
263 AVIEW
264 "BA/A= "
265 ARCL 02
266 AVIEW
267 FIX 1
268 "BAG/A= "
269 ARCL 03
270 AVIEW
271 FIX 2
272 RCL 00
273 RCL 01
274 /
275 "D GRO= "
276 ARCL X
277 AVIEW
278 FIX 0
279 "VOL/A= "
280 ARCL 04
281 AVIEW
282 "VG/A= "
283 ARCL 05
284 AVIEW
285 FIX 1
286 RCL 05
287 RCL 04
288 /
289 100
290 *
291 "VG%= "
292 ARCL X
293 AVIEW
294 GTO 01
295 END
```

§ This program line determines 2-inch diameter-classes. Change the digit "2" to "1" for 1-inch diameter-classes.

Program Listing: FIXP

```
01♦LBL "FIXP"
02 "FIX PLOT"
03 AVIEW
04 "COPYRIGHT 1984"
05 "OREGON STATE"
06 "UNIVERSITY"
07 "FOREST RESEARCH"
08 "LABORATORY"
09 CF 15
10 SF 16
11 SF 21
12 CF 29
13 .005454154
14 STO 25
15♦LBL 01
16 0
17 STO 00
18 STO 01
19 STO 02
20 STO 03
21 STO 04
22 STO 05
23 FIX 2
24 1
25 "PLOT SIZE"
26 PROMPT
27 /
28 STO 13
29 FIX 0
30 "RGY?"
31 PROMPT
32 STO 14
33♦LBL 02
34 0
35 STO 06
36 STO 07
37 STO 08
38 STO 09
39 STO 10
40 STO 11
41 STO 12
42 STO 21
43 "SPECIES?"
44 AON
45 PROMPT
46 AOFF
47 ASTO 15
48 "DO YOU HAVE"
49 AVIEW
50 "TARIF TREES?"
51 AON
52 PROMPT
53 AOFF
54 ASTO Y
55 "NO"
56 ASTO X
57 X=Y?
58 GTO 05
59♦LBL 03
60 RCL 21
61 1
62 +
63 FIX 0
64 "DBH NO. "
65 ARCL X
66 "⊢ ?"
67 FIX 1
68 PROMPT
```

```
69 X<=0?
70 GTO 06
71 STO 16
72 FIX 0
73 "HT?"
74 PROMPT
75 STO 17
76 "RG?"
77 PROMPT
78 STO 18
79 XEQ IND 15
80 FIX 1
81 "CVTS="
82 ARCL X
83 AVIEW
84 XEQ "TN"
85 "TN="
86 ARCL X
87 AVIEW
88 ST+ 11
89♦LBL 04
90 RCL 18
91 10
92 /
93 RCL 14
94 /
95 ST+ 12
96 1
97 ST+ 21
98 GTO 03
99♦LBL 05
100 "AV. TARIF?"
101 FIX 1
102 PROMPT
103 STO 11
104 "AV. DG?"
105 FIX 2
106 PROMPT
107 STO 12
108 GTO 07
109♦LBL 06
110 RCL 21
111 ST/ 11
112 ST/ 12
113♦LBL 07
114 FIX 1
115 "AV. TN="
116 ARCL 11
117 AVIEW
118 "AV. DG="
119 FIX 2
120 ARCL 12
121 AVIEW
122 FIX 0
123 "MIN. DBH CL.?"
124 PROMPT
125 STO 17
126 "MAX. DBH CL.?"
127 PROMPT
128 STO 18
129♦LBL 08
130 RCL 17
131 STO 21
132 X↑2
133 RCL 25
134 *
135 STO 22
136 "CL. "
137 ARCL 17
138 "⊦ TREES?"
