THE WOODLAND WORKBOOK

FOREST MEASUREMENT

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Stand Volume and Growth: Getting the Numbers

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Contents

The procedures outlined in this publication show you how to estimate standing volume and annual growth of timber *stands*—areas that are uniform in age, stand characteristics, and species. Estimates of volume and growth are helpful in planning when to harvest or how much to remove in a thinning operation. These estimates also can assist you with financial analysis and the tax implications of a timber harvest.

Don't confuse the simplified procedure that we describe for collecting and analyzing tree volumes with the more complex and precise techniques that professional foresters use to estimate timber values for sales, land appraisals, or legal purposes. Our system allows you to get reasonably accurate gross volumes of timber but does not address net volumes, log grades, or monetary values.

Volume and growth numbers generated by any tree measuring system are estimates. You usually can't afford the time and money to measure all your trees, so you'll measure a few sample trees. You'll use the sample to obtain an index called a *tarif number,* which will be used to compute individual tree and stand volumes.

Of European origin, the tarif system was adapted for Pacific Northwest use by the State of Washington. The tarif system shows the gross volume of trees based on species, tree diameter, and total height. It's one of several types of tree-volume tables. The tree-volume tables supported by this publication are for Douglas-fir, grand fir, western hemlock, ponderosa pine, western redcedar, and red alder.

If you have a question about the appropriateness of the tarif system for management decisions regarding your timber stand—or if you need help with a complex situation—contact the Extension forestry agent who serves your county, or your state service forester from the Oregon Department of Forestry, or a consulting forester.

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Key numbers that you'll generate

By following the procedures we outline, you'll be able to generate the following kinds of numbers that describe your stand and help you evaluate its performance.

Number of trees per acre

This is a good start, but other numbers generated through the use of this publication are more valuable in making management decisions.

Number of trees per acre by diameter class

Also called a *stand table,* these numbers can be used to plan logging jobs and to evaluate the tree size that's available to merchandise. We'll also use these numbers as the starting point for projecting future stand growth.

Average stand diameter

This is valuable when making decisions on merchantability, in selecting appropriate logging equipment, and for projecting stand growth. Average stand diameter, along with number of trees per acre, can be useful in making thinning decisions.

Basal area

This is the area of a cross-section of the tree at a point 4.5 feet above the ground on the uphill side of the tree, a point commonly called *breast height*. The sum of the basal area for all trees in the stand is the total stand basal area, a common measure of stand density.

Tarif number

A tarif number identifies the taper or shape of your trees and is the key to determining volumes. A tarif number is the cubic foot volume of a tree with a basal area of 1 square foot and a given height. For example, a tree that's 13.56 inches in diameter has a basal area of 1 square foot. If this tree had a volume of 35 cubic feet, its tarif number would be 35. Trees with lots of taper have low tarif numbers; trees with high tarif numbers have a minimum of taper.

Stand volumes

Using the tarif numbers of your sample trees, you can look up volumes of trees of various diameters in board-foot or cubic-foot volume tables. To convert these into per-acre volumes by diameter class, multiply the individual tree volumes by the number of trees per acre. Tree volumes are probably the most useful numbers you'll generate. It's important to remember, however, that they are gross volumes—they don't consider losses for defects and breakage.

Board-foot volume often is of greatest interest, since most timber in the Pacific Northwest is sold at a price per 1,000 board feet (MBF). There are several methods of scaling or measuring board feet; we've used the most common for the Pacific Northwest, the Scribner Volume Table.

There's help available

To complete the procedures described in this publication, you need a basic understanding of how to measure trees and distance and how to do simple math calculations.

To better understand the preparatory steps essential to using this publication, read *Mapping and Managing Poorly Stocked Douglas-fir Stands,* EC 1133*,* which defines terms, shows how to divide your trees into separate stands, and tells how to make sampling plans.

Tools for Measuring Your Forest, EC 1129, discusses tools you need to measure your trees.

A computer program is available for those who want to avoid math calculations. *VARPLOT: Stand Measurement Software* uses measurements of tarif trees and of plot trees (from either fixed- or variable-radius plots) to estimate trees per acre, basal area per acre, and cubic-foot and board-foot volumes per acre. Stand parameters are reported by diameter classes in 1-inch increments for the total stand. *VARPLOT* also estimates average diameter at breast height (DBH), a growth projection factor, and board-foot volume growth expressed as mean annual increment (MAI) and periodic annual increment (PAI). In addition, *VARPLOT* estimates a stand density index (SDI) and relative density (RD), which are measures of stand density and competition that are important in managing your timber stand.

Table 1.—**Steps to measuring a stand's volume and growth.**

Procedure	How	Tools needed
1. Identify distinct stands.	Mark on map or photo, using field data.	Aerial photo, map, EC 1133
2. Choose a sampling plan.	Follow procedures in EC 1133.	EC 1133, aerial photo, map
3. Estimate the plot size you'll need.	Begin with a plot of 1⁄20 (0.05) acre; adjust if needed after 3 or 4 plots.	Compass, tape
4. Collect plot information.	Establish a plot.	Tape, compass, Tree Tally Card (Appendix C)
	Measure tree diameters.	Diameter tape
	Measure tarif trees.	Tree Tally Card (Appendix C), clinometer
	Take increment cores.	Increment borer

Cubic-foot volume of the tree stem is a basic measure of wood volume that's independent of how the tree is cut into logs. It's also useful in determining some basic growth relationships for the stand and for comparison with other stands or species.

Using the numbers described above, along with measuring the tree ring widths from increment cores, you'll be able to measure past growth and estimate future growth. This will allow you to determine:

Growth projection factor (GPF) This can be used in conjunction with board-foot or cubic-foot volumes to determine future stand volumes given current growth rates.

Mean annual increment (MAI) This is the average volume growth per year over the life of the stand.

Periodic annual increment (PAI) This is the annual volume growth measured over a specified period, usually 5 or 10 years. We recommend you use the growth over the past 5 years to calculate PAI.

Our example: "Coleman's Conifers"

Beginning on page 5, you'll find boxes like this, on a shaded background. Text in the boxes describes our example to help you work through the procedures. Each time you see one of these boxes, we're applying the steps explained in nearby text and are moving our calculations one step farther.

Measuring stand volume and growth

Table 1 summarizes the necessary steps for measuring your stand*, how to accomplish those steps, and the tools you'll need to perform the task. Steps 1 through 4 explain the information in Table 1.

Step 1. Identify distinct stands

Carefully select the area or stand you wish to sample. It should be relatively uniform in *stocking* (trees per acre or space between trees) and in size of trees. Publication EC 1133 explains how to divide your land into logical stand types. You can do this on an aerial photo, but you must verify your decisions on the ground by walking through the stand.

Here are some ways to deal with different stand characteristics.

- If one area of your stand contains trees consistently and substantially smaller (by 6 inches or more) in diameter at breast height (DBH) than trees in the rest of the stand, *treat the two areas as separate stands*.

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*This publication is not designed to obtain precise total volumes for your timber stands. If you need this kind of information, you should take a larger sample and precisely calculate acreage for each stand. Or, hire a consulting forester.

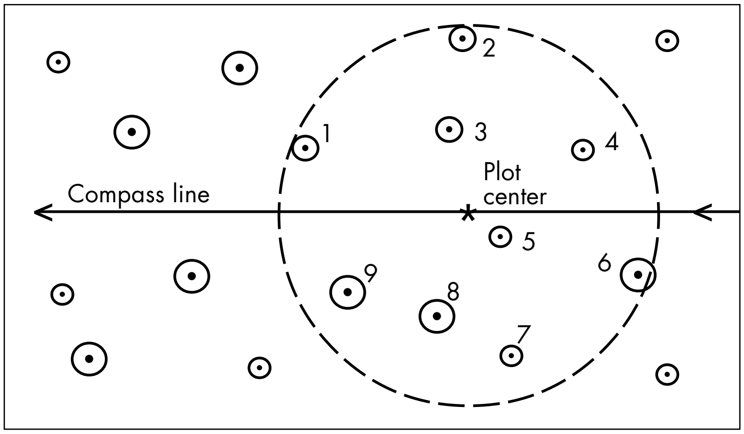


Figure 1.—Establishing plot 1 for Coleman's Conifers (consisting of nine "in" trees).

- If you have a few trees of larger diameter mixed uniformly into a younger stand, sample it as one stand, *but estimate the volumes separately based on different tarif numbers measured from the large and small trees*. Combine the results to obtain total stand growth and yield.
- If you have a distinct smaller area (1 to 3 acres) with poor stocking in a larger well-stocked area, *exclude the smaller area from your sample and volume estimate; measure it separately*.
- If you have several openings of 0.25 to 0.5 acre scattered through a larger stand that is otherwise uniform, *sample the entire area*. The confidence you place in your estimate may be lower, but the numbers you generate will be more accurate than if you had ignored the openings.
- If you have a mixed-species stand of conifers and hardwoods, *sample each species separately* and combine the volumes for total stand growth and yield.

Step 2. Choose a sampling plan

Once you determine which areas are similar enough to be sampled together as stands, it's time to make your sampling plan. To avoid any bias, you must locate samples using systematic measurements. If you wander through your stand and pick likely looking spots, your estimates will be inaccurate. As publication EC 1133 shows you, mark intended plot locations on your photo or map. One plot per 1 to 2 acres generally will give you a good estimate for uniform stands, but more diverse stands require at least one plot per acre.

