TIMBER CRUISING HANDBOOK

CHAPTER 20 - ESTIMATING TREE VOLUME AND WEIGHT

Contents

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This chapter includes general guidelines for using tree volume and tree product estimators and defines acceptable direct tree volume and product determination techniques. Guidelines for estimating the weight of trees and components of trees are also given.

21 - LOG RULES AND CUBIC FORMULAS.

21.1 - Log Rules. A log rule is a table of estimated volume of lumber which might be sawn from logs of different sizes under assumed conditions. The Scribner Decimal C, and International 1/4-inch rules are used by the Forest Service to estimate board-foot contents in roundwood.

21.2 - Cubic Formulas. A cubic-foot formula expresses roundwood volume without reference to product class. Use the Smalian formula to determine the cubic volume of roundwood. The Smalian formula, in general terms, is:

$$V = \frac{A + a}{2} \times L$$

Where: V = Volume in cubic feet (ft^3)
A = Large end cross section area (ft^2)
a = Small end cross section area (ft^2)
L = Log length (ft)

22 - TREE VOLUME DETERMINATION.

See FSH 2409.12a, Volume Estimator Handbook, for detailed descriptions of all phases of developing tree volume and product estimators, stem profile models, model verification, model validation, and model calibration.

22.1 - Utilization Limits. Determine volume to utilization limits applicable to the place and time when the timber sale will be sold. These limits are usually expressed in terms of height and diameter. Calculate or measure a merchantable height, which is the height from a specified stump to a specified top diameter.

The advent of whole-tree chipping may extend utilization to include the entire main stem and the branches as well. Under these conditions, call the entire stem merchantable. For sawtimber trees, utilization may not necessarily end with the sawlog portion, but may include the chippable portion above the sawlog. Merchantability criteria for the sawlog portion can change over time, affecting not only the smallest tree diameter considered merchantable, but also extending utilization farther up the stem.

22.2 - Tree Volume and Product Estimators. Apply the term "tree volume estimator" (sec. 05) to either an equation or its tabular representation, or both, for estimating the cubic content of a tree. Compute tree volumes from equations or from stem profile models. Use volume tables only when hand summary of volumes is necessary.

The term "product estimator" (sec. 05) is similar to the volume estimator except cubic feet may not be the unit of measure. Thus, sawtimber portions may be expressed in board feet, poles may be in lineal feet, pulpwood in cords or units, and peeler blocks may be board feet or square feet. Cubic feet may be used to express the solid wood content for any wood product and its use is preferable to other product estimators.

22.21 - Tree Stem Components. Measure the dimensions usually necessary for calculating volume. The most common measurements are DBH and height to a specific point on the stem, or to the tip of the tree.

To the extent possible, partition the tree into product components. Product feasibility is based on local utilization practices and markets for the various products.

The main stem components are:

1. The sawlog portion to a specified top limit.

2. The topwood portion from the top of the sawlog to a specified top limit, such as 4 inches DOB (or DIB), or to the tip of the tree when only the main stem is considered.

3. The crownwood portion includes all branches and that portion of the main stem above the merchantable limit.

The components mentioned in paragraphs 2 and 3 are often classed as chippable material.

Topwood in the main stem may be estimated by a separate product volume equation having DBH as one of its variables. It may also be estimated using a stem profile model by specifying the sawlog top limit and a topwood limit of either height or diameter. Crownwood volume may be estimated as the difference between total tree cubic volume, including branches, and stem volume to the defined merchantable height.

22.22 - Types and Use of Tree Volume and Product Estimators. Use the appropriate type of estimator from those available. Four types of volume estimators are recognized based on the independent variables used. They are discussed in sections 22.22a-22.22e.

Before starting a cruise, know the specific product or volume estimator characteristics used to derive tract volumes. Select the most appropriate volume estimators for each species and product class to be cruised. For each applicable product or volume estimator know the top limits and stump heights, and whether use of a form factor is needed. Not having such information, or failing to apply it properly, will lead to a bias in the tract product volume or estimate.

22.22a - Standard Tree Volume Estimators--Volume and Stem Profile Models. Standard volume estimators use diameter breast height (DBH) and height as independent variables and diameter inside bark (DIB) or diameter outside bark (DOB) to define diameter limit. The height variable is defined as: a) total height, from ground to tip or stump to tip; b) height to a specified diameter limit; or c) height to a point otherwise defined. In timber cruising, DOB is the preferred way to define the diameter limit since this is all the cruiser can accurately determine.

When using standard volume estimators:

1. Clearly understand the criteria that define the height for the applicable volume estimator. Heights other than total height are collectively called reference height and define the stem section for estimating volume if the section is less than the total stem length.

