Measuring Your Trees

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Woodland owners value their lands for many reasons, including aesthetics, privacy, recreation, fish and wildlife, income, and more. Whatever your objectives, sound forest management plans require a thorough ***inventory***: basic information such as tree size, species, density, growth rates, and merchantable volume. An accurate estimate of these parameters helps answer important management questions: Do I have too few trees? Too many trees? Are my trees growing well? How much volume is in my trees?

How do you obtain this information? One approach is to measure every tree in the stand and add it all up. However, this is impractical for even small acreages. A more sensible alternative is to select an appropriate sample of trees that are representative of the entire stand, accurately measure that sample, and then use the information to estimate stand characteristics. If done correctly, this sampling process will give satisfactory results and save time and money.

The step-by-step procedures in this publication show how to estimate standing volume and annual growth of individual timber stands that are relatively uniform in species, age, size, and density. 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 with financial analysis and the tax implications of a timber harvest.

Don't confuse this simplified process for collecting and analyzing a forest inventory with the more complex and precise techniques professional foresters use to estimate timber values for sales, land appraisals, or legal purposes. This simplified process allows you to get reasonably accurate gross volumes of timber but does not address net volumes, log grades, or monetary values.

Abbreviations at a glance

The following abbreviations are used throughout this publication.

DBH: Diameter at breast height
MBF: 1,000 board feet
ARG: Average radial growth
GPF: Growth projection factor
MAI: Mean annual increment
PAI: Periodic annual increment
SDI: Stand density index
RD: Relative density

Contents

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This publication replaces OSU Extension publication EC 1190, *Stand Volume and Growth: Getting the Numbers*.

Oregon State University Extension Service

The tarif system

All forest inventory systems generate estimates of tree volume and growth. The ***tarif system*** originated in Europe and was adapted for Pacific Northwest use by the State of Washington. Very simply, tarif refers to the relationship between tree height and diameter.

The tarif system is a type of tree volume table that allows you to determine the gross wood volume of individual trees on the basis of species, tree diameter at breast height (DBH), and total height. The system applies a tarif number that signifies the total height-to-diameter relationship of an individual tree. The tree volume tables supported by this publication include Douglas-fir, grand fir, western hemlock, ponderosa pine, western redcedar, and red alder.

This simplified system is appealing to woodland owners because it is easier to use and requires fewer measurements than other systems, lessening the chance for error. Many professionals use the ***form class inventory method***, which requires additional measurements along the tree stem, necessitating additional measuring tools and experience to obtain accurate tree estimates.

If you have questions about the appropriateness of using the tarif system to make management decisions regarding your timber stand or need help with a complex situation, contact the Extension forester who serves your county, a Stewardship Forester from the Oregon Department of Forestry, or a private consulting forester.

Key numbers to generate

By following the procedures in this publication, you'll generate several numbers that describe your timber stand.

Number of trees per acre

This is a good start and the basis for many other calculations.

Number of trees per acre by diameter class

Also called a ***stand table***, these numbers can be used to plan logging jobs and evaluate tree sizes available to merchandise. This is important because many mills require a narrow range of log specifications. You'll also use these numbers as the starting point for projecting future stand growth.

Average stand diameter

This number is valuable for making decisions about merchantability and selecting appropriate logging equipment. It is also used to project stand growth and, along with trees per acre, can provide useful information for making thinning decisions.

Basal area

This is the cross-sectional (circular) area of a tree. It is measured at breast height (4.5 feet above the ground) and taken on the uphill side of the tree. The sum of the basal area for all trees in the stand is the total stand basal area, a common measure of stand density and tree size and a very important piece of information for making stand-management decisions.

Tarif number

A tarif number identifies the taper, or shape, of trees and is the key to determining tree and individual log 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.

Given two trees with the same DBH, the easiest way to understand the corresponding tarif numbers is that a low tarif number means the tree has a lot of taper and less volume, and a high tarif number means the tree has minimal taper and greater volume. For example, a 90-foot-tall Douglas-fir with a 12-inch DBH has a tarif number of 30, while a 130-foot-tall Douglas-fir with the same DBH has a tarif number of 40.

Tarif numbers differ slightly among species, but in general, a low tarif number for a timber stand is less than 30, a medium tarif number is between 30 and 40, and a high tarif number is greater than 40. Typically, higher quality sites have trees with higher tarif numbers.

Stand volumes

You can use the tarif number of your sample trees to look up volumes of trees of various diameters in board-foot or cubic-foot volume tables. Then, you can convert these into per-acre volumes by diameter class by multiplying individual tree volumes by the number of trees per acre. Tree volumes are some of the most useful numbers to generate. It is important to remember that these numbers are ***gross volumes***. They don't consider losses for defects and breakage that can occur during harvest or natural defects in a tree, all of which can affect ***net volumes***.