Step 3. Estimate the plot size you'll need

Your objective is to select a plot size that will give you five to eight sample trees per plot. The proper plot size to use for sampling depends on the number of trees per acre, which is directly related to distance between trees.

Before you leave for the field, use Table 2 as a checklist to ensure that you have the proper equipment.

To begin, refer to the sampling plan you determined for the stand under step 2. Locate on the ground the point where you'll start the sample.

Measure a straight line, in your planned compass direction, to the first plot center. The dots in Figure 1 represent trees in a hypothetical stand. An asterisk (*) marks the center point for your plot. Note that the plot center does not need to be a tree. It is simply the center point according to your measurements.

From your plot center, proceed to measure all trees within a radius of 26 feet and 4 inches. This plot size—which is one-twentieth of an acre (0.05 acre)—often gives you a sufficient number of trees per plot. If you don't achieve the desired five to eight trees after recording plot 1, don't change your plot size yet.

Proceeding along your planned compass direction, in plot 2 measure the number of trees within the plot radius of 26 feet and 4 inches. If you continue to have too many or too few sample trees after measuring three or four plots, then return to plot 1 and adjust plot size accordingly.

Remember, it is much better to have a few more trees than you'd planned than to not have enough, so be sure you have an adequate plot size. Eight to ten trees per plot may seem a lot of trees to measure and record, but it is much better than getting only two to four trees per plot and risking an inaccurate volume estimate.

Once you have obtained the proper plot size, continue with your sampling plan for the entire stand.

***Table 2.*—Tools needed for field measurements.**

Needs	**Purposes**
A. To obtain volume information:	
1. Logger's or similar tape	Measure distance to plot boundaries and tarif trees.
2. Diameter tape or Woodland Stick	Measure tree diameters.
3. Clinometer or Woodland Stick	Measure tree heights.
4. Tarif access tables and tarif volume tables in the appendices.	Provide information needed to transform measurements to volumes.
5. A second person (optional but recommended)	Hold one end of the tape when measuring boundaries; tally information while you take measurements; hold one end of the tape when measuring distance from tarif trees; shake tarif trees so you can see the tops when measuring heights.
B. To obtain growth information:	
1. Increment borer	Extract a core sample from tarif trees. (Also an option for determining tree age.)
2. Small ruler	Measure the width of annual rings in the core sample.
3. A carrier for core samples (optional but recommended)	Take the core sample home for measurement.

*See publication EC 1129 for details about selecting measurement tools.

Step 4. Collect plot information

Establish a plot

Using point * as your plot center (see Figure 1) and the plot radius you determined in step 3, identify the trees within your plot. It's not necessary to mark the entire outer limits of the plot or to measure the distance to trees that are clearly "in" the plot. From the plot center, measure the distance only to trees near the perimeter.

As you traverse your compass line and reach the location for your next plot, immediately locate the plot center. Do not deviate from your compass line! Moving the plot center one way or the other to get more trees in the plot may overstate actual stand volume. A temporary marker (a flag or stick) at the plot center is fine for most purposes. Establish a more permanent plot center if you have a long-range plan to sample the same stand repeatedly.

Measure tree diameters

Recording plot trees Moving clockwise from your compass line, begin recording the trees in the plot. Remember the first tree you measured so you don't accidentally count it a second time. A tree is "in" the plot if its center falls inside the plot boundary. Measure DBH and record these numbers on the Plot Trees section of the Tree Tally Card. Figure 3 (page 7) is a sample completed Tree Tally Card for Coleman's Conifers. A blank card is available in Appendix C.

Be sure to read the key that explains the Tree Tally Card's dot-tally system. Record diameters to the nearest full inch. If a tree measures exactly at the 0.5-inch mark, round the diameter *down* to the nearest full

Estimating plot size

To estimate plot size and location, first find the center of plot 1 by pacing off from the stand boundary. You can measure virtually any timber stand with a plot of one-fiftieth (0.02), one-twentieth (0.05), or one-tenth (0.1) acre. A 0.05-acre plot is the default. After measuring three or four plots, you may find there are too few or too many trees per plot. If so, return to plot 1 and adjust plot size accordingly. Discuss stands that fall outside this suggested plot range with a professional forester before proceeding with sampling.

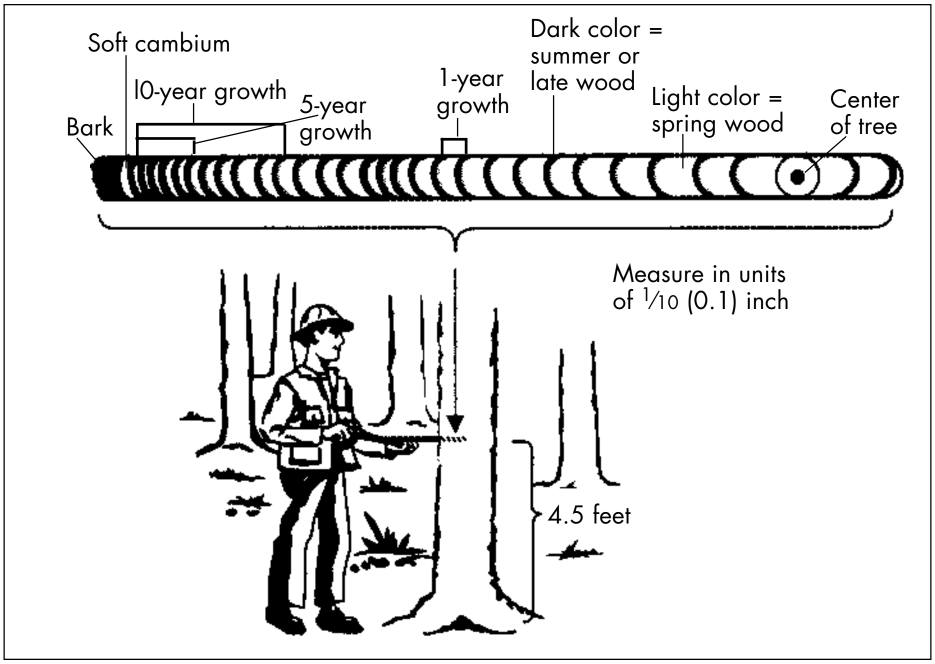


Figure 2.—Increment core sampling to determine radial growth.

inch. Make a mental note of this decision; when you encounter the next tree measuring at the 0.5-inch mark, round the diameter *up* to the nearest full inch. Repeat this process as necessary.

Recording tarif trees To find your tarif tree in the plot, look in a clockwise direction from your compass line; ordinarily, your tarif tree will be the first tree you encounter. (In Figure 1, for example, the tarif tree is shown with the number one.) Your tarif tree should be representative of the other trees in the stand. If the first tree is suppressed, dead, or has a broken top, go to the second tree in the plot and use it as your tarif tree. (In subsequent plots, go back to using the first tree as your tarif tree unless the first tree is not representative of trees in your stand.) You already recorded the tarif tree's diameter on the Plot Trees section of your Tree Tally Card. Now you record its diameter and total height on the Tarif Trees section of the Tree Tally Card.

Pick a vantage point from which you can see the top of the tarif tree. Your estimates will be more accurate if you take your observations from about the same level as the base of the tree. Record its height, to the nearest 5 feet, on the Tarif Tree section of the Tree Tally Card. See publication EC 1129 for more information on measuring the heights of your trees.

Taking increment cores for stand age and growth rates If you have not determined the age of your stand from old records or by counting growth rings on stumps, now is the time. If counting rings on a stump, remember to add the number of years since the tree was cut.

To determine stand age using an increment borer, bore on an exactly horizontal line into the center of the tree at breast height. Bore slightly farther than the tree's radius (for example, bore 8 inches if tree radius is 7 inches). You can recognize the center of the tree by viewing the direction of the slight arc in the growth rings from the extracted core (Figure 2). To properly determine stand age, you will have to add 6 to 10 years to the number you obtained from your increment core. Add 6 years for a high-growth-rate site, 10 years for a low-rate site, to account for the years it took the tree to grow to breast height.

Next, use your increment borer to take a growth rate measurement from your tarif

Taking plot data

You're ready to record plot information (refer to Figures 1 and 3). You identify nine "in" trees on plot 1 (see Figure 1). The first tree measures 12.2 inches DBH, so tally a dot under Plot Trees on plot 1 next to 12 inches DBH. The second tree is 13.3 inches; tally a 13. Continue to measure and record DBH for the remaining seven trees in the plot.

Now you need the tarif tree for plot 1. Remember, the first "in" tree on the plot is your tarif tree. The first tree measures 12.2 inches DBH, so you record 12 in the DBH column under Tarif Trees. You measure its height as 94 feet and record 95 in the Height column. This tree had nonuniform growth over the past 10 years, so you measure the distance from the outermost five rings and find 0.6 inch radial growth, which you record in the radial growth column of the Tarif Trees section.

Figure 3 shows a completed sample of 10 plots for our stand. The next step is to find a comfortable place to calculate the Tree Tally Card data and turn it into some valuable stand volume and growth information.

Figure 3.— Sample Tree Tally Card, completed.