2. Measure heights to the specified diameter limit. Do not disregard the basic assumptions of the volume estimator regardless of utilization practiced by operators. When volume estimators specify DIB limit, use a standard DOB equivalent for a particular species or assume a bark thickness to determine height where the DIB occurs.

3. Observe the stratification (site, defect, species, other) on which the volume estimator is applicable.

4. Properly apply defect deduction methods in keeping with the basic premises of the volume estimator(s) being used. For example, if the volume estimator is based on measuring the entire stem length to a specified reference diameter, make the suitable percentage deduction from tree volume for any defective segments downstem from the reference diameter. Do not measure a shorter height or record fewer logs for the tree to account for the defect.

<u>22.22b</u> - <u>Local Tree Volume Estimators</u>. Local volume estimators use only DBH as a predictor. They are constructed using sample tree data from the population of trees whose volume is to be estimated. Use of local volume estimators requires approval by the Regional Forester (sec. 04).

Evaluate the use of local volume estimators by considering the purpose of the cruise estimate and the level of accuracy required. The chance for bias is increased by the loss of the height variable, and a local volume estimator's usefulness is limited to stands having uniform height conditions within DBH classes, or where it is practical to stratify site conditions.

<u>22.22c</u> - <u>Tarif Volume Estimators</u>. A tarif tree volume system is an indexed system of local tree volume estimators based on the relationship of tree volume to tree basal area. For many species of trees in even-aged stands, the relationship is expressed as a linear regression called a volume/basal area line. While the tarif concept is not limited to even-aged stands, the volume/basal area line is especially suited to stands having relatively uniform tree heights within DBH classes. Tarif estimators do not indicate volume of trees by log position and do not provide a direct means for determining defect and grade.

The basal area variable is converted to DBH equivalents for incorporation into a tarif volume reference. The tarif volume reference is defined by a specific volume/basal area line and identified by an indexed tarif number. Tarif number is defined as the cubic foot volume to the specified top of a tree of 1.0 square foot basal area.

To find the specific tarif number of an even-aged stand, measure the DBH and height of about 25 sample trees. Use the DBH and height of each tree to determine its tarif number. Average the tree tarif numbers to find the tarif number for the stand. The stand tarif number indicates the correct volume estimator.

To find the tarif number in an uneven-aged or mixed species stand, stratify the stand by species-DBH group and find an average tarif for each species-DBH group.

Use single tree tarif numbers when referencing tarif volume estimators to find volumes and volume/basal area ratios from a fixed point, point sample, or 3P cruise.

22.22d - Aerial Volume Estimators. Aerial volume estimators are specifically intended for estimating tree volume from aerial photographs. Aerial volume estimators are analogues of conventional tree volume estimators but use crown diameter as the independent variable instead of tree DBH. They may be based on crown diameter and total height or on crown diameter alone.

Use aerial volume estimators only when more generalized information with a larger sampling error will meet the cruise objective. Use of aerial volume estimators requires approval by the Regional Forester (sec. 04).

The use of aerial volume estimators is limited because aerial cruises require special photogrametric skills and a larger scale photography (1:5000 or 1:8000) than is generally required for the usual sale planning purposes. They also have a greater sampling error because the tree volume is more closely related to DBH than crown diameter.

22.22e - Stem Profile Models. A stem profile model expresses the form of the tree stem. It can also function as a volume estimator with greater versatility than conventional volume equations. Not all profile models use the same form or independent variables, so collect data for the variables defined in the profile model to be used.

In cruising, profile models may be used to estimate:

1. Diameter at desired heights on the stem.

2. Height to a given diameter.

3. Volume for the entire stem or in a given portion of the stem.

22.23 - Validation of Tree Volume Estimators. Validate the volume estimators for first-time use. A validation check serves two purposes:

1. to validate the ability of the equation to predict volume within the constraints of the initial assumptions, and

2. to check the validity of the actual assumptions.

Statistical precision or goodness of fit measures for a tree volume estimator only apply to the data used in its derivation. Validation using an independent sample is a measure of how well the equation estimates volume of trees from applicable stands. See the Timber Volume Estimator Handbook, FSH 2409.12a, for details of validation.

22.3 - Estimating Tree Defect and Net Tree Volume. The standard practice in National Forest volume determination is to sell only merchantable wood volume. Partition roundwood volume into two components: gross and net.

Gross is the total volume in the tree to a specified top limit.

Net is the residual volume after deducting wood loss (defect) from gross volume. Requirements for specifying measurement limits are the same as for gross volume.