Board-foot volume

This number is often of greatest interest since most timber is sold at a price per 1,000 board feet (MBF). There are several methods of scaling or measuring board feet. This publication uses the most common method in the Pacific Northwest: the Scribner volume table.

Cubic-foot volume

This is a basic measure of the total wood volume in a tree and is independent of how the tree is cut into various log lengths and diameters. It is also useful for determining basic growth relationships for the stand and for comparing stands or species.

You can use the numbers described above along with tree ring widths from increment cores to measure past growth and estimate future growth:

- **Growth projection factor (GPF).** This number can be used in conjunction with board-foot or cubic-foot volumes to estimate future stand volumes given current growth rates.
- **Mean annual increment (MAI).** This number is the average volume growth per year over the total life of the stand.
- **Periodic annual increment (PAI).** This number is the annual volume growth measured over a specified period, usually 5 or 10 years (5 years is recommended).

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. Consult the following OSU Extension publications for more information:

EC 1133, *Mapping and Managing Poorly Stocked Douglas-fir Stands*, defines terms, shows how to divide trees into separate stands, and explains how to make sampling plans.

EC 1129, *Tools for Measuring Your Forest*, describes tools used to measure your trees.

EM 9059, *Measuring Your Trees Workbook*, is a computer-based calculator you can use instead of doing calculations by hand. This workbook does the following:

- Uses measurements of tarif trees and plot trees 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 of 1-inch increments for the total stand.
- Estimates average diameter at breast height (DBH), growth projection factor (GPF), and board-foot volume growth expressed as mean annual increment (MAI) and periodic annual increment (PAI).
- Estimates stand density index (SDI) and relative density (RD), which are measures of stand density and competition—two important considerations in managing a timber stand.

Example: Coleman's Conifers

Throughout this publication, we use a fictional stand called Coleman's Conifers to illustrate the steps needed to take an inventory of your trees. Where you see shaded boxes, like this one, you'll find an example from Coleman's Conifers that will help you work through the procedures. Each box applies the steps explained in nearby text and moves the calculations one step further.

Table 1: Steps to measure stand volume and growth

Procedure	Directions	Tools needed
Identify distinct stands.	Mark on map or photo, using field data.	Aerial photo, map, EC 1133[1]
Make a sampling plan.	Follow procedures in EC 1133.	EC 1133, aerial photo, map
Estimate the plot size you'll need.	Begin with a 1⁄20-acre plot size.	Compass, tape
	Adjust if needed after 3 or 4 plots.	
Collect plot data.	Establish a plot.	Tape, compass, Tree Tally Card[2]
	Measure tree diameters.	Diameter tape
	Measure tarif trees.	Clinometer, Tree Tally Card
	Take increment cores.	Increment borer

[1] OSU Extension publication EC 1133, *Mapping and Managing Poorly Stocked Douglas-fir Stands*.

[2] See Appendix C for a blank Tree Tally Card.

Measure stand volume and growth

Table 1 summarizes the steps for measuring a stand, how to accomplish those steps, and the tools you'll need to perform each task. Steps 1 through 5 explain the information in Table 1.

Step 1: Identify distinct stands

Carefully select the area or stand to sample. It should be relatively uniform in ***stocking*** (trees per acre or space between trees) and in size of trees. OSU Extension publication EC 1133 explains how to divide your land into logical stand types, which often correlate to a management unit. 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 the stand contains trees consistently and substantially smaller (by 6 inches DBH or more) than trees in the rest of the stand, *treat those two areas as separate stands*.
- 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 smaller area (1 to 3 acres) that is distinctly different from the rest of the stand (poor stocking, different species, etc.), *measure the smaller area separately*. Note: Calculating area is critical in determining accurate estimates of a timber stand. Be sure to measure areas accurately; use a GPS unit if possible.
- If you have several openings of ¼ to ½ acre scattered through a larger stand that is otherwise uniform, *sample the entire area*. Your confidence in the estimate may be lower, but the numbers you generate will be more accurate than if you attempt to measure these smaller areas separately.
- 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: Make a sampling plan

After you determine which areas are similar enough to sample together as stands, it is time to make a sampling plan.

If you wander through the stand and pick likely looking spots, estimates will be inaccurate and possibly inflated. A better process is to determine how many sampling points are needed and systematically distribute those points uniformly across the whole stand. Mark intended plot locations on a photo or map. Then, as accurately as possible, establish those locations on the ground. One plot for every 2 acres will generally give a good estimate for uniform stands, but more diverse stands require at least one plot per acre.

