

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

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

The tariff 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 tariff 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 ½-acre plot size. Adjust if needed after 3 or 4 plots. | Compass, tape |
| Collect plot data. | Establish a plot. Measure tree diameters. Measure tariff trees. Take increment cores. | Tape, compass, Tree Tally Card ² Diameter tape Clinometer, Tree Tally Card 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 tariff 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.

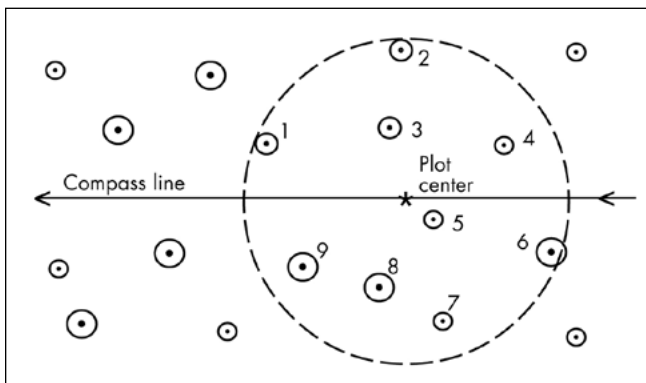


Figure 1. Plot 1 for Coleman's Conifers (includes nine "in" trees).

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 tariff 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 tariff trees. |
| To obtain growth information: | |
| Increment borer | Extract a core sample from tariff 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 tariff trees. To find the tariff tree in the plot, look clockwise from your compass line. Ordinarily, the tariff tree will be the first tree in the plot. For example, in Figure 1, the tariff tree is marked with the number one. The tariff 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 tariff 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 tariff 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 _____ Plot size 1/20 Multiplication factor* 2
 Stand name Coleman's Conifers Species Doug-fir Average tariff number 39
 Date _____ Stand age 50

| DBH (in.) | Plot number | | | | | | | | | | Total trees | Total trees per acre |
|-----------|-------------|----|----|----|----|----|----|----|----|----|-------------|----------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| 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 | | | | | | | | | | | | |
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| 29 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| Total | | | | | | | | | | | 80 | 160 |

| Tariff Trees | | | | |
|--------------|-----------|-------------------------|--------------------------------|------------------------------|
| 1 | 2 | 3 | 4 | 5 |
| Plot no. | DBH (in.) | Height to nearest 5 ft. | Radial growth for 5 yrs. (in.) | 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 |

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

- 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 Tariff 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" | 34'2" |
| Plot radius (ft) | 11.8 | 16.7 | 26.3 | 34.2 |
| Plot size correction factor | 100 | 50 | 20 | 10 |

To measure total height, pick a vantage point from which you can see the top of the tariff 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.

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 tariff 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 tariff tree. If you did not use a core sample to determine stand age, take a core sample from the tariff 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 Tariff 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 tariff trees in each plot, and record the information on your Tree Tally Card.

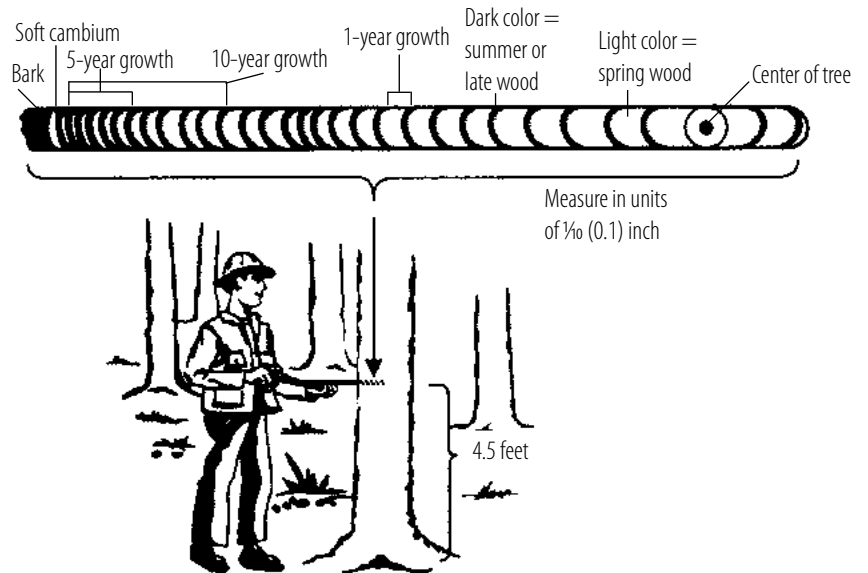


Figure 3. Increment core sampling to determine radial growth.

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 tariff tree information for Plot 1. Remember: The first "in" tree in the plot is the tariff tree. The tariff tree measures 12.2 inches DBH, so record a 12 in the DBH column under Tariff Trees. The tariff 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 \times 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 tariff 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 |

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:

$$\text{Beginning average stand diameter} = \text{Current average stand diameter} - (2 \times \text{ARG})$$

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:

$$\text{Beginning average basal area per tree} = (\text{Beginning average stand diameter})^2 \times 0.005454$$

Step 3: Calculate growth projection factor (GPF)

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

$$\text{GPF} = \frac{\text{Current average basal area per tree}}{\text{Beginning average basal area per tree}}$$

Step 4: Calculate future volume per acre

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

$$\text{Future volume of stand} = \text{Current volume} \times \text{GPF}$$

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:

$$\text{MAI} = \frac{\text{Total current volume per acre}}{\text{stand age (years)}}$$

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:

$$\text{PAI} = \frac{(\text{Total volume per acre at end of time period} - \text{Total volume per acre at beginning of time period})}{\text{Number of years in the time period}}$$

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:

$$13.002 \text{ inches} - (2 \times 0.6 \text{ inches}) = 11.8 \text{ inches}$$

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:

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

Growth projection factor (GPF)

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

$$0.922 \text{ square feet} / 0.759 \text{ square feet} = 1.215$$

Future volumes

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

$$23,900 \text{ board feet per acre} \times 1.215 = 29,039 \text{ board feet per acre}$$

$$\text{Or: } 5,724 \text{ cubic feet per acre} \times 1.215 = 6,955 \text{ cubic feet per acre}$$

Mean annual increment (MAI)

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

$$23,900 \text{ board feet per acre} / 50 \text{ years} = 478 \text{ board feet per acre per year}$$

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:

$$(29,039 \text{ board feet per acre} - 23,900 \text{ board feet per acre}) / 5 \text{ years} = 1,028 \text{ board feet per acre per year for the next 5 years.}$$

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.