User name ______
Stand name Coleman's Conifers
Date ______

Plot size 1/20
Species Doug-fir
Stand age 50

Multiplication factor* 2
Average tarif number 39

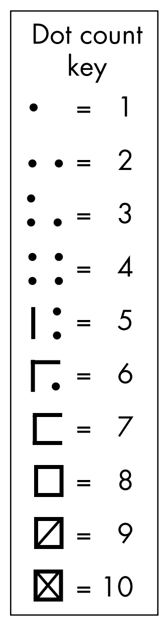
Plot Trees

DBH (in.)	Plot number 1	2	3	4	5	6	7	8	9	10	Total trees	Total trees per acre
7												
8			•							•	2	4
9									•		1	2
10	•		•	•	•					•	5	10
11		•	••	•	•	•		•	•	••	10	20
12	•	•	••	•••	••		••	••		•	14	28
13	••	••	•	•	•	•••	••••	••	•	••	19	38
14	•••	••			••		••	•••	••	•	15	30
15	••			•		•	•	•	•		7	14
16		•	•		•	•				•	5	10
17					•				•		2	4
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
										Total	80	160

Tariff Trees

1 Plot no.	2 DBH (in.)	3 Height to nearest 5 ft.	4 Radial growth for 5 yrs. (in.)	5 Tarif no. from access tables
1	12	95	0.6	38
2	13	100	0.6	39
3	10	80	0.5	35
4	15	115	0.6	43
5	14	110	0.7	42
6	13	105	0.6	41
7	15	110	0.8	41
8	13	90	0.5	35
9	17	105	0.5	37
10	16	110	0.6	40
		Total	6.0	391
		Average	0.6	39.1

$$* \quad \text{Multiplication factor} = \frac{\text{Plot size correction factor}}{\text{Number of plots}}$$



Remember
The first tree from each plot is recorded as a Plot Tree ***and*** as a Tarif Tree.

Recommended plot sizes	Distance between trees: less than 8 ft.	8–16 ft.	16–24 ft.	more than 24 ft.
Plot size (acres)	1/100th	1/50th	1/20th	1/10th
Plot radius (ft. & in.)	11'10"	16'8"	26'4"	37'2"
Plot radius (ft.)	11.8	16.7	26.3	37.2
Plot size correction factor	100	50	20	10

tree. You can use the same core sample used to determine stand age. If you didn't use a core for the stand age, you need to bore only far enough (2 to 4 inches) to see growth for the most recent 5 to 10 years.

Count five growth rings from the outermost ring, and measure the distance in tenths of an inch (Figure 2). Record this measurement in the fourth column of the Tarif Trees section of the Tree Tally Card.

You can store cores in a plastic straw and examine them later, but it's important to label them properly and to examine them before they dry out and shrink.

Use your compass and proceed to the second plot. Repeat all the steps used to measure your Plot Trees and Tarif Trees on each of the other plots and record the information on your Tree Tally Card.

Calculating stand volume and growth

Now that you've collected the plot information, you can take it home and translate it into numbers that will more accurately describe your stand. The numbers to generate include:

- Trees per acre
- Tarif number for the stand
- Average radial growth
- Stand volume
- Basal area and average stand diameter
- Volume projections

Calculating trees per acre

Looking at Figure 3, Coleman's Conifers has a total of 80 trees on 10 plots. The multiplication factor is 2 (a plot size correction factor of 20 divided by the number of plots, which is 10). For example, we have 14 trees with a 12-inch diameter, thus we have 28 (14 plot trees times the multiplication factor of 2) 12-inch trees per acre in the stand.

Getting the tarif numbers

In our example, we measured 10 tarif trees in the Douglas-fir stand. Adding the tarif numbers for all sample trees (see Appendix A1) and dividing by 10, we find an average of 39.1. Rounding to the nearest whole number, 39 is the tarif number for the stand.

Computing average radial growth (ARG)

In the Tarif Trees section of the Tree Tally Card, the total of column 4 is 6.0. This means the average tree had 0.6 inch in radial growth (6.0 ÷ 10 trees measured) in the 5-year period. Diameter growth was 1.2 inches (0.6 radial growth times 2).

Trees per acre

We will use the completed Tree Tally Card for Coleman's Conifers (Figure 3) for the data in our computations, and we'll consult the completed Volume Computation Form (Figure 4, page 11) for our completed stand volume and growth calculations. A blank Tree Tally Card (Appendix C) and Volume Computation Form (Appendix D) have been provided for you to copy and use in your own timber stand calculations.

To determine the total trees per acre, refer to the Plot Trees section of your Tree Tally Card (Figure 3). Total the trees tallied for each diameter class and enter the number in the Total Trees column.

The next step is to calculate total trees per acre. First, find your plot size in the bottom table in the Tree Tally Card; the corresponding plot size correction factor is at the bottom of that column. Divide this factor by the number of plots in your sample to get the multiplication factor.

The multiplication factor expresses how many trees per acre are represented by each tree in a sample plot. To find how many trees per acre are in each diameter class, look at the Plot Trees section and multiply the value in the Total Trees column for each diameter class by the multiplication factor. Next, add the values in the Total Trees per Acre column to calculate total trees per acre. Transfer this information to column 1 of your Volume Computation Form (Figure 4, page 11).

Tarif number for the stand

The average tarif number for the stand is the average of the tarif numbers for all the tarif trees you sampled.

Determine the tarif number for each sample tree on the Tarif Trees section of your Tree Tally Card by looking up the value in the tarif access table for that tree species (Appendices A1 through A6). These tables list a tarif number based on tree species, DBH, and total tree height.

In our example, we record height to the nearest 5 feet and diameter to the nearest whole inch. We then look in the appropriate appendix and record the corresponding tarif number on the Tarif Trees section of the Tree Tally Card.

Next, we total these values and divide by the number of tarif trees to determine the average tarif number of the stand. Place this number at the top of your Volume Computation Form (Figure 4). Average tarif number identifies the taper of your trees, and it's the key to determining tree volumes.

Using *VARPLOT: Stand Measurement Software*, you can measure tarif trees to the nearest tenth of an inch in diameter and the nearest foot in height. In some—but not all—instances, these more accurate measurements will give slightly different figures than the rounded numbers used in our example.

Average radial growth (ARG)

Estimate radial growth for the stand by adding the core samples recorded in column 4 of the Tarif Trees section of the Tree Tally Card (Figure 3). Compute average radial growth by dividing the total of the column by the number of tarif trees measured. Remember, this is a radial—not a diameter—measurement. (Figure 2 illustrates radial growth.) Transfer this information to the average radial growth line in the upper right of your Volume Computation Form.

Estimating stand volume

The next step is to estimate stand volume from field measurements and the average tarif number.

In column 1 of the Volume Computation Form, write in the number of trees per acre by diameter class, drawing that information from the Total Trees per Acre column on the Tree Tally Card.

Next, record average radial growth and your average tarif number at the top of the Volume Computation Form. Don't worry about average basal area/tree or average stand diameter at this time; you'll fill in these lines during the next step.

Tree volume tables are in Appendices B1 through B3. The volumes you use are in the column under the appropriate tarif numbers. For our example, we determined 39 as our average tarif number for the stand.

To estimate board-foot volumes in 32-foot logs, use Appendix B1. (Appendix B2 is for volumes in 16-foot logs, and cubic-foot volumes are in Appendix B3.) Record board feet in column 2 and cubic feet in column 4 of the Volume Computation Form.

To get the total board-foot and cubic-foot volumes per acre for each diameter class, multiply trees per acre (column 1) by volume per tree (columns 2 and 4, respectively) on the Volume Computation Form. Enter total volumes per acre for each diameter class in columns 3 and 5. The sum of column 3 is your total board-foot volume per acre, and the sum of column 5 is your total cubic-foot volume per acre.

Estimating stand volume

Assume you want to estimate board-foot volumes in 32-foot logs with 8 inches DBH. The Tree Tally Card shows four trees per acre with a DBH of 8 inches. Using Appendix B1, our average tarif number of 39 shows a volume of 40 board feet for each tree with an 8-inch DBH.

On the Volume Computation Form, multiply four trees (column 1) by 40 board feet (column 2) to get 160 board-foot volume per acre for trees in our 8-inch diameter class (column 3). Repeat this process for each diameter class. Adding the values in columns 1 and 3 shows a total of 160 trees per acre with a volume of 23,900 board feet per acre.

Basal area and average stand diameter

In column 6 of the Volume Computation Form, basal area per tree has been calculated for each diameter class on the form. To determine basal area per acre of trees by diameter class (column 7), multiply values in column 1 by those in column 6. Add column 7 to get total basal area per acre and record at the bottom of the column.

To compute average basal area per tree, we need the total basal area per acre (column 7) and trees per acre (column 1). The formula is:

Average basal area/tree = Total basal area/acre (i.e., Total of col. 7) ÷ Total trees/acre (i.e., Total of col. 1)

Average stand diameter is the diameter of a tree with average basal area. To find this diameter, convert from basal area (square feet) to diameter (inches):

Average stand diameter = square root of (Average basal area/tree ÷ 0.005454)

Now, record average basal area/tree and average stand diameter on the appropriate lines at the top of the Volume Computation Form.

Calculating basal area

On the Volume Computation Form, still on the line for 8-inch DBH, multiply 4 trees per acre (column 1) by 0.349 basal area per tree (column 6) to get a total basal area of 1.396 square feet. Repeat this process for all the diameter classes and add column 7 to get the total basal area per acre, 147.46 square feet.