If you have less than 10 acres, you may choose a more intense sampling plan. Two or three plots per acre may be reasonable and accurate. Small-acreage tracts usually develop from regional zoning changes that have allowed farm or forestry land to be subdivided into rural residential zoning. These areas have been previously harvested, often with marginal reforestation efforts, resulting in many different tree species and sizes.

If you have less than 5 acres, you may choose to measure each individual tree (a 100% sampling plan). This is feasible but requires a lot of work. It might be more efficient to use two, three, or four plots per acre.

It is important to remember that regardless of acreage, using more plots does not necessarily result in greater accuracy.

Step 3: Develop a strategy

To ensure a successful timber evaluation and nonbiased coverage, use a systematic approach to establish plots and measure each stand. Do everything the same, each time, every time.

Begin at one corner of the timber stand. Regardless of the number of plots in your sampling plan, measure or pace 50 feet along the edge of the stand, perpendicular to your planned compass line. Then proceed 50 feet along the compass line to the first plot center. By avoiding the stand boundaries, you'll ensure that all plots will contain trees inside the desired timber stand even if you make slight errors when traversing the compass line (it's difficult to stay in a perfectly straight line).

Whatever your sampling plan, if a plot happens to be adjacent to the boundary line and some of the trees will be outside the stand, measure 50 feet backwards along the compass line to establish the plot.

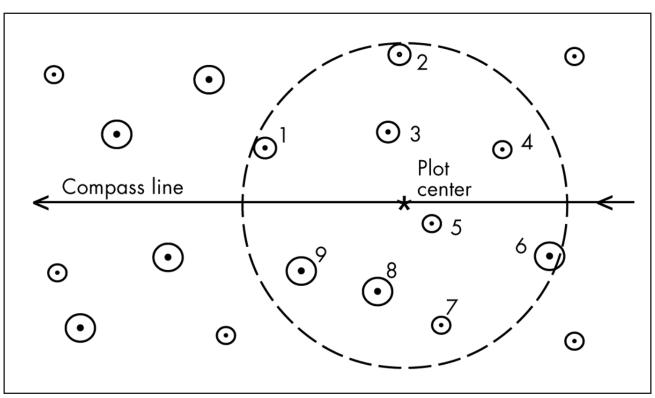

Figure 1. Plot 1 for Coleman's Conifers (includes nine "in" trees).

Step 4: Estimate the plot size you'll need

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 starting your fieldwork, use Table 2 as a checklist to ensure you have the proper equipment.

To begin, refer to the sampling plan you developed for the stand under Step 2. Locate the point where you'll start the sample. Place a flag, stick, or stake in the ground so you can locate the plot in the future.

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 the plot. The plot center does not need to be a tree. It is simply the center point according to the measurements.

From the plot center, count all trees within a radius of 26 feet and 4 inches. This plot size—which is $\frac{1}{20}$ of an acre—will often give you a sufficient number of trees per plot. If you don't have the desired five to eight trees after recording the first plot, don't change the plot size yet.

Proceed along your planned compass line to the second plot and count the number of trees within the plot radius. If there are still too many or too few sample trees after measuring three or four plots, return to the first plot and adjust the plot size accordingly.

It is better to have a few too many trees than not enough, so be sure you have an adequate plot size. Eight to 10 trees per plot may seem like 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 determine the proper plot size, continue with your sampling plan for the entire stand.

Table 2: Tools needed for field measurements

Needs and tools	Purpose
To obtain volume information:	
Logger's or similar tape	Measure distance to plot boundaries and tarif trees. Pacing is acceptable for establishing adjacent plot centers.
Diameter tape or woodland stick	Measure tree diameters.
Clinometer or woodland stick	Measure tree heights.
Tarif access and tree volume tables	Provide information needed to transform measurements to volumes.
A second person (optional but recommended)	Hold one end of the tape when measuring boundaries. Tally information while you take measurements. Hold end of tape when measuring distance from tarif trees.
To obtain growth information:	
Increment borer	Extract a core sample from tarif trees (also an option for determining tree age).
Small ruler	Measure width of annual rings in the core sample.
A carrier for core samples (optional but recommended)	Take core samples home for measurement.

Step 5: Collect plot data

Establish plots

Using point * as your plot center (Figure 1) and the plot radius you determined in Step 4, identify the trees within the first plot. You don't need to mark the entire outer limits of the plot or measure the distance to trees that are clearly "in" the plot. From the plot center, measure the distance only to trees near the perimeter. You may want to identify each tree in the plot with flags or paint to ensure the proper tree count.

