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Southern Forest Inventory and Analysis Volume Equation User's Guide

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Cover photo: Logging on an upland hardwood site in Hot Spring County, Arkansas. (photo by Tony G. Johnson)

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Abstract

Reliable volume estimation procedures are fundamental to the mission of the Forest Inventory and Analysis (FIA) program. Moreover, public access to FIA program procedures is imperative. Here we present the volume estimation procedures used by the southern FIA program of the U.S. Department of Agriculture Forest Service, Southern Research Station. The guide presented includes a description of the relevant variables populated in the public FIA database, a description of the set of equations used to estimate tree volume in the south, the volume equations, definition of terms, species-specific (or species group) coefficients for each equation, and examples of estimating individual tree volume.

Keywords: Biomass, FIA, volume, volume equation, volume estimation.

Introduction

The Forest Inventory and Analysis (FIA) program of the U.S. Department of Agriculture Forest Service, Southern Research Station (SRS) is charged with producing State-level estimates of various forest resource values, levels, and trends for 13 Southern States, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands territory. Sound estimation procedures are desideratum to generating credible population estimates in order to evaluate the status and trends in resource conditions. As such, volume estimation is an integral component of forest resource analysis and reporting.

Reliable volume estimation procedures are fundamental to FIA's mission. Copious data have been collected and used to estimate species-specific parameters. Currently, the SRS FIA utilizes inside bark volume estimators of the conventional linear regression model form:

$$V = \alpha + \beta\left(dbh^2 Ht\right) + \varepsilon$$

where

dbh = bole diameter at breast height
Ht = tree height
α and β are species-specific (or species-group-specific) coefficients (Spurr 1952)

to derive volume estimates (Zarnoch and others 2003). The SRS FIA program along with other SRS scientists began destructive sampling of southern tree species more than 50 years ago (*sensu* Cost (1978) modified for felled trees) with the objective of building volume equations. That undertaking resulted in the development of volume equations that have long been in use as one of the foundational elements of the SRS FIA program. However, those equations and associated species-specific coefficients currently used by the SRS FIA program are not readily available in the published literature.

Recently, FIA adopted a nationally consistent method for estimating individual tree component biomass (Components Ratio Method (CRM) – Heath and others 2009) that is dependent upon estimates of sound volume. Those interested in replicating SRS FIA biomass estimation procedures require access to SRS FIA volume equations. This makes it imperative that the volume estimation procedures be publicly available. This publication facilitates such access in a comprehensive and transparent manner.

Using the Guide

This user's guide presents the set of inside bark equations and coefficients the SRS FIA program currently uses to populate seven individual tree volume variables in the public FIA database (FIADB currently version 4.0). In addition, we explain how to implement the SRS FIA volume estimation procedures.

There are six components to this guide: 1) a description of the relevant variables populated in the FIADB, 2) a description of the set of equations used to estimate tree volume in the South, 3) the volume equations, 4) definition of terms, 5) species-specific (or species group) coefficients for each equation, and 6) examples of estimating individual tree volume using this guide.

Variable Descriptions

Seven primary volume variables are populated in the FIADB (table 1). Each of the seven primary volume variables describes a unique portion of an individual stem (fig. 1). While SRS FIA has developed equations for total stem volume, not all estimates are used to populate variables in FIADB.

Descriptions of populated variables are provided as background information to help explain how each variable is calculated and used to derive various volume estimates. Detailed descriptions of all FIADB variables can be found in the FIA Database Description and Users Manual Version 4.0 for Phase 2 accessed online at http://www.fia.fs.fed.us/library/database-documentation.

Table 1—Volume variables populated in FIADB 4.0

Variable	Tree form	Populated in FIADB when:	Estimated volume accounts for:	Units
VOLCFGRS	Timber	Live, dead, or cut tree, DBH ≥ 5"	Central stem, 1' stump to 4" top DOB	ft^3
	Woodland	Live, dead, or cut tree, EDRC ≥ 5"	DRC measurement point to 1.5" top DOB	ft^3
VOLCFNET	Timber	Live, dead, or cut tree, DBH ≥ 5"	Central stem, 1' stump to 4" top DOB less rotten and missing cull	ft^3
	Woodland	Live, dead, or cut tree, EDRC ≥ 5"	DRC measurement point to 1.5" top DOB less rotten and missing cull (For SRS FIA, VOLCFNET, and VOLCFSND report the same volume)	ft^3
VOLCFSND	Timber	Live or dead tree, DBH ≥ 5"	Central stem, 1' stump to 4" top DOB less rotten and missing cull	ft^3
	Woodland	Live or dead tree, EDRC ≥ 5"	DRC measurement point to 1.5" top DOB less rotten and missing cull	ft^3
VOLCSGRS	Timber	Live tree, DBH ≥ 9" (softwoods) ≥ 11" (hardwoods), Tree Class = Growing Stock	Saw-log portion, 1' stump to 7" (softwoods) or 9" (hardwoods) top DOB	ft^3
	Woodland	Not populated		
VOLCSNET	Timber	Live tree, DBH ≥ 9" (softwoods) ≥ 11" (hardwoods), Tree Class = Growing Stock	Saw-log portion, 1' stump to 7" (softwoods) or 9" (hardwoods) top DOB less rotten and missing cull	ft^3
	Woodland	Not populated		
VOLBFGRS	Timber	Live tree, DBH ≥ 9" (softwoods) ≥ 11" (hardwoods), Tree Class = Growing Stock	Saw-log portion, 1' stump to 7" (softwoods) or 9" (hardwoods) top DOB	*board feet*
	Woodland	Not populated		
VOLBFNET	Timber	Live tree, DBH ≥ 9" (softwoods) ≥ 11" (hardwoods), Tree Class = Growing Stock	Saw-log portion, 1' stump to 7" (softwoods) or 9" (hardwoods) top DOB less rotten and missing cull and cull volume removed due to poor form[a].	*board feet*
	Woodland	Not populated		

FIADB = Forest Inventory and Analysis Database; VOLCFGRS = gross cubic-foot volume; VOLCFNET = net cubic volume; VOLCFSND = sound cubic foot volume; VOLCSGRS = gross cubic-foot volume in the saw-log portion; VOLCSNET = net cubic-foot volume in the saw-log portion; VOLBFGRS = gross board-foot volume in the saw-log portion; VOLBFNET = net board-foot volume in the saw-log portion; DBH = diameter at breast height; DOB = diameter outside bark; EDRC = equivalent diameter at root collar; DRC = diameter at root collar.

[a] Cull volume due to poor form was accounted for in the development of the board-foot equations. Form cull is not measured in the field by SRS FIA.