Computing average basal area/tree

Per acre, total basal area is 147.46 square feet, and you have 160 total trees per acre. Therefore:

$$\text{Avg. basal area/tree} = \frac{147.46 \text{ sq. ft.}}{160} = 0.922 \text{ sq. ft.}$$

Computing average stand diameter

Given an average basal area per tree of 0.922 square feet, average stand diameter is:

$$\sqrt{\frac{0.922 \text{ sq. ft.}}{0.005454}} = 13.00 \text{ in.}$$

Using the numbers

Volume projections

Your completed Volume Computation Form (Figure 4) includes all the information you need to determine past and present stand volumes and the volume growth rate of your trees and to project future volumes. Upon completing the volume projections for your stand, you'll have information that is essential to making well-informed decisions about managing your woodland property. To project volumes, you need to perform some basic calculations and follow a few simple steps.

Step 1. Calculate beginning average stand diameter

We want to calculate average stand diameter at the beginning of the most recent 5-year growth period. (We are using 5 years as our measurement period because, when we took our increment core, growth rings in the core were quite different for the most recent 5 years.) First, double the average radial growth figure recorded on your Volume Computation Form (remember, we need diameter growth, so we double the radial growth figure). Subtract diameter growth from your current average stand diameter to find the average diameter of your trees 5 years ago.

Beginning average stand diameter = Current average stand diameter – (2 x Average radial growth)

Step 2. Calculate beginning average basal area per tree

Now we'll determine the basal area per tree at the beginning of the 5-year growth period. Convert from diameter (in inches) to basal area (in square feet) with the formula:

Beginning average basal area/tree = (Average diameter at beginning of growth period)^2 x 0.005454

Figure 4.— Sample Volume Computation Form, completed.

Stand name Coleman's Conifers
Species Doug-fir
Stand age 50
Average tarif number 39
Multiplication factor 2

Date
Average radial growth 0.6
Average basal area/tree 0.922
Average stand diameter 13.002
Board-foot volumes (16′ or 32′) 32

	1	2	3	4	5	6	7
DBH	Trees/ acre	Board ft. vol./tree (from Tree Volume Tables)	Board ft. vol./acre (col. 1 x col. 2)	Cubic ft. vol./tree (from Tree Volume Tables)	Cubic ft. vol./acre (col. 1 x col. 4)	Basal area/tree	Basal area/acre by diameter class (col. 1 x col. 6)
7						0.267	
8	4	40	160	11	44	0.349	1.396
9	2	70	140	15	30	0.442	0.884
10	10	90	900	20	200	0.545	5.45
11	20	100	2000	24	480	0.66	13.2
12	28	120	3360	30	840	0.785	21.98
13	38	150	5700	36	1368	0.922	35.036
14	30	180	5400	42	1260	1.069	32.07
15	14	210	2940	49	686	1.227	17.178
16	10	230	2300	56	560	1.396	13.96
17	4	250	1000	64	256	1.576	6.304
18						1.767	
19						1.969	
20						2.182	
21						2.405	
22						2.64	
23						2.885	
24						3.142	
25						3.409	
26						3.687	
27						3.976	
28						4.276	
29						4.587	
30						4.909	
31						5.241	
32						5.585	
33						5.939	
34						6.305	
35						6.681	
36						7.068	
	160		23,900		5724		147.458
	Total trees/acre		Total board-foot volume/acre		Total cubic-foot volume/acre		Total basal area/acre

Projecting volumes

Beginning average stand diameter

Average stand diameter 5 years ago (the beginning of the growth period) is:

13.002 (Current avg. stand diameter)
– [2 x 0.6 (Avg. radial growth)]
= 11.8 in.

Beginning average basal area/tree

Given a beginning average stand diameter of 11.8 in., the average basal area per tree at the beginning of the growth period is:

$(11.8 \text{ in.})^2$
x 0.005454
= 0.759 sq. ft.

Growth projection factor (GPF)

Inserting average basal area into the GPF formula gives the growth projection factor. Once you have determined this number, you can look to the future. GPF equals:

$$\frac{0.922 \text{ (Current avg. basal area/tree)}}{0.759 \text{ (Beginning avg. basal area/tree)}}$$
$$= 1.215$$

Future volumes

Multiplying current stand volume by the GPF shows us the stand in 5 years should have a volume of approximately 29,039 bd. ft. (23,900 x 1.215) or 6,955 cu. ft. (5,724 x 1.215).

Calculating mean annual increment

MAI is calculated for the life of the stand. Divide current total volume per acre by stand age:

$$\frac{23{,}900}{50}$$
= 478 bd. ft./acre per year

Periodic annual increment

To calculate PAI for the next 5 years, subtract the stand's current total volume per acre from its future volume and divide by the number of years in the growth period. (Remember, future volume was determined by using the growth projection factor.)

$$\frac{29{,}039 - 23{,}900}{5}$$
= 1,028 bd. ft./acre per year for the next 5 years

In this case, PAI exceeds MAI, suggesting the stand is not biologically mature and should be allowed to continue growing, although it may need thinning.

Step 3. Calculate growth projection factor

To estimate how fast your stand is growing, calculate its growth projection factor (GPF). Find the current average basal area per tree on your Volume Computation Form. You calculated beginning average basal area per tree in step 2.

Growth projection factor = Current average basal area/tree ÷ Beginning average basal area/tree

Step 4. Calculate future volume per acre

Now you can project the future volume per acre. Multiply current volume (from your Volume Computation Form) by the growth projection factor. This assumes that current stand volume growth will continue at the same rate as in the previous 5-year period, so the projection's accuracy will depend on how consistently your stand is growing. For most young stands (less than 50 years old), this estimate may be on the conservative side—that is, it may be slightly less than actual growth. As the stand ages beyond 50 years, tree growth rate tends to slow (see Figure 5).

Future stand volume = Current volume x GPF

Step 5. Calculate mean annual increment (MAI)

Another useful stand number is the mean annual increment (MAI) of volume growth. This represents the average volume growth per acre per year over the life of the stand. You already have generated the numbers necessary to determine MAI. They are:

Mean annual increment = Total current volume/acre ÷ Stand age (years)

You can calculate cubic-foot MAI for stands of any age, but you can't calculate board-foot MAI until trees in a stand reach a minimum merchantable size. Think of MAI as the long-term average or track record of the stand's growth.

Step 6. Calculate periodic annual increment (PAI)

The average annual volume growth of a timber stand measured over a specific period is its periodic annual increment (PAI). This figure is useful because volume growth per acre can vary substantially as the stand ages. The PAI of either board-foot or cubic-foot volumes can be calculated for any period, but 5- or 10-year periods are most common. Calculate PAI:

Periodic annual increment = (Total volume/acre at end of period – Total volume/acre at beginning of period) ÷ Number of years in the period

PAI can measure previous growth or project future growth. Core samples enable you to take measurements back from the present, and your calculated growth projection factor enables you to estimate a future periodic annual increment. This enables you to determine how your stand is growing by taking a "snapshot" in time.

Hypothetical ideal harvest time

Foresters have a long tradition of analyzing timber stand growth. Figure 5 shows the growth pattern for Douglas-fir, but the pattern for even-age stands tends to be similar for all tree species.

From analyses and long experience, foresters have derived the general rule that when PAI falls below MAI, the timber stand is "mature"—that is, it has passed its peak of wood growth production in the biological sense. Thus, the stand might be harvested if growth rate is the overriding factor in the harvest decision.

The point where the PAI line crosses the MAI line also is the highest value for MAI. This point, therefore, is referred to as *culmination* of MAI. The stand will continue to add volume after this point but at a slower rate than before. Thus, by comparing estimates of PAI and MAI, we can test whether our stands are biologically mature. Thinning stands can boost the growth of residual trees and delay the culmination of MAI.

Often, factors such as cash flow or market cycles dictate a timber harvest before or after culmination of MAI. By combining this biological information with financial analysis, you can tailor your management decisions to your own situation and objectives.

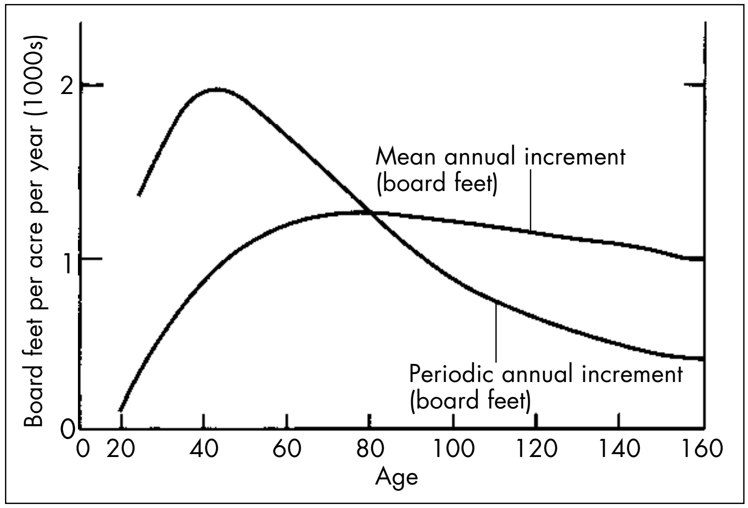


Figure 5.—Periodic and mean annual increments of board-foot volume for Douglas-fir, showing culmination of mean annual increment at about 80 years. Absolute age of culmination varies, but the pattern in this graph is similar for all species. Adapted from McArdle et al., *The Yield of Douglas Fir in the Pacific Northwest,* USDA Technical Bulletin 201, 1961.