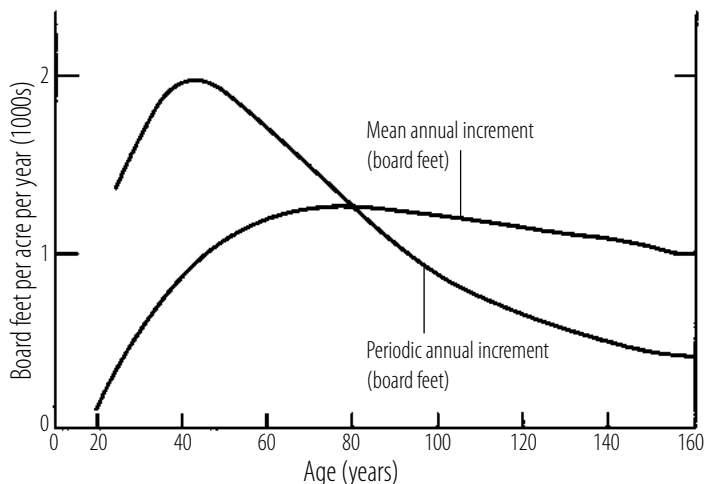


Figure 5. Periodic and mean annual increments of board-foot volume for Douglas-fir, showing culmination of mean annual increment at about 80 years. Absolute age of culmination varies, but the pattern in this graph is similar for all species. Adapted from McARDLE et al., *The Yield of Douglas Fir in the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

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

$$\text{RD (expressed as a percentage)} = (\text{SDI}/\text{maximum density for that tree species}) \times 100$$

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

$$\text{SDI} = 160 \times (13.002/10)^{1.6} = 243$$

$$\text{RD} = (243/600) \times 100 = 41\%$$

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.*

Appendices A1–A6 (Tarif access tables)

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 | | | | | | | | |

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) | Tariff 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 | 10 | 20 | 20 | 30 | 30 | 30 | 30 | 30 | 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 | 10 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | | |
| 9 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | | |
| 10 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | |
| 11 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | |
| 12 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | |
| 13 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 14 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 | 50 | 50 | 50 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | |
| 15 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 | 50 | 50 | 50 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | |
| 16 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 40 | 40 | 40 | 40 | 50 | 50 | 50 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| 17 | 50 | 60 | 70 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 |
| 18 | 60 | 70 | 80 | 90 | 110 | 100 | 130 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 |
| 19 | 70 | 80 | 80 | 110 | 110 | 130 | 140 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 |
| 20 | 70 | 80 | 110 | 110 | 130 | 130 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 |
| 21 | 80 | 80 | 110 | 140 | 130 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 | 160 |
| 22 | 80 | 100 | 140 | 140 | 150 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 |
| 23 | 80 | 110 | 140 | 160 | 170 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 |
| 24 | 100 | 140 | 160 | 150 | 180 | 210 | 210 | 250 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 |
| 25 | 100 | 140 | 160 | 170 | 210 | 210 | 250 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 260 |
| 26 | 130 | 160 | 180 | 170 | 210 | 210 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 |
| 27 | 130 | 160 | 180 | 200 | 250 | 250 | 300 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 | 310 |
| 28 | 130 | 180 | 210 | 200 | 250 | 300 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 |
| 29 | 150 | 180 | 210 | 240 | 300 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 |
| 30 | 150 | 180 | 250 | 240 | 300 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 | 340 |
| 31 | 150 | 210 | 250 | 290 | 340 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | 390 | |
| 32 | 150 | 210 | 250 | 330 | 340 | 390 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | 450 | |
| 33 | 170 | 210 | 300 | 330 | 390 | 450 | 500 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | |
| 34 | 170 | 250 | 300 | 330 | 450 | 450 | 500 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | 510 | |
| 35 | 170 | 250 | 340 | 380 | 450 | 500 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | 580 | |
| 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 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | 1700 | | |

Appendix C (Tree Tally Card)

User name _____ Plot size _____ Multiplication factor* _____
 Stand name _____ Species _____ Average tariff number _____
 Date _____ Stand age _____

Plot Trees

| DBH (in.) | Plot number | | | | | | | | | | Total trees | Total trees per acre |
|--------------|-------------|---|---|---|---|---|---|---|---|----|----------------|-------------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| 7 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | |
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| 35 | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | |
| | | | | | | | | | | | Total | |

Tariff Trees

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

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

- 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 Tariff 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" | 34'2" |
| Plot radius (ft) | 11.8 | 16.7 | 26.3 | 34.2 |
| Plot size correction factor | 100 | 50 | 20 | 10 |

Appendix D (Volume Computation Form)

Stand name _____
 Species _____
 Stand age _____
 Average tariff 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 |

Trade-name products and services are mentioned as illustrations only. This does not mean that the Oregon State University Extension Service either endorses these products and services or intends to discriminate against products and services not mentioned.

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