139 PROMPT
140 X<=0?
141 GTO 09
142 RCL 13
143 *
144 STO 20
145 ST+ 06
146 RCL 22
147 *
148 STO 24
149 ST+ 07
150 XEQ "CVTS"
151 RCL 20
152 *
153 ST+ 09
154 RCL 17
155 .01
156 -
157 STO 21
158 X↑2
159 RCL 25
160 *
161 STO 22
162 XEQ "CVTS"
163 STO 23
164 RCL 17
165 .01
166 +
167 STO 21
168 X↑2
169 RCL 25
170 *
171 STO 22
172 XEQ "CVTS"
173 RCL 23
174 -
175 .02
176 /
177 RCL 12
178 *
179 RCL 20
180 *
181 ST+ 10
182 RCL 12
183 RCL 17
184 2
185 *
186 +
187 RCL 12
188 *
189 RCL 25
190 *
191 RCL 20
192 *
193 ST+ 08
194♦LBL 09
195 RCL 18
196 RCL 17
§197 2
198 +
199 STO 17
200 X<=Y?
201 GTO 08
202 "SPECIES "
203 ARCL 15
204 AVIEW
205 FIX 0
206 "T/A= "
207 ARCL 06
208 AVIEW
209 "BA/A= "
210 ARCL 07
211 AVIEW
212 FIX 1
213 "BAG/A= "
214 ARCL 08
215 AVIEW
216 FIX 2
217 "D GRO= "
218 ARCL 12
219 AVIEW
220 FIX 0
221 "VOL/A= "
222 ARCL 09
223 AVIEW
224 "VG/A= "
225 ARCL 10
226 AVIEW
227 FIX 1
228 RCL 10
229 ST+ 05
230 RCL 09
231 ST+ 04
232 /
233 100
234 *
235 "VG%= "
236 ARCL X
237 AVIEW
238 RCL 06
239 ST+ 01
240 RCL 12
241 *
242 ST+ 00
243 RCL 07
244 ST+ 02
245 RCL 08
246 ST+ 03
247 "ANOTHER SET?"
248 AON
249 PROMPT
250 AOFF
251 ASTO Y
252 "NO"
253 ASTO X
254 X≠Y?
255 GTO 02
256♦LBL 10
257 "TOTALS"
258 AVIEW
259 FIX 0
260 "T/A= "
261 ARCL 01
262 AVIEW
263 "BA/A= "
264 ARCL 02
265 AVIEW
266 FIX 1
267 "BAG/A= "
268 ARCL 03
269 AVIEW
270 FIX 2
271 RCL 00
272 RCL 01
273 /
274 "D GRO= "
275 ARCL X
276 AVIEW
277 FIX 0
278 "VOL/A= "
279 ARCL 04
280 AVIEW
281 "VG/A= "
282 ARCL 05
283 AVIEW
284 FIX 1
285 RCL 05
286 RCL 04
287 /
288 100
289 *
290 "VG%= "
291 ARCL X
292 AVIEW
293 GTO 01
294 .END.
```

§ This program line determines 2-inch diameter-classes. Change the digit "2" to "1" for 1-inch diameter-classes.

Notation

ALD	alder	MAX. DBH CL.	maximum diameter class
ASP	aspen	MAP	big-leaf maple
AV	average	MIN. DBH CL.	minimum diameter class
BA	basal area	PP	ponderosa pine
BA/A	basal area per acre	RG	radial growth
BAF	basal-area factor	RGY	radial growth years
BAG	basal-area growth	SS	Sitka spruce
BAG/A	basal-area growth per acre	T/A	trees per acre
CL.	diameter class	TN	tarif number
CVTS	cubic-foot volume, total stem	VARP	variable-radius plot
D	midpoint DBH of the diameter class	VG%	percentage of volume growth per year
DBH	diameter at breast height, 4.5 ft.	VG/A	cubic volume growth per year
DF	Douglas-fir	VOL/A	volume per acre
DG, D GRO	diameter growth	VOLGRO	volume growth per tree of the diameter class

FIXP	fixed plot
GM	growth multiplier
HM	western hemlock
HT	height

Subscripts

av	average
d	diameter class
t	individual tree

TAPPEINER, J.C., J.C. GOURLEY, and W.H. EMMINGHAM. 1985. A USER'S GUIDE FOR ON-SITE DETERMINATIONS OF STAND DENSITY AND GROWTH WITH A PROGRAMMABLE CALCULATOR. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 11. 18 p.

Instructions are given for estimating current volume and basal area and periodic volume, basal area, and diameter growth of forest stands with a hand-held, programmable calculator. The technique, which uses the tarif system of Cole and Chambers and Foltz, enables estimates to be made in the field. Use of the estimates in silviculture prescriptions is discussed.

KEYWORDS: Stand growth, stand examination, growth and yield, silviculture prescriptions, programmable calculator.

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KEYWORDS: Stand growth, stand examination, growth and yield, silviculture prescriptions, programmable calculator.

Forest Research Laboratory
College of Forestry
Oregon State University
Corvallis, OR 97331-5704

Address Correction Requested