Where to go from here

Good stand information is essential to making the decisions necessary for managing your woodland property. Stand measurements are critical to logging and marketing options. They are also important as indicators of a stand's health and vigor and its susceptibility to insect and disease problems. And, measurements might be important in deciding whether a harvest operation will generate the desired cash flow.

Measurements taken according to the procedures described here are suitable for understanding how a timber stand may develop over time; however, they're no substitute for professional timber appraisals or inventories done by foresters.

If you want to refine these techniques or to study timber growth further, contact your Extension forestry agent for possible opportunities.

For further reading

Mapping and Managing Poorly Stocked Douglas-fir Stands, EC 1133. 1997. Green, Daniel, Michael C. Bondi, and William H. Emmingham. $1.50

Tools for Measuring Your Forest, EC 1129. 2004. Bowers, Steve. $2.00

Measuring Timber Products Harvested from Your Woodland, EC 1127. 2003. Oester, Paul and Steve Bowers. $3.00

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Appendix A1.—Tarif access table for **Douglas-fir**. Condensed from VARPLOT Tree Volume Tarif Access Tables (2002).

Height (feet)

DBH (inches)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170
7		15	17	20	23	26	29	31	33	37	40	42	44																
8		15	17	19	22	25	27	30	32	35	38	39	42	44															
9		15	16	18	21	24	25	28	30	33	36	38	40	41	45														
10			15	17	21	22	25	27	29	31	34	36	38	40	43	45													
11			15	17	19	21	24	27	28	30	32	35	37	39	41	43	45												
12			15	16	18	21	23	25	27	29	31	34	36	38	40	42	44												
13			15	16	18	21	22	24	27	29	30	32	34	36	39	41	42	45											
14				15	17	19	21	24	25	28	30	32	34	36	38	40	41	43	45										
15				15	17	19	21	23	25	27	29	31	33	34	37	39	40	42	44										
16				15	16	18	21	23	24	27	28	30	32	34	36	38	39	41	43	45									
17				15	16	18	21	22	24	27	28	29	31	33	35	38	39	41	42	44									
18				15	16	18	19	21	23	25	27	29	31	32	34	36	38	40	41	43	45								
19					15	17	19	21	23	25	27	28	30	32	34	36	38	39	41	42	44								
20					15	17	18	21	22	24	27	28	29	31	33	35	36	38	40	42	43	45							
21					15	17	18	21	22	24	25	27	29	31	32	34	36	38	39	41	43	44							
22					15	16	18	19	21	23	25	27	28	31	32	33	35	37	38	40	42	43	45						
23					15	16	18	19	21	23	25	27	28	30	31	33	35	36	38	40	41	43	44						
24					15	16	17	19	21	23	24	26	27	29	31	32	34	36	38	39	41	42	44	45					
25					15	16	17	19	21	22	24	26	27	29	30	32	34	35	37	38	40	42	43	45					
26						15	17	19	21	22	23	25	27	28	30	32	33	35	36	38	39	41	43	44					
27						15	17	19	21	22	23	25	26	28	30	31	33	35	36	38	39	41	42	43	45				
28						15	17	18	20	21	23	25	26	28	29	31	32	34	35	37	38	40	41	43	44				
29						15	16	18	19	21	23	24	26	28	29	30	32	33	35	37	38	39	41	42	44	45			
30						15	16	18	19	21	22	24	25	27	28	30	31	33	34	36	38	39	40	42	43	45			
31						15	16	17	19	21	22	24	25	27	28	30	31	33	34	35	37	38	40	41	43	44			
32						15	16	17	19	21	22	23	25	27	28	29	31	32	34	35	37	38	39	41	42	44	45		
33						15	16	17	19	20	21	23	25	26	28	29	30	32	33	35	36	38	39	40	42	43	45		
34							16	17	19	20	21	23	24	26	27	29	30	32	33	34	36	38	39	40	41	43	44		
35							15	17	19	20	21	22	24	26	27	28	30	31	33	34	35	37	38	40	41	43	44	45	
36							15	17	18	19	21	22	24	25	27	28	29	31	33	34	35	37	38	39	41	42	44	45	

Appendix A2.—Tarif access table for **grand fir**. Condensed from VARPLOT Tree Volume Tarif Access Tables (2002).

	Height (feet)																											
DBH (inches)	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**105**	**110**	**115**	**120**	**125**	**130**	**135**	**140**	**145**	**150**	**155**	**160**	**165**
7		15	18	20	23	26	29	34	37	39	44																	
8		15	17	20	21	24	28	31	34	37	39	44																
9			15	18	21	24	25	29	32	35	38	41	44															
10			15	17	20	23	25	27	29	33	36	38	41	44														
11			15	17	19	21	24	26	29	31	34	37	39	41	45													
12				15	18	20	23	25	28	30	32	35	38	39	42	45												
13				15	17	20	22	24	27	29	31	34	36	38	42	44												
14				15	17	19	21	23	26	28	30	33	35	38	40	43	45											
15				15	17	18	20	23	25	27	29	31	34	37	39	41	44	45										
16				15	17	18	20	22	24	26	29	31	33	35	38	40	43	45										
17					15	17	19	21	24	26	28	30	32	35	37	39	42	44										
18					15	17	19	21	23	25	28	29	32	34	36	38	41	43	45									
19					15	17	18	20	23	25	27	29	31	33	35	38	40	42	45									
20					15	17	18	20	21	24	26	28	30	32	34	37	39	41	44	45								
21					15	17	18	20	21	24	26	28	30	32	34	36	38	40	43	45								
22					15	17	17	19	21	23	25	27	29	31	33	35	38	40	42	44								
23						15	17	19	21	23	25	27	28	31	33	35	37	39	41	43	45							
24						15	17	19	21	22	24	26	28	30	32	34	36	39	41	43	45							
25						15	17	18	20	22	24	26	28	30	32	34	36	38	40	42	44							
26						15	17	18	20	22	24	26	27	29	31	33	35	37	39	42	44	45						
27						15	17	18	20	21	23	25	27	29	31	33	35	37	39	41	43	45						
28						15	17	18	19	21	23	25	27	29	31	32	34	36	38	40	43	45						
29						15	17	18	19	21	23	25	26	28	30	32	34	36	38	40	42	44						
30						15	17	18	19	21	22	24	26	28	29	32	34	35	38	39	41	43	45					
31							15	17	19	20	22	24	26	28	30	31	33	35	37	39	41	43	45					
32							15	17	19	20	22	24	26	27	29	31	33	35	37	39	41	43	45					
33							15	17	18	20	22	23	25	27	29	31	33	34	36	38	40	42	44					
34							15	17	18	20	21	23	25	27	29	30	32	34	36	38	40	42	44	45				
35							15	17	18	20	21	23	25	26	28	30	32	34	36	37	39	41	43	45				
36							15	17	18	20	21	23	25	26	28	30	32	34	35	37	39	41	43	45				

Appendix A3.—Tarif access table for **ponderosa pine**. Condensed from VARPLOT Tree Volume Tarif Access Tables (2002).

	Height (feet)																											
DBH (inches)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165
7			16	18	20	22	24	27	29	31	32	36	38	40	43	45												
8			15	16	19	21	23	25	27	28	31	34	36	38	40	42	45											
9			15	16	18	20	22	24	26	28	30	32	34	37	38	40	43	45										
10				15	17	19	20	23	25	27	29	31	33	35	37	39	41	43	45									
11				15	17	18	20	22	24	26	28	30	32	34	36	38	40	42	44	45								
12				15	16	18	20	22	23	25	27	29	31	33	35	37	38	40	42	44								
13				15	16	18	19	21	23	25	27	28	30	32	34	36	37	39	41	43	45							
14					15	18	19	21	22	24	26	28	30	31	33	35	37	39	40	42	44							
15					15	17	18	20	22	24	25	27	29	31	33	34	36	38	40	41	43	45						
16					15	16	18	20	21	23	25	27	28	30	32	34	35	37	39	41	42	44						
17					15	16	18	19	21	23	25	26	28	30	31	33	35	36	38	40	42	44	45					
18					15	16	18	19	21	23	24	26	28	30	31	33	34	36	38	39	41	43	45					
19					15	16	17	19	21	22	24	25	27	29	30	32	34	36	37	39	41	42	44					
20					15	16	17	19	20	22	24	25	27	28	30	32	33	35	37	38	40	42	44	45				
21						15	17	19	20	22	23	25	27	28	30	31	33	35	36	38	40	41	43	45				
22						15	17	18	20	21	23	25	26	28	29	31	33	34	36	38	39	41	43	44				
23						15	17	18	20	21	23	24	26	28	29	31	32	34	36	37	39	41	42	44				
24						15	17	18	20	21	23	24	26	28	29	31	32	34	35	37	39	40	42	43	45			
25						15	16	18	19	21	22	24	26	27	29	30	32	33	35	37	38	40	41	43	45			
26						15	16	18	19	21	22	24	25	27	28	30	32	33	35	36	38	40	41	43	44			
27						15	16	18	19	21	22	24	25	27	28	30	31	33	35	36	38	39	41	42	44			
28						15	16	17	19	20	22	23	25	27	28	30	31	33	34	36	37	39	41	42	44	45		
29						15	16	17	19	20	22	23	25	26	28	29	31	33	34	36	37	39	40	42	43	45		
30						15	16	17	19	20	22	23	25	26	28	29	31	33	34	35	37	38	40	42	43	45		
31						15	16	17	19	20	22	23	25	26	28	29	31	32	34	35	37	38	40	41	43	44		
32						15	16	17	19	20	21	23	24	26	27	29	30	32	33	35	36	38	40	41	43	44		
33						15	16	17	18	20	21	23	24	26	27	29	30	32	33	35	36	38	39	41	42	44	45	
34							15	17	18	20	21	23	24	26	27	29	30	32	33	35	36	38	39	41	42	44	45	
35							15	17	18	20	21	23	24	25	27	28	30	31	33	34	36	37	39	41	42	43	45	
36							15	17	18	20	21	22	24	25	27	28	30	31	33	34	36	37	39	41	42	43	45	

Appendix A4.—Tarif access table for **red alder**. Condensed from VARPLOT Tree Volume Tarif Access Tables (2002).

