Chapter 7: Basic Inventory Calculations

In the previous chapters, you learned how to establish and take measurements in sample plots. The next step is to make some basic calculations with your inventory data that will help you to better understand and steward your forest.

As discussed at the beginning of this manual, you should decide which calculations are appropriate to the scale of your property and your management objectives. Trees per acre is an easy calculation to generate and, when combined with tree diameters and live crown ratios, can provide important information about the stocking of the stand, potential need for thinning, and forest health. Basal area is another measure of stand density or stocking, but is less intuitive. Volume data is not required for a forest management plan, but is useful when considering timber harvest options.

Learning Objectives

How to compute the following for your forest:

1. Basal area
2. Trees per acre (TPA)
3. Volume

Materials Needed

1. Completed plot data recording sheets
2. Calculator (or a spreadsheet program)

A. Determining basal area

Basal area is the cross-sectional area of a tree trunk at breast height (calculated under the assumption that the cross section is roughly circular). Basal area is computed at the stand level as the sum of the basal area values for each individual tree, which is usually expressed as square feet per acre.[15] The amount of basal area in a stand is a function of the number of trees and the size of the trees. As such, it is a measure of the overall level of competition for resources between trees in the stand, and it is frequently used to determine whether a stand should be thinned to meet a particular management objective.[16]

[15] In countries or applications in which the metric system is used, basal area for a stand would be expressed as square meters per hectare.

[16] For more information on this, please review Hanley, D.P. and D.M. Baumgartner. 2005. Silviculture for Washington Family Forests. WSU Extension publication EB2000, http://cru.cahe.wsu.edu/CEPublications/eb2000/eb2000.pdf.

Determining basal area from fixed plots

1. Determine the expansion factor for plot trees (the number of trees per acre a given plot tree represents; e.g., 20 for a 1/20th acre plot).
2. For each plot tree, determine the basal area (in square feet) by multiplying the DBH (in inches) by itself (i.e., square it) and then multiplying by 0.005454:

   Tree BA = .005454 x DBH²
3. Multiply the basal area for each tree by the expansion factor to determine the basal area per acre represented by each tree.

   BA/acre = Tree BA x Expansion Factor
4. Repeat this procedure for the rest of the trees in the plot to determine the total basal area per acre represented by that plot.
5. Compute the basal area per acre for all the plots in the stand, and then find the average by adding the basal area from all plots and dividing by the number of plots.

Example: Suppose you acquired data on two 1/20th acre plots. Suppose that there were six trees in the first plot and five in the second, and that the first tree in the first plot was 14.5 inches DBH.

1. With 1/20th acre plots, the expansion factor would be 20.
2. The basal area of the first tree = 14.5 x 14.5 x 0.005454 = 1.15 square feet.
3. Multiply 1.15 by the expansion factor of 20 to get 23 square feet per acre (sq ft/ac) of basal area represented by that tree.
4. Repeat this for the other trees and plots.
5. Sum the values across all plots and divide by the number of plots to get the average basal area per acre for the stand (Table 7-1).

Determining basal area from variable plots

Determining basal area is a little easier for variable plots because each "in" tree in a plot represents a given amount of basal area, as determined by the basal area factor (BAF). For example, if you established variable plots using a BAF of 30, each tree would represent 30 square feet of basal area.

Here are the steps for determining basal area per acre from variable plots:

1. Add up the total number of trees in a plot and

Table 7-1: An example of computing the total basal area per acre for a stand with two 1/20th-acre plots. Basal area is computed for each tree and then multiplied by the expansion factor (in this case, 20) to put it on a per acre basis. The total basal area per acre is then computed for each plot, and the plots are then averaged to determine the average basal area per acre for the stand.

Plot	Tree	DBH (in)	Tree Basal Area (sq ft)	Basal Area per acre (sq ft)
1	1	14.5	1.15	23.0
	2	11.2	0.68	13.6
	3	8.7	0.41	8.2
	4	10.4	0.59	11.8
	5	11.1	0.67	13.4
	6	7.1	0.27	5.4
			Plot 1 Total:	75.4
2	1	9.9	0.53	10.6
	2	11.4	0.71	14.2
	3	13.8	1.04	20.8
	4	16.0	1.40	28.0
	5	7.9	0.34	6.8
			Plot 2 Total:	80.4
			Sum of Plot 1 and Plot 2:	155.8
			Average for the stand:	**77.9**

multiply by the BAF to get the basal area per acre represented by that plot.