Traverse your planned compass line until you reach the location for the next plot, and then immediately locate and mark the plot center. ***Do not deviate from the 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 (e.g., a flag or stick) at the plot center is fine for most purposes. Establish a more permanent marker if you have a long-range plan to sample the same stand repeatedly. Identify all trees within the second plot. Then repeat this process until you've established all sample plots in the stand.

Measure tree diameters

Record 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 in the Plot Trees section of the Tree Tally Card. Figure 2 is a sample completed Tree Tally Card for the Coleman's Conifers example. A blank Tree Tally Card is available in Appendix C.

Be sure to read the key that explains the Tree Tally Card's dot-tally system. Record DBH to the nearest full inch. If a tree measures exactly at the half-inch mark, round down to the nearest full inch. Make a mental note of this decision. When you encounter the next tree measuring at the half-inch mark, round up to the nearest full inch. Repeat this process as needed.

Record tarif trees. To find the tarif tree in the plot, look clockwise from your compass line. Ordinarily, the tarif tree will be the first tree in the plot. For example, in Figure 1, the tarif tree is marked with the number one. The tarif tree should be representative of other trees in the stand. If the first tree is suppressed, dead, or has a broken top, use the second tree in the plot as the tarif tree. In subsequent plots, go back to using the first tree unless it is not representative of other trees in the stand.

You already recorded the tarif tree's DBH in the Plot Trees section of the Tree Tally Card. Now, record its DBH and total height (to the nearest 5-foot increment) in the Tarif Trees section of the Tree Tally Card.

Figure 2. Sample completed Tree Tally Card for Coleman's Conifers.

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

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″	34′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	12	95	0.6	38
2	13	100	0.6	39
3	10	80	0.5	34
4	15	115	0.6	42
5	14	110	0.7	42
6	13	105	0.6	41
7	15	110	0.8	41
8	13	90	0.5	34
9	17	105	0.5	38
10	16	110	0.6	40
		Total	6.0	389
		Average	0.6	39

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

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

To measure total height, pick a vantage point from which you can see the top of the tarif tree. The measurement tool you use will determine how far away from the tree you need to stand, and your estimates will be more accurate if you take observations from about the same level as the base of the tree. See OSU Extension publication EC 1129 for more information on measuring tree height.

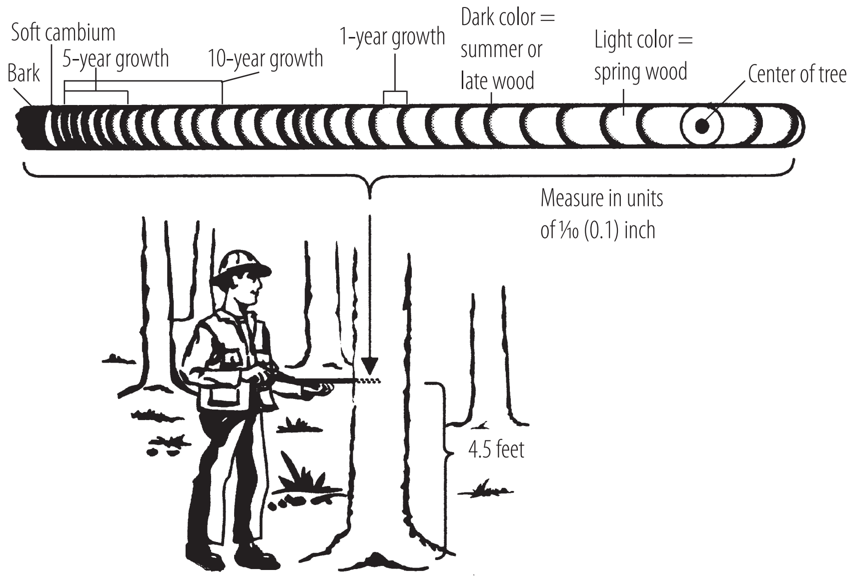

Figure 3. Increment core sampling to determine radial growth.

Take increment cores for stand age and growth rates. If you have not determined the age of the stand from old records or by counting growth rings on existing stumps, now is the time. If you count rings on a stump, remember to add the number of years since the tree was cut plus a couple of years to account for seedling age at the time of planting.

To determine stand age using an increment borer, bore on an exactly horizontal line into the center of the tarif tree at breast height. Bore slightly farther than the tree's radius. For example, bore 8 inches if the tree's radius is 7 inches. Identify the center of the tree by locating the change in direction of the slight arc in the growth rings from the extracted core (Figure 3). To determine stand age, add 6 to 10 years to the number you obtained from the increment core to account for the years it took for the tree to grow to breast height. Add 6 years for a high-growth-rate site and 10 years for a low-growth-rate site.