	Height (feet)																											
DBH (inches)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165
7		15	18	21	23	25	29	31	33	37	39	42	44															
8		15	17	20	22	25	27	30	32	35	37	39	42	44														
9		15	16	19	21	23	26	28	30	33	35	38	40	42	45													
10			15	18	20	22	25	27	29	31	34	36	38	40	43	45												
11			15	17	19	21	23	26	28	30	32	35	37	39	41	43	45											
12			15	16	19	21	23	25	27	29	31	34	36	38	40	42	44											
13			15	16	18	20	22	24	26	28	30	32	34	37	39	41	43	45										
14				15	17	19	22	24	26	28	30	32	34	36	37	40	41	43	45									
15				15	17	19	21	23	25	27	29	31	33	34	37	39	40	42	44									
16				15	17	18	20	22	24	26	28	30	32	34	36	38	39	41	43	45								
17				15	16	18	20	22	24	26	27	29	31	33	35	37	39	40	42	44								
18				15	16	18	20	21	23	25	27	29	31	32	34	36	38	40	41	42	44							
19					15	17	19	21	23	25	26	28	30	32	34	35	37	39	41	42	44							
20					15	17	19	21	22	24	26	28	30	31	33	35	36	38	40	42	43	45						
21					15	17	18	20	22	24	25	27	29	31	32	34	36	37	39	41	42	44						
22					15	16	18	20	22	23	25	27	28	30	32	33	35	37	38	41	42	43	45					
23					15	16	18	19	21	23	25	26	28	30	31	33	35	36	38	40	41	43	44					
24					15	16	17	19	21	23	24	26	27	29	31	32	34	36	37	39	41	42	44	45				
25					15	16	17	19	21	22	24	25	27	29	30	32	34	35	37	38	40	42	43	45				
26						15	17	19	20	22	23	25	27	28	30	32	33	35	36	38	39	41	43	44				
27						15	17	18	20	22	23	25	26	28	30	31	33	34	36	37	39	40	42	43	45			
28						15	17	18	20	21	23	24	26	28	29	31	32	34	35	37	38	40	41	43	44			
29						15	16	18	19	21	23	24	26	27	29	30	32	33	35	36	38	39	41	42	44	45		
30						15	16	18	19	21	22	24	25	27	28	30	31	33	34	36	37	39	40	42	43	45		
31						15	16	17	19	20	22	24	25	27	28	30	31	33	34	35	37	38	40	41	43	44		
32						15	16	17	19	20	22	23	25	26	28	29	31	32	34	35	37	38	39	41	42	44	45	
33						15	16	17	19	20	21	23	24	26	27	29	30	32	33	35	36	38	39	40	42	43	45	
34							15	17	18	20	21	23	24	26	27	29	30	32	33	34	36	37	39	40	41	43	44	
35							15	17	18	20	21	22	24	25	27	28	30	31	33	34	35	37	38	40	41	42	44	45
36							15	16	18	19	21	22	24	25	27	28	29	31	32	34	35	37	38	39	40	42	43	45

Appendix A5.—Tarif access table for **western hemlock**. Condensed from VARPLOT Tree Volume Tarif Access Tables (2002).

	Height (feet)																											
DBH (inches)	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165
7	15	17	19	22	25	27	30	33	36	38	40	44																
8		16	18	21	23	26	29	31	34	36	39	42	45															
9		15	17	20	22	25	27	30	32	35	38	40	43	45														
10		15	17	19	22	24	26	29	31	34	36	39	41	44														
11		15	16	18	21	23	26	28	30	33	35	38	40	42	45													
12		15	16	18	20	22	25	27	30	32	34	37	39	41	44													
13			15	17	20	22	24	27	29	31	33	36	38	40	42	45												
14			15	17	19	21	23	26	28	30	33	35	37	39	42	44												
15			15	17	19	21	23	25	28	30	32	34	36	39	41	43	45											
16			15	16	18	21	23	25	27	29	31	33	35	38	40	42	44											
17			15	16	18	20	22	24	27	29	31	33	35	37	39	41	44	45										
18			15	16	18	20	22	24	26	28	30	32	34	36	39	41	43	45										
19			15	16	17	19	21	23	26	28	30	32	34	36	38	40	42	44										
20				15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45									
21				15	17	19	21	23	25	27	29	31	33	35	36	39	41	43	44									
22				15	17	19	20	22	24	26	28	30	32	34	36	38	40	42	44									
23				15	16	18	20	22	24	26	28	30	32	34	35	37	39	41	43	45								
24				15	16	18	20	22	23	25	27	29	31	33	35	37	39	41	43	44								
25				15	16	18	20	21	23	25	27	29	31	33	34	36	38	40	42	44								
26				15	16	17	19	21	23	25	27	28	30	32	34	36	38	39	41	43	45							
27				15	16	17	19	21	23	24	26	28	30	32	33	35	37	39	41	43	45							
28					15	17	19	20	22	24	26	28	29	31	33	35	37	38	40	42	44							
29					15	17	18	20	22	24	25	27	29	31	32	34	36	38	40	41	43	45						
30					15	17	18	20	22	23	25	27	29	30	32	34	36	37	39	41	43	44						
31					15	16	18	20	21	23	25	26	28	30	32	33	35	37	39	40	42	44						
32					15	16	18	19	21	23	24	26	28	30	31	33	35	36	38	40	42	43	45					
33					15	16	18	19	21	22	24	26	27	29	31	32	34	36	37	39	41	43	44					
34					15	16	17	19	20	22	24	25	27	29	30	32	34	35	37	39	40	42	44	45				
35						15	17	19	20	22	23	25	27	28	30	32	33	35	36	38	40	42	43	45				
36						15	17	18	20	22	23	25	26	28	30	31	33	35	36	38	39	41	43	44				

Appendix A6.—Tarif access table for **western redcedar**. Condensed from VARPLOT Tree Volume Tarif Access Tables (2002).

DBH (inches)	Height (feet) 30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165
7	15	17	20	23	26	28	31	34	36	39	42	45																
8	15	16	19	21	24	26	29	31	34	35	39	41	44															
9		15	18	20	22	25	27	29	32	34	37	39	41	44														
10		15	16	18	21	23	25	28	30	32	35	37	39	42	44													
11		15	16	18	20	22	24	26	29	31	33	35	38	40	41	44												
12			15	17	19	21	23	25	28	30	32	34	36	38	40	43	45											
13			15	16	19	21	22	24	26	29	31	33	35	37	39	41	43	45										
14			15	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44										
15			15	16	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45									
16				15	17	19	21	23	24	26	28	30	32	34	36	38	40	42	44	45								
17				15	17	18	20	22	24	26	27	29	31	33	35	37	39	41	43	44								
18				15	16	18	20	22	23	25	27	29	31	32	34	36	38	40	42	43	45							
19				15	16	18	19	21	23	24	26	28	30	32	34	36	37	39	41	43	44							
20				15	16	17	19	21	23	24	26	28	29	31	33	35	37	38	40	42	43	45						
21					15	17	19	20	22	24	26	27	29	31	32	34	36	38	39	41	43	44						
22					15	17	18	20	22	23	25	27	28	30	32	33	35	37	39	40	42	44	45					
23					15	17	18	20	21	23	25	26	28	30	31	33	35	36	38	40	41	43	45					
24					15	16	18	20	21	23	24	26	28	29	31	33	34	36	38	39	41	42	44					
25					15	16	18	19	21	22	24	26	27	29	30	32	34	35	37	39	40	42	44	45				
26					15	16	18	19	21	22	24	25	27	29	30	32	33	35	37	38	40	41	43	45				
27					15	16	17	19	20	22	23	25	27	28	30	31	33	35	36	38	39	41	43	44				
28					15	16	17	19	20	22	23	25	26	28	29	31	33	35	36	37	39	41	42	44	45			
29						15	17	18	20	21	23	24	26	28	29	31	32	34	35	37	38	40	42	43	45			
30						15	17	18	20	21	23	24	26	27	29	30	32	33	35	37	38	40	41	43	44			
31						15	17	18	20	21	22	24	25	27	28	30	32	33	35	36	38	39	41	42	44	45		
32						15	16	18	19	21	22	24	25	27	28	30	31	33	34	36	38	39	40	42	43	45		
33						15	16	18	19	21	22	24	25	26	28	29	31	32	34	36	37	38	40	42	43	44		
34						15	16	18	19	20	22	23	25	26	28	29	31	32	34	35	37	38	40	41	43	44		
35						15	16	17	19	20	22	23	25	26	27	29	30	32	33	35	36	38	39	41	42	44	45	
36						15	16	17	19	20	22	23	24	26	27	29	30	32	33	34	36	37	39	40	42	43	45	

Appendix B1.—Tree volume table **(Scribner volume table, 32' logs to 5" top)**. Condensed from VARPLOT Scribner Volume Tables.