Defect is any tree condition that reduces either product yield (lumber or veneer, for example) or wood fiber yield. Examples of defect include soft rots, crook, sweep, heart check, and fire scars. All of these defects can reduce product yield, but of the examples given, only soft rots and fire scar reduce fiber yield. Refer to detailed defect information in the National Forest Log Scaling Handbook, FSH 2409.11, and the Cubic Scaling Handbook, FSH 2409.11a.

<u>22.31</u> - <u>Defect Deduction Methods</u>. Estimate defect in standing trees in one of two ways:

1. Ocularly estimate the extent and position of defect in the tree, then refer to a table of percentages of stem volume (sec. 22.31a, ex. 01 and 02). Where only a part of a standard segment length is affected by the defect, multiply the tabular volume percent by the fraction affected.

2. Make defect deductions in the raw data used for deriving the volume estimators to calculate the net volume of each sample tree. The result is a net volume estimate.

In using percentage deduction methods, decide on the suitable deduction from an ocular assessment of stem condition. Tailor these methods to specific Regions or sub-Regions to allow for the differing defect characteristics of species. Most methods require tables that show the average percentage distribution of tree volume for each log based on the log position in the tree.

Successful application of ocular defect estimation methods demands considerable skill by the cruiser and a knowledge of rot characteristics for the species being cruised. Each cruiser must continually update their skills by periodically visiting sawmills and logged areas to relate the extent of rot to surface indicators.

<u>22.31a</u> - <u>Volume Distribution in Trees</u>. Where the cruiser must make ocular assessments of defect in standing trees, use tables that show the percent of tree volume in different parts of a tree. These tables show percentage of volume by 16-foot segments within the merchantable length, although other segment lengths may also be used. Examples of such tables are shown in Exhibits 01 and 02. Tables showing volume distribution in trees should specify the area of applicability and species or species group to which they apply.

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22.31a - Exhibit 01
Percent of Tree Product Volume by 16-Foot Logs, Scribner Dec.C Log Rule

MERCH. HT.1/ (feet)	LOG HT.	Log number 1	2	3	4	5	6	7	8	9	10
9-25	1	100									
26-42	2	68	32								
43-59	3	47	36	17							
60-75	4	38	29	22	11						
76-92	5	33	27	20	14	6					
93-108	6	28	25	20	16	7	4				
109-125	7	26	23	19	17	8	3	3			
126-141	8	24	21	18	15	10	6	4	2		
142-158	9	19	17	15	14	13	10	6	4	2	
159-174	10	19	17	15	14	13	9	6	4	2	1

1/ Not total tree height

22.31a - Exhibit 02
Percent of Tree Product Volume by 16-Foot Logs, Smalian Cubic Volume

MERCH. HT.1/ (feet)	LOG HT.	Log number 1	2	3	4	5	6	7	8	9	10
9-25	1	100									
26-42	2	63	37								
43-59	3	45	33	22							
60-75	4	37	28	21	14						
76-92	5	32	25	19	15	9					
93-108	6	27	22	19	14	11	7				
109-125	7	24	21	19	17	11	5	3			
126-141	8	22	19	17	15	11	8	5	3		
142-158	9	20	16	14	13	12	10	7	5	3	
159-174	10	19	16	14	13	12	10	7	5	3	2

1/ Not total tree height

When volume estimators are based on measuring entire stem length to a specified reference diameter and it becomes necessary to reduce merchantable length because of defect, express this as a percentage deduction from tree volume, rather than by tallying the tree as being shorter than it is.

22.31b - Rots. Where ocular deduction methods are used, the extent of rot in a standing tree requires a knowledge of indicators. Since the cruiser can only base any judgment of rot on indicators visible on the standing stem, use local defect guides for determining the average distances up and down the stem a particular rot extends from an indicator. Since rot characteristics can vary by species, separate guides are needed. When site index affects extent of rot, prepare site index-specific guides.

22.31c - Sweep and Crook. Sweep is a stem deflection which, compared to crook, is less abrupt and more continuous. Sweep is generally counted deductible where it is excessive within a product length in the stem. Crook is a more abrupt deflection in the stem. Refer to FSH 2409.11a, Chapter 40 for detailed information about sweep and crook.

22.31d - Missing Wood. Missing wood includes such things as missing parts of trees, catface, and fire scar. Cases also occur where the top of the tree is missing. If the volume estimator requires measuring height to a fixed top diameter, estimate where that point would have been if the stem remained intact. To do otherwise is to incur estimating bias from a miscalled height. Also, handle the missing stem portion as a deduction from gross volume by assigning it a suitable percentage deduction.