Next, use the same core sample to take a growth rate measurement from the tarif tree. If you did not use a core sample to determine stand age, take a core sample from the tarif tree, but 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 3). Record this measurement in the Tarif Trees section of the Tree Tally Card. You'll use this measurement later to project stand growth.

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

Proceed along your compass line to the second and subsequent plots. Repeat all steps to measure plot trees and tarif trees in each plot, and record the information on your Tree Tally Card.

Refer to Figures 1 and 2.

Taking plot data

Plot 1 for Coleman's Conifers has nine "in" trees. The first tree measures 12.2 inches DBH, so tally a dot under Plot Trees, Plot 1 next to 12 inches DBH. The second tree measures 13.3 inches DBH, so tally a 13. Continue to measure and record DBH for the remaining seven trees in the plot.

Now you need the tarif tree information for Plot 1. Remember: The first "in" tree in the plot is the tarif tree. The tarif tree measures 12.2 inches DBH, so record a 12 in the DBH column under Tarif Trees. The tarif tree is 94 feet tall, so record a 95 in the height column. This tree had nonuniform growth over the past 10 years and the distance of the outermost five rings measures 0.6 inch, so record this number in the radial growth column.

Figure 2 shows a sample completed Tree Tally Card for 10 plots for the example Coleman's Conifers stand. The next step is to calculate valuable stand volume and growth information from Tree Tally Card data.

Calculate stand volume and growth

After collecting plot data, take it home or to your office and translate it into numbers that will more accurately describe the stand:

- Trees per acre
- Tarif number for the stand
- Average radial growth (ARG)
- Current stand volume (board feet and cubic feet)
- Basal area and average stand diameter
- Volume projections (5 or 10 years)

Use the sample completed Tree Tally Card (Figure 2) and Volume Computation Form (Figure 4) for Coleman's Conifers to follow along with these computations. Use the blank Tree Tally Card (Appendix C) and Volume Computation Form (Appendix D) for your own timber stand calculations.

Refer to Figures 2 and 4.

Calculating trees per acre

Coleman's Conifers has a total of 80 trees on 10 plots. The multiplication factor is 2 (plot size correction factor of 20 divided by the number of plots, which is 10). There are 14 trees with a 12-inch DBH, so there are 28 (14 plot trees times a multiplication factor of 2) 12-inch-DBH trees per acre in the stand.

Getting the tarif numbers

Use Appendix A1 (Tarif access table for Douglas-fir) to determine the tarif numbers for each of the 10 tarif trees in the Coleman's Conifers stand. Total these values and divide by 10 to get an average of 38.9 Round to the nearest whole number, and record 39 as the average tarif number for the stand.

Calculating average radial growth (ARG) and diameter growth

The total of column 4 in the Tarif Trees section of the sample completed Tree Tally Card is 6.0 inches. This means the average tree had 0.6 inches radial growth (6.0/10 trees measured) in the 5-year period. Diameter growth is 1.2 inches (0.6 radial growth × 2).

Trees per acre

Refer to the Plot Trees section of the Tree Tally Card. Total the trees tallied for each diameter class, and record that number in the total trees column.

Next, find the plot size and corresponding plot size correction factor in the table at the bottom of the Tree Tally Card. Divide this factor by the number of plots in the sample to get the multiplication factor.

The multiplication factor expresses how many trees per acre each tree in a sample plot represents. To find the number of trees per acre in each diameter class, multiply the value in the total trees column for each diameter class by the multiplication factor, and record that number in the total trees per acre column. Transfer this information to column 1 of the Volume Computation Form.

Tarif number for the stand

The average tarif number for the stand is the average of tarif numbers from all sampled tarif trees. It identifies the taper of your trees and is key to determining tree volumes.

To determine the tarif number for each sample tree in the Tarif Trees section of the Tree Tally Card, look up the value in a tarif access table for that tree species (Appendices A1–A6). These tables list tarif numbers based on tree species, DBH, and total tree height.

Next, total these values and divide by the total number of tarif trees to determine the average tarif number of the stand. Record this number at the top of the Volume Computation Form.

Average radial growth (ARG) and diameter growth

To estimate radial growth for the stand, first total all core sample values in column 4 of the Tarif Trees section of the Tree Tally Card. Then divide that number by the total number of tarif trees to calculate ARG. Remember: This is a radial—not a diameter—measurement (Figure 3 illustrates radial growth). Record this number at the top of the Volume Computation Form. Diameter growth is two times radial growth.

Figure 4. Sample completed Volume Computation Form for Coleman's Conifers.