	Tarif numbers																														
DBH (inches)	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
7	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20	20	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
8	10	10	10	10	10	10	10	10	10	10	30	30	30	30	30	30	30	40	40	40	40	40	40	40	40	40	40	60	70	70	70
9	20	20	20	20	20	20	20	30	30	30	30	30	40	40	40	70	70	60	60	60	60	60	60	70	70	70	70	70	70	80	80
10	20	20	20	20	20	30	30	30	30	40	40	60	70	70	60	60	60	70	70	80	80	80	80	80	90	90	90	90	90	90	90
11	20	20	20	30	30	30	30	40	60	60	70	70	70	70	70	70	80	80	80	90	90	100	100	100	100	100	100	100	110	110	130
12	20	20	30	30	30	40	60	60	80	80	80	70	70	80	90	90	90	90	90	100	100	100	100	120	120	120	150	150	150	150	150
13	20	30	30	30	60	60	70	80	80	70	80	80	90	90	90	110	110	120	120	120	120	120	120	130	150	150	150	150	160	200	200
14	30	30	30	60	60	70	80	90	80	80	80	110	110	110	110	120	120	120	150	150	150	180	180	180	180	190	190	200	200	200	220
15	30	30	60	70	70	80	90	80	80	110	110	110	110	140	150	150	150	150	150	170	180	200	210	210	210	220	230	230	230	240	240
16	30	60	70	70	90	90	80	100	110	110	140	140	150	150	150	170	170	170	190	200	210	210	210	220	230	230	250	260	280	280	280
17	50	60	70	90	90	110	100	110	140	140	140	150	170	170	170	170	170	220	220	230	230	230	250	250	250	270	280	280	280	280	310
18	60	70	80	90	110	100	130	140	140	160	160	170	170	190	190	190	220	220	230	230	270	280	280	300	300	310	310	340	340	340	370
19	70	80	80	110	110	130	140	160	160	160	190	190	190	190	190	240	260	260	270	270	280	300	300	300	380	380	380	380	400	430	430
20	70	80	110	110	130	130	160	160	180	190	190	190	220	220	240	260	260	310	310	340	340	340	370	380	380	380	400	400	430	440	440
21	80	80	110	140	130	160	160	180	180	190	220	220	220	280	290	300	310	310	330	340	420	420	430	450	450	450	450	500	510	510	520
22	80	100	140	140	150	180	180	180	220	220	220	260	260	280	300	360	360	380	390	420	420	420	450	450	490	510	540	550	550	590	600
23	80	110	140	160	170	180	210	210	220	260	260	260	330	350	350	360	380	380	460	460	480	490	490	510	510	530	580	580	590	600	670
24	100	140	160	150	180	210	210	250	260	260	310	310	330	390	400	420	420	460	460	480	540	560	560	560	610	620	630	640	690	710	710
25	100	140	160	170	210	210	250	260	310	310	310	370	390	400	400	420	500	510	530	530	560	560	590	610	680	690	740	750	770	770	860
26	130	160	180	170	210	250	250	310	310	350	350	370	440	450	470	500	510	530	590	610	620	650	650	670	730	740	740	820	820	850	910
27	130	160	180	200	250	250	300	310	350	350	400	420	440	450	530	560	590	590	610	620	700	700	760	780	780	840	870	870	900	950	970
28	130	180	210	200	250	300	340	350	350	400	420	490	510	530	560	590	640	660	660	700	700	740	760	830	920	940	950	1020	1020	1050	1050
29	150	180	210	240	300	340	340	400	400	460	480	500	560	580	610	640	660	660	780	780	820	840	910	910	920	990	1020	1020	1050	1120	1120
30	150	180	250	240	300	340	390	400	460	460	530	550	580	610	710	740	740	770	820	820	920	940	960	1010	1030	1070	1120	1140	1170	1170	1200
31	150	210	250	290	340	390	390	460	460	510	530	640	660	690	710	740	820	820	870	920	920	980	1010	1030	1150	1180	1200	1230	1290	1320	1340
32	150	210	250	330	340	390	450	460	510	590	620	640	710	760	780	790	820	860	980	980	1040	1060	1120	1140	1180	1260	1260	1290	1320	1320	1440
33	170	210	300	330	390	450	500	510	590	590	670	690	740	760	850	880	920	980	980	1020	1120	1190	1220	1250	1320	1340	1370	1450	1450	1510	1530
34	170	250	300	330	450	450	500	590	590	640	670	770	800	820	850	880	1000	1060	1100	1100	1180	1200	1280	1320	1340	1470	1480	1510	1550	1660	1720
35	170	250	340	380	450	500	580	590	640	660	730	770	820	920	960	1000	1050	1100	1160	1230	1240	1320	1340	1430	1450	1470	1510	1630	1650	1720	1730
36	170	250	340	380	500	580	580	640	700	720	820	850	900	920	1020	1060	1110	1160	1210	1230	1310	1450	1530	1560	1580	1700	1700	1740	1810	1880	1950

Appendix B2.—Tree volume table **(Scribner volume table, 16' logs to 5" top)**. Condensed from VARPLOT Scribner Volume Tables.

DBH (inches)	Tarif numbers 15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30	30	30	30	30	30	30	40	40	40	40	40	40	40	40	40
8	10	10	10	10	10	10	10	10	10	10	30	30	30	30	40	40	40	50	50	50	50	50	50	50	50	50	50	50	60	60	60
9	10	10	10	10	10	10	10	30	30	30	40	40	50	60	60	60	70	60	60	60	60	60	70	70	70	70	70	80	80	80	80
10	10	10	10	10	10	40	40	50	50	60	60	60	70	70	60	60	60	60	80	80	80	80	90	90	90	90	90	90	90	100	100
11	10	10	10	40	40	50	50	60	60	60	70	70	70	70	70	80	80	80	80	90	90	100	100	100	100	110	110	120	120	130	130
12	10	10	40	50	50	60	60	60	70	90	90	80	80	90	90	90	100	100	100	100	100	100	110	120	130	130	140	140	140	140	140
13	10	40	50	50	70	70	70	90	90	80	80	110	110	110	120	120	130	130	140	140	150	150	150	150	160	160	160	160	160	180	200
14	40	60	60	70	70	100	110	110	100	100	110	110	120	130	140	140	150	150	150	180	180	180	190	190	190	200	210	220	220	220	230
15	60	60	90	90	100	110	110	110	110	130	130	130	140	140	170	170	170	180	190	190	200	210	220	230	230	240	240	240	270	270	270
16	80	80	90	110	120	120	110	120	140	140	140	170	180	180	180	180	200	200	210	220	220	230	230	250	260	260	290	300	300	310	320
17	80	100	110	110	130	130	130	140	160	160	190	200	210	210	210	220	230	230	250	250	280	280	290	290	290	310	320	320	330	330	340
18	90	110	120	130	140	150	160	180	180	190	210	210	210	220	250	250	250	260	290	290	290	300	330	330	350	350	360	360	400	400	400
19	110	120	120	160	160	170	180	190	210	220	220	230	230	250	250	250	300	340	340	350	360	360	370	380	390	420	430	440	440	440	460
20	120	140	140	160	180	190	200	200	250	260	260	260	290	300	320	330	340	350	360	360	390	390	400	420	430	450	480	490	490	510	510
21	140	140	170	190	210	230	230	250	260	260	300	310	320	340	360	380	380	380	390	410	410	470	490	500	510	520	520	530	540	570	590
22	150	160	200	220	220	230	260	280	300	300	310	320	350	370	390	400	440	440	460	480	500	510	520	530	540	570	590	600	630	630	660
23	150	190	220	250	250	260	260	320	320	340	340	370	370	420	430	440	440	500	510	550	560	590	590	590	620	620	630	690	710	720	730
24	180	230	240	240	280	280	310	320	360	370	420	430	440	450	490	490	520	530	550	560	590	610	620	670	670	720	730	760	770	790	820
25	210	230	270	260	280	330	350	360	370	420	430	470	490	520	520	550	570	610	610	630	670	680	690	720	740	800	820	830	840	860	870
26	210	260	270	300	330	330	390	390	430	450	490	490	510	600	600	620	650	650	690	740	750	750	810	830	840	870	870	890	920	960	1000
27	230	300	310	330	360	370	420	470	520	510	530	560	600	600	620	650	710	720	750	790	790	850	880	890	930	940	980	1000	1020	1050	1060
28	280	300	340	350	410	440	460	490	520	560	580	580	650	660	670	720	740	790	820	820	850	880	910	930	970	1020	1070	1090	1140	1150	1170
29	280	340	400	390	410	470	500	510	570	560	610	660	690	730	780	790	820	840	870	930	950	980	990	1070	1080	1080	1140	1160	1190	1230	1250
30	310	380	400	420	460	490	530	580	590	640	660	710	720	760	830	910	920	960	980	1000	1060	1090	1130	1150	1170	1240	1260	1300	1320	1360	1380
31	360	380	430	420	490	520	560	630	670	720	740	770	840	850	890	910	940	1000	1030	1050	1110	1140	1220	1220	1250	1280	1340	1360	1440	1480	1520
32	380	420	460	480	560	590	640	660	710	760	810	830	870	910	940	980	1000	1050	1070	1180	1200	1220	1250	1270	1340	1380	1400	1470	1480	1540	1560
33	380	450	460	530	580	610	660	720	730	800	810	880	970	990	1030	1100	1130	1150	1220	1240	1280	1340	1440	1450	1490	1520	1590	1610	1690	1700	1740
34	410	500	540	570	600	640	750	780	830	870	920	940	1000	1050	1100	1120	1220	1270	1330	1410	1420	1460	1480	1550	1580	1620	1680	1720	1760	1840	1860
35	460	510	560	570	690	730	770	820	910	930	990	1030	1080	1120	1190	1240	1270	1350	1390	1430	1480	1520	1570	1590	1670	1730	1750	1780	1880	1880	1970
36	460	530	640	650	730	770	850	890	910	960	1060	1130	1180	1220	1290	1320	1410	1420	1480	1520	1530	1600	1710	1800	1810	1860	1940	1950	2040	2120	2160