2. Repeat this for the other plots in the stand.
3. Add up the basal area for all plots in the stand and then divide by the number of plots to get the average basal area per acre for the stand.

Example: Suppose you did two variable plots using a BAF of 30, with eight trees in the first plot and six in the second.

1. The basal area for the first plot is 8 x 30 = 240 sq ft/ac.
2. The basal area for the second plot is 6 x 30 = 180 sq ft/ac.
3. Adding 240 and 180 and then dividing by 2 yields an average basal area for the stand of 210 sq ft/ac.

B. Determining trees per acre (TPA)

One of the most important things an inventory can tell you is how dense the trees are in your stand. The most basic measure of stand density is the number of trees per unit of area, which is often expressed as trees per acre (TPA).[17]

Determining TPA from fixed plots

Here are the steps for determining TPA from fixed plots:

1. Determine the expansion factor for the plot trees (the number of trees per acre a given plot tree represents; e.g., 20 for a 1/20th acre plot).
2. Add up the total number of trees in a plot and multiply by the expansion factor to get the trees per acre represented by that plot.
3. Repeat this for the other plots in the stand.
4. Add up the TPA for all plots in the stand and then divide by the number of plots to get the average TPA for the stand.

Example: Suppose you acquired data on two 1/20th acre plots. Suppose that there were six trees in the first plot and five in the second.

1. With 1/20th acre plots, the expansion factor would be 20.
2. The TPA represented by the first plot is 6 x 20 = 120.
3. The TPA represented by the second plot is 5 x 20 = 100.
4. Adding 120 and 100 and then dividing by 2 yields an average of 110 TPA for the whole stand.

Determining TPA from variable plots

Determining TPA from variable plots is more complicated, as each "in" tree in a plot does not represent a fixed number of trees per se, but rather an amount of basal

[17] In countries or applications in which the metric system is used, stand density would be expressed as trees per hectare.

area, as determined by the BAF used to establish the plots. Compute an expansion factor by calculating each tree's actual basal area and dividing that into the BAF. This means that the expansion factor will be different for each tree depending on its diameter (DBH).

Here are the steps for determining TPA from variable plots:

1. For each tree in a plot, compute its basal area (in square feet) by multiplying the DBH (in inches) by itself (i.e., square it) and then multiplying by 0.005454.

   Tree BA = .005454 x DBH²

2. Divide the basal area factor (BAF) by the basal area of each tree (BAF / Tree BA) to get the TPA represented by that tree, which is its expansion factor.

3. Repeat these steps to compute the expansion factors for all of your plot trees and add these values up to get the total TPA represented by that plot. A spreadsheet is particularly useful for this.

4. Repeat this for the other plots in the stand.

5. Add up the TPA for all plots in the stand and then divide by the number of plots to get the average trees per acre for the stand.

Example: Suppose you did two variable plots using a BAF of 30. The first tree in the first plot is 12.8 inches DBH.

1. The basal area of the first tree = 12.8 x 12.8 x 0.005454 = 0.89 square feet.

2. Dividing 30 (the BAF) by 0.89 yields 33.71 TPA. This is the expansion factor for that first tree.

3. Repeat this for the other trees and plots.

4. Sum the values across all plots and divide by the number of plots to get the average TPA for the stand (Table 7-2).

C. Determining tree volume

If you are managing for timber and wood products, knowing how much wood volume you have will be of particular importance. Determining the volume of wood in a tree can be challenging, as the stem of the tree is not a perfect cylinder. Rather, the stem is tapered, meaning that it starts out wide at the bottom and becomes narrower as you go up the tree, giving the tree a cone shape.

Tree volume is most commonly determined using volume tables, which list volumes by tree height and DBH based on species and location. Consult your local Extension or

Table 7-2: An example of computing the total TPA for a stand with two variable plots done with a BAF of 30. Expansion factors are computed for each tree, then added together to determine the total TPA for the stand.