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						.267	
8	4	40	160	11	44	.349	1.396
9	2	70	140	15	30	.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**

Estimate stand volume

The next step is to estimate stand volume on the basis of average tarif number. You've already transferred the number of trees per acre by diameter class, ARG, and average tarif number from the Tree Tally Card to the Volume Computation Form.

Tree volume tables are in Appendices B1–B3. These tables list volumes based on average tarif number and DBH. To estimate board-foot volumes in 32-foot logs, use Appendix B1. Appendix B2 is for volumes in 16-foot logs, and Appendix B3 is for cubic-foot volumes. Record board feet in column 2 and cubic feet in column 4 of the Volume Computation Form.

Appendix B1 more closely resembles board-foot volumes that correlate to requirements found in most purchase orders. Appendix B2 gives a better estimate of log volume if you are using a portable sawmill. Appendix B3 may provide more useful information for making stand-management decisions.

To estimate 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. Record these calculated values in columns 3 and 5. The sum of column 3 is the total board-foot volume per acre, and the sum of column 5 is the total cubic-foot volume per acre.

Basal area and average stand diameter

Column 6 of the Volume Computation Form lists the basal area per tree for each diameter class on the form. To determine basal area per acre by diameter class, multiply trees per acre (column 1) by basal area per tree (column 6). Record these calculated values in column 7. The sum of column 7 is the total basal area per acre. To calculate average basal area per tree, use the following formula:

Average basal area per tree =
Total basal area (total column 7)/Total trees per acre (total column 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) using the following formula:

Average stand diameter =
$\sqrt{(\text{Average basal area per tree}/0.005454)}$

You can also calculate average stand diameter by multiplying total trees per acre by each diameter class, summing those values, and then dividing by the total trees per acre. Using the above formula merely makes the process faster and easier.

Record average basal area per tree and average stand diameter at the top of the Volume Computation Form.

Refer to Figure 4.

Estimating Stand Volume

For this example, assume you want to estimate board-foot volumes in 32-foot logs. There are four trees per acre with 8-inch DBH, and average tarif number is 39. According to Appendix B1, the corresponding board-foot volume is 40.

Multiply four trees per acre (column 1) by 40 board feet (column 2) to get 160 board feet per acre for trees in the 8-inch diameter class (column 3). Repeat this process for each diameter class, and total the values in column 3.

The Coleman's Conifers stand has a total of 160 trees per acre with a volume of 23,900 board feet (about 24 MBF) per acre.

Calculating basal area

Still using the example of trees with 8-inch DBH, multiply four trees per acre (column 1) by 0.349 basal area per tree (column 6) to get a total basal area per acre of 1.396 square feet for the 8-inch diameter class (column 7). Repeat this process for each diameter class, and total the values in column 7 to get a total basal area per acre of 147.458 square feet.

Calculating average basal area per tree

Total basal area per acre for the stand is 147.458, and there are 160 trees per acre.

Average basal area per tree =
147.458 square feet/160 = 0.922 square feet

Calculating average stand diameter

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

$\sqrt{(0.922 \text{ square feet}/0.005454)} = 13.002$ inches

Use the numbers

Volume projections

A completed Volume Computation Form includes all the information you need to determine past and present stand volumes and calculate the volume growth rate to project future volumes. Volume projections provide essential information to help you make well-informed management decisions.

To project volumes, you need to perform some basic calculations and follow a few simple steps.

Step 1: Calculate beginning average stand diameter

For this example, assume you want to use 5 years as a measurement period because growth rings in your increment core (Figure 3) were quite different for the most recent 5 years. First double the ARG value (remember: diameter growth is two times radial growth). Then calculate average stand diameter at the beginning of the most recent 5-year growth period using the following formula:

Beginning average stand diameter = Current average stand diameter – (2 × ARG)

Step 2: Calculate beginning average basal area per tree

To find basal area per tree at the beginning of the 5-year growth period, convert from diameter (inches) to basal area (square feet) using the following formula:

Beginning average basal area per tree = (Beginning average stand diameter)^2 × 0.005454

Step 3: Calculate growth projection factor (GPF)

To estimate how fast the stand is growing, calculate its GPF using the following formula:

GPF = Current average basal area per tree/ Beginning average basal area per tree

Step 4: Calculate future volume per acre

Now you can use current volume and GPF to project the future stand volume per acre:

Future volume of stand = Current volume × GPF

This assumes that current stand volume growth will continue at the same rate as in the previous 5-year growth period, so the projection's accuracy depends on how consistently the stand is growing. For most young stands (less than 50 years old), this estimate may be somewhat conservative—that is, it may be slightly less than actual growth. As the stand ages beyond 50 years, tree growth rate tends to slow.