Appendix B3.—Tree volume table **(cubic volume table to 4" top)**. Condensed from VARPLOT Scribner Volume Tables.

DBH (inches)	Tarif numbers 15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
7	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	9	9
8	4	5	5	5	5	6	6	6	7	7	7	7	8	8	8	9	9	9	9	10	10	10	11	11	11	11	12	12	12	13	13
9	6	6	7	7	7	8	8	9	9	9	10	10	10	11	11	12	12	12	13	13	14	14	14	15	15	16	16	16	17	17	17
10	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23
11	9	10	11	11	12	13	13	14	14	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	24	25	26	26	27	28	28
12	11	12	13	14	15	15	16	17	18	18	19	20	21	21	22	23	24	24	25	26	27	28	28	29	30	31	31	32	33	34	34
13	14	15	16	16	17	18	19	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	36	37	37	38	39	40	41
14	16	17	18	19	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	37	38	39	40	41	42	43	44	45	46	47	48
15	19	20	21	22	24	25	26	27	29	30	31	32	34	35	36	37	39	40	41	42	44	45	46	47	49	50	51	52	54	55	56
16	22	23	24	26	27	29	30	32	33	34	36	37	39	40	42	43	44	46	47	49	50	52	53	54	56	57	59	60	62	63	65
17	24	26	28	29	31	33	34	36	38	39	41	42	44	46	47	49	51	52	54	55	57	59	60	62	64	65	67	69	70	72	73
18	28	29	31	33	35	37	39	40	42	44	46	48	50	52	53	55	57	59	61	63	64	66	68	70	72	74	75	77	79	81	83
19	31	33	35	37	39	41	43	45	47	49	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	85	87	89	91	93
20	34	37	39	41	44	46	48	50	53	55	57	60	62	64	67	69	71	73	76	78	80	83	85	87	89	92	94	96	99	101	103
21	38	41	43	46	48	51	53	56	58	61	63	66	69	71	74	76	79	81	84	86	89	91	94	97	99	102	104	107	109	112	114
22	42	45	48	50	53	56	59	62	64	67	70	73	76	78	81	84	87	89	92	95	98	101	103	106	109	112	115	117	120	123	126
23	46	49	52	55	58	61	64	67	71	74	77	80	83	86	89	92	95	98	101	104	107	110	113	116	120	123	126	129	132	135	138
24	50	54	57	60	64	67	70	74	77	80	84	87	90	94	97	100	104	107	110	114	117	120	124	127	131	134	137	141	144	147	151
25	55	58	62	66	69	73	76	80	84	87	91	95	98	102	106	109	113	116	120	124	127	131	135	138	142	146	149	153	156	160	164
26	59	63	67	71	75	79	83	87	91	95	99	103	106	110	114	118	122	126	130	134	138	142	146	150	154	158	162	166	170	174	177
27	64	68	72	77	81	85	89	94	98	102	107	111	115	119	124	128	132	136	141	145	149	153	158	162	166	170	175	179	183	187	192
28	69	73	78	83	87	92	96	101	106	110	115	119	124	129	133	138	142	147	151	56	161	165	170	174	179	184	188	193	197	202	207
29	74	79	84	89	94	99	104	108	113	118	123	128	133	138	143	148	153	158	163	168	173	177	182	187	192	197	202	207	212	217	222
30	79	85	90	95	100	106	111	116	121	127	132	137	143	148	153	158	164	169	174	180	185	190	195	201	206	211	217	222	227	232	238
31	85	90	96	102	107	113	119	124	130	136	141	147	152	158	164	169	175	181	186	192	198	203	209	215	220	226	232	237	243	248	254
32	90	96	102	108	114	120	126	133	139	145	151	157	163	169	175	181	187	193	199	205	211	217	223	229	235	241	247	253	259	265	271
33	96	103	109	115	122	128	135	141	147	154	160	167	173	180	186	192	199	205	212	218	224	231	237	244	250	256	263	269	276	282	289
34	102	109	116	123	129	136	143	150	157	163	170	177	184	191	198	204	211	218	225	232	238	245	252	259	266	272	279	286	293	300	307
35	108	116	123	130	137	144	152	159	166	173	181	188	195	202	210	217	224	231	238	246	253	260	267	275	282	289	296	303	311	318	325
36	115	122	130	138	145	153	161	168	176	184	191	199	207	214	222	229	237	245	252	260	268	275	283	291	298	306	314	321	329	337	344

Tree Tally Card

User name ______________________

Stand name ______________________

Date ______________________

Plot size ____________

Species ____________

Stand age ____________

Multiplication factor* ____________

Average tarif number ____________

Plot Trees

DBH (in.)	Plot number 1	2	3	4	5	6	7	8	9	10	Total trees	Total trees per acre
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												
										Total		

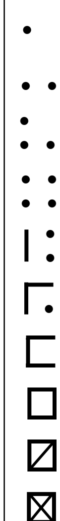
Recommended plot sizes	Distance between trees: less than 8 ft.	8–16 ft.	16–24 ft.	more than 24 ft.
Plot size (acres)	1/100th	1/50th	1/20th	1/10th
Plot radius (ft. & in.)	11′10″	16′8″	26′4″	37′2″
Plot radius (ft.)	11.8	16.7	26.3	37.2
Plot size correction factor	100	50	20	10

Tariff Trees

1 Plot no.	2 DBH (in.)	3 Height to nearest 5 ft.	4 Radial growth for 5 yrs. (in.)	5 Tarif no. from access tables
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
		Total		
		Average		

* $\text{Multiplication factor} = \dfrac{\text{Plot size correction factor}}{\text{Number of plots}}$

Dot count key



= 1

= 2

= 3

= 4

= 5

= 6

= 7

= 8

= 9

= 10

Remember

The first tree from each plot is recorded as a Plot Tree ***and*** as a Tarif Tree.

Volume Computation Form

Stand name ____________________

Species ____________________

Stand age ____________________

Average tarif number ____________________

Multiplication factor ____________________

Date ____________________

Average radial growth ____________________

Average basal area/tree ____________________

Average stand diameter ____________________

Board-foot volumes (16′ or 32′) ____________________

	1	2	3	4	5	6	7
DBH	Trees/ acre	Board ft. vol./tree (from Tree Volume Tables)	Board ft. vol./acre (col. 1 x col. 2)	Cubic ft. vol./tree (from Tree Volume Tables)	Cubic ft. vol./acre (col. 1 x col. 4)	Basal area/tree	Basal area/acre by diameter class (col. 1 x col. 6)
7						0.267	
8						0.349	
9						0.442	
10						0.545	
11						0.66	
12						0.785	
13						0.922	
14						1.069	
15						1.227	
16						1.396	
17						1.576	
18						1.767	
19						1.969	
20						2.182	
21						2.405	
22						2.64	
23						2.885	
24						3.142	
25						3.409	
26						3.687	
27						3.976	
28						4.276	
29						4.587	
30						4.909	
31						5.241	
32						5.585	
33						5.939	
34						6.305	
35						6.681	
36						7.068	
	Total trees/acre		Total board-foot volume/acre		Total cubic-foot volume/acre		Total basal area/acre

The Woodland Workbook is a series of some 60 publications prepared by Oregon State University Extension foresters specifically for owners and managers of private, nonindustrial woodlands. Workbook publications contain information of long-range and day-to-day value for anyone interested in wise management, conservation, and use of woodland properties. Publications are available for purchase separately. For information about how to order, and for a current list of titles and prices, contact the OSU Extension Service office that serves your county. Or, visit the Extension Web site at http://eesc.oregonstate.edu/ then Publications & Videos, then Forestry.

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