Plot	Tree	DBH (in)	Tree Basal Area (sq ft)	Expansion Factor (TPA)
1	1	12.8	0.89	33.71
	2	13.1	0.94	31.91
	3	8.7	0.42	71.43
	4	11.3	0.70	42.86
	5	14.7	1.18	25.42
	6	6.8	0.25	120.00
	7	13.7	1.02	29.41
	8	10.0	0.55	54.55
			Plot 1 Total:	409.29
2	1	9.7	0.51	58.82
	2	12.2	0.81	37.04
	3	14.9	1.21	24.79
	4	17.0	1.58	18.99
	5	6.3	0.22	136.36
	6	10.2	0.57	52.63
			Plot 2 Total:	328.63
			Sum of Plot 1 and Plot 2:	**737.92**
			Average for the stand: (rounded to the nearest whole number)	**369**

state service forester for information on volume tables appropriate for your stands. Using a volume table requires that heights be measured for all plot trees, which can be the most time-consuming part of doing a forest inventory.

Another way to determine volume in the Pacific Northwest is by using the Tarif System. Tarif is a number used to characterize tree taper and volume based on both the diameter and height of the tree. With this system, you use a tarif access table to determine the tarif number for each tree that was measured for height. Tarif tables are species specific; tables for the most common commercial species in the Pacific Northwest are included in Appendix A. Once you have determined the tarif number for each tree you measured height for in a given stand, take the average of these numbers (rounding to the nearest whole number) to get a tarif number for the whole stand. The stand tarif number is an indicator of the degree to which trees in the stand taper.

Once you have computed the stand tarif number, you can determine the volume of each tree in your stand based on its DBH. The volume table in Appendix B allows you to look up tree volume by DBH and stand tarif number. An advantage of the Tarif System is that you do not have to measure the height of every plot tree, only a subsample (see Chapter 6). The Tarif System provides reasonable volume estimates for several major commercial species in Oregon and Washington, though further inland (e.g., Idaho) they may not be as applicable.

Once you have determined the volume of each tree, multiply that volume by the tree's expansion factor (which you determined above when calculating TPA and basal area) to get volume on a per acre basis. Add the per acre volumes for all the trees in each plot and then take the average across all plots to get the average volume per acre in your stand. A computer spreadsheet is very helpful for doing these computations.

Tree volume is expressed differently in different regions and depending upon the product of interest. The volume table in Appendix B expresses volume as board feet. A board foot is the volume of a piece of wood that is 1 foot by 1 foot by 1 inch. Another common volume measurement is the cubic foot, which is 1 foot by 1 foot by 1 foot.[18] There are different sets of rules for measuring board foot volume. The volume table in Appendix B uses the Scribner rules (also called Scribner scale), which is commonly used in the Pacific Northwest.

Once you have determined the volume per acre in your stand, you can multiply by the number of acres to find the total stand volume. If you know the current price per volume of wood in your area (you can ask your local Extension forester about this), you can estimate the approximate commercial value of the timber in your stand.

[18] Note that a cubic foot is not equal to 12 board feet, as you would not be able to slice up a cubic foot into 12 pieces without losing part of the volume to the width of each cut. Conversion factors are available to convert between board feet and cubic feet depending on the type of wood and application.

Gross vs. Net Volume

This publication deals primarily with determining gross volumes of timber. But a volume figure you get back from a lumber mill after selling logs will often be less than the gross volume you sent in. Deductions are made for stem decay, log deformities, or anything else that reduces lumber recovery. Determining how many of these defects are present in standing timber is best informed by years of professional experience, so hiring a consulting forester to make these estimates can pay off. Mistakes made in bucking fallen trees into logs also reduce net volume (what you get paid for), so it is wise to hire an operator who knows how to get the most value from your trees.

On your own:

Determine the basal area, number of trees, and total volume on a per acre basis for each of your stands. Discuss your stand density (TPA) and basal area with your local Extension forester, state service forester, or private consulting forester with respect to whether or not your forest needs thinning or other management intervention. Make sure your forester understands what your overall management objectives are.