22.31e - Breakage and Hidden Defect. Estimate this defect where appreciable breakage from felling is a normal occurrence. Ordinarily, deductions for breakage need to be applied only to the sawlog portion of the tree since the recovery of fiber volume is not greatly affected unless shattered breakage occurs.

Certain defects, such as ring shake, heart check, and some rots are internal in the tree and cannot be seen by the cruiser. All of these defects can reduce lumber yield and are, therefore, important in estimating sawlog volume. Soft rots reduce wood fiber volume but shake and checks do not.

Account for breakage and hidden defect by applying a factor, based on experience, to the cruise volumes. Determine loss from breakage and hidden defect for specific timber types and localities.

22.31f - Net Volume Estimators. In younger timber, when the occurrence of defects are infrequent or are uniformly found, their effects can be accounted for directly in the volume equation. In such applications, the equation predicts net volume of the tree.

Obtain greater precision for the net volume predictor by stratifying stems into classes better correlated to the incidence of defect. For example, if it is found that defect percentage tends to be lower in trees having no external indicators of rot, and higher in those trees having obvious indicators, trees might be classified as "apparently sound" and "obviously defective." Therefore, classify each tree by the presence or absence of indicators. Compute volume from a separate set of equations for each condition class.

22.4 - Direct Tree Volume Estimation Methods. For direct measurement, measure felled sample trees (sec. 22.42) or standing trees with a dendrometer. Direct methods have the advantage of basing volume estimates on measurements of samples representative of the tract being cruised and are, therefore, less prone to the bias inherent in indirect methods.

22.41 - Measuring Standing Trees. For standing trees, estimate volume directly using a type of dendrometer capable of measuring outside bark diameters at selected points on the stem and the heights above ground to those points. A variety of devices are available for doing this. Some devices, such as the Spiegel Relaskop, read directly in standard measurement units. Others, like the Barr and Stroud dendrometer, require translation to get standard units. Estimate defect using the methods described in Section 22.3.

22.42 - Fall, Buck, and Scale. Another method of direct measurement is to fall a sample of trees on the area being cruised, cut them into logs, and determine their gross and net volumes using standard scaling procedures (FSH 2409.11a; FSH 2409.11).

1. Use data obtained from such scales to:

   a. Serve as a training experience for cruisers in assessing cull and defect in standing trees.

   b. Check the reliability of tree volume estimators.

   c. Build up data files for developing tree volume regressions.

   d. Serve as a sample in some cruising systems such as 3P (sec. 30).

2. Establish regional standards to produce consistent cruise estimates when using fall, buck, and scale. These standards must cover the following specifications:

   a. Measurement of height (total height, from ground or stump, or merchantable height).

   b. Minimum top scaling diameters.

   c. Minimum scaling lengths and segmentation rules.

   d. Guidelines to account for broken chunks, highly defective material, and extremely knotty material.

   e. Bucking requirements.

   f. Tree identification.

   g. Data to be recorded.

23 - WEIGHT DETERMINATION. Use weight estimation for tree components, such as crownwood, that do not readily lend themselves to volume determination methods. Tree weight estimates are used for planning helicopter logging and timber hauling operations.

Weight is much more closely related to cubic volume than board foot units of measure, and weight may be a useful estimator when cubic units of volume are of interest.

23.1 - Merchantable Components. Weight predictors can be derived to estimate weight of various tree components: total tree, tree bole to specified top limit, branches to specified minimum diameters, and foliage and twigs. Weights may be for wood alone, or for wood and bark.

Separate bark weight prediction equations are also available. In addition, weight is expressed on an oven-dry or green basis, or both.

Weight equations usually express weights for tree components as a function of species, DBH, and stem height. Therefore, weight estimates can be determined from the regular cruise data collected for conventional volume estimates.

23.2 - Residues. Weight is used to quantify two types of residues that result from timber harvesting.

1. Logging residues are tree portions left behind in logging and are outside the products specified in the timber sale contract.

2. Standing residues are standing trees not meeting merchantability specifications on the timber sale contract for standard products.

23.21 - Logging Residues. Residues are the tree crowns and unmerchantable segments of the trees. Logging residue potential prediction equations have been developed for given utilization standards in several species and may be used when precise estimates are not needed.

Greater accuracy is obtained by some form of post-logging residue sampling. The line-intersect, planar-intercept method, or some other suitable method, may be used to get a tally of material lengths and critical diameters, by species. Estimates are expressed in tons per-acre.

Specific information about line-intersect sampling procedures can be found in a publication by C. E. Van Wagner (1968).

23.22 - Standing Residues. Trees considered unmerchantable are not included for removal under the timber sale contract. Tally these trees as separate cruise components and apply weight coefficients as necessary.