Step 5: Calculate mean annual increment (MAI)

The MAI of volume growth is another useful stand number. It represents average volume growth per acre per year over the total life of the stand. Think of MAI as the long-term average, or track record, of the stand's growth. Calculate MAI using the following formula:

MAI = Total current volume per acre/ stand age (years)

Step 6: Calculate periodic annual increment (PAI)

The PAI is the average annual volume growth of a timber stand measured over a specific time period. This number is useful because volume growth per acre can vary substantially as the stand ages. You can calculate the PAI of board-foot or cubic-foot volumes for any time period, but 5- or 10-year periods are most common. Calculate PAI using the following formula:

PAI = (Total volume per acre at end of time period – Total volume per acre at beginning of time period)/Number of years in the time period

The PAI can measure previous growth or project future growth. You can use core samples to record measurements from the past or use the calculated GPF to estimate a future PAI. This enables you to determine how a stand is growing by taking "snapshots" over time.

Projecting volumes

Refer to Figure 4.

Beginning average stand diameter

Use the current average stand diameter of 13.002 inches and ARG of 0.6 inches to calculate average stand diameter 5 years ago:

13.002 inches − (2 × 0.6 inches) = 11.8 inches

Beginning average basal area per tree

Use the beginning average stand diameter of 11.8 inches to calculate average basal area per tree at the beginning of the growth period:

$(11.8 \text{ inches})^2 \times 0.005454 = 0.759$ square feet

Growth projection factor (GPF)

Use current and beginning average basal area per tree to calculate the GPF:

0.922 square feet/0.759 square feet = 1.215

Future volumes

Multiply current stand volume by the GPF to project the volume of the stand in 5 years:

23,900 board feet per acre × 1.215 =
29,039 board feet per acre

Or: 5,724 cubic feet per acre × 1.215 =
6,955 cubic feet per acre

Mean annual increment (MAI)

Divide current total volume per acre by stand age to calculate MAI for the life of the stand:

23,900 board feet per acre/50 years =
478 board feet per acre per year

Periodic annual increment (PAI)

To calculate PAI for the next 5 years, subtract the current total volume per acre of the stand from the future volume (which was determined using the GPF), and divide by the number of years in the growth period:

(29,039 board feet per acre – 23,900 board feet per acre)/5 years = 1,028 board feet per acre per year for the next 5 years.

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

Growth of the Timber Stand

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

From analyses and long experience, foresters have derived a 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. You might harvest such a stand if growth rate is the overriding factor in your harvest decision.

The point where the PAI line crosses the MAI line also is the highest value for MAI. This point is referred to as ***culmination*** of MAI. The stand will continue to add volume after this point, but at a slower rate. Comparing estimates of PAI and MAI shows whether stands are biologically mature. Thinning may increase the growth of residual trees and delay culmination of MAI.

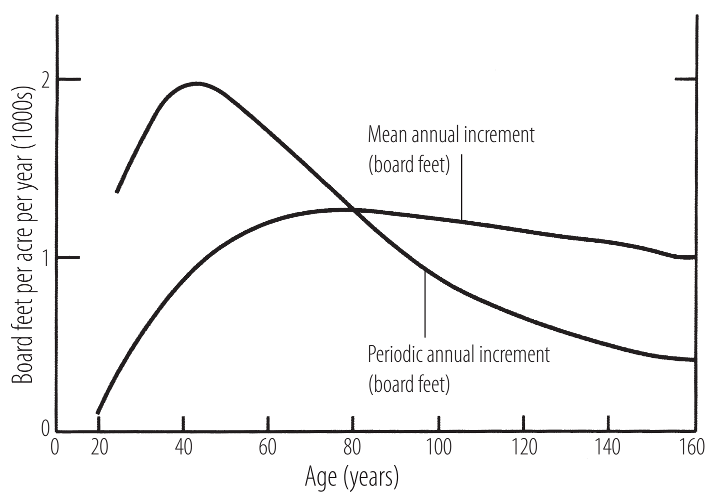

Figure 5. Periodic and mean annual increments of board-foot volume for Douglas-fir, showing culmination of mean annual increment at about 80 years. Absolute age of culmination varies, but the pattern in this graph is similar for all species. Adapted from McArdle et al., *The Yield of Douglas Fir in the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

You can examine a stand in even more detail by determining stand density index (SDI) and relative density (RD). The SDI is a measure of the stocking of a stand of trees based on the number of trees per unit area and DBH of the tree of average basal area. It can also be defined as the degree of crowding within stocked areas, using various ratios based on crown length or diameter, tree height or diameter, and spacing. Basal area is usually satisfactory as a measure of SDI because it is easier to calculate than SDI.

Growth models commonly adjust maximum densities for local growing conditions. When using RD, be aware that timber stands and conditions are unique, and published values for maximum densities may change over time. Because RD is a function of maximum density, RD may change accordingly.

Trees compete for resources such as light, water, and nutrients. The bigger the tree, the more resources it needs to survive. Both SDI and RD are based on the concept that each acre can support only a certain number of trees of a given size. When a stand approaches this maximum, some trees must die before others can grow larger. For any range of densities below the maximum, foresters can approximate the health, vigor, growth rates, crown ratios, and other characteristics of trees in the stand.

The following zones represent averages established from examinations of hundreds of stands and many experiments. As with any average, there are stands that do better or worse.

- **Mortality zone:**
  SDI of 330–600 (RD of 55–100)
- **Optimum or healthy zone:**
  SDI of 210–330 (RD of 35–55)
- **Diversity zone:**
  SDI of 120–240 (RD of 20–40)

In the mortality zone, trees will self-thin to survive. The healthy zone represents optimum growth for the timber stand. The diversity zone promotes growth of understory vegetation or tree regeneration. If you are interested in further stand examination, use the following formulas to calculate SDI and RD:

SDI = total trees per acre × (average stand diameter/10)$^{1.6}$

RD (expressed as a percentage) = (SDI/maximum density for that tree species) × 100

Using numbers previously calculated in the Coleman's Conifers example:

SDI = 160 × (13.002/10)$^{1.6}$ = 243

RD = (243/600) × 100 = 41%

Keep in mind there are also stand-management considerations that have nothing to do with how trees are growing. Often, factors such as cash flow or market cycles dictate whether a timber harvest occurs before or after culmination of MAI. Combine biological information with financial analysis to tailor management decisions to unique situations and objectives.

Where to go from here

Good stand information is essential to making the decisions necessary for managing your woodland. Stand measurements are critical when determining logging and marketing options. They are also important indicators of stand health, vigor, and susceptibility to insect and disease problems. And stand measurements might help you decide whether a harvest operation will generate the desired cash flow.

This publication introduced concepts of timber volume and growth and outlined how to calculate important stand numbers. Measurements taken according to the procedures described here are suitable for understanding how a timber stand may develop over time; however, this simplified process is not a substitute for professional timber appraisals or inventories done by foresters.

If you want to refine these techniques or study timber growth further, contact your Extension forester for assistance.

For more information

OSU Extension publications
http://extension.oregonstate.edu/catalog

EC 1127. *Measuring Timber Products Harvested from Your Woodland.*

EC 1129. *Tools for Measuring Your Forest.*

EC 1133. *Mapping and Managing Poorly Stocked Douglas-fir Stands.*

EC 1609. *Tarif Access Tables: A Comprehensive Set.*

Appendix A1. Tarif access table for **Douglas-fir**—condensed. For full table, see OSU Extension publication EC 1609.

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	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. For full table, see OSU Extension publication EC 1609.

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	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. For full table, see OSU Extension publication EC 1609.

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			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						
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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				
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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			
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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. For full table, see OSU Extension publication EC 1609.

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	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. For full table, see OSU Extension publication EC 1609.

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	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. For full table, see OSU Extension publication EC 1609.

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	

Appendices B1–B3 (Tree volume tables)

Appendix B1. Tree volume table (Scribner volume, 32-foot logs to 5-inch top)—condensed. For full table, see OSU Extension publication EC 1609.

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	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, 16-foot logs to 5-inch top)—condensed. For full table, see OSU Extension publication EC 1609.

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, to 4-inch top)—condensed. For full table, see OSU Extension publication EC 1609.

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

Appendix C (Tree Tally Card)

User name ______________________ Plot size ____________ Multiplication factor* ____________

Stand name ______________________ Species ____________ Average tarif number ____________

Date ______________________ Stand age ____________

Plot Trees

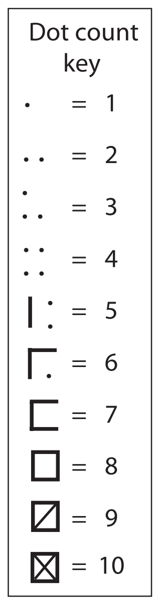
DBH (in.)	Plot number 1	2	3	4	5	6	7	8	9	10	Total trees	Total trees per acre
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
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″	34′2″
Plot radius (ft)	11.8	16.7	26.3	34.2
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		

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



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

Appendix D (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						.267	
8						.349	
9						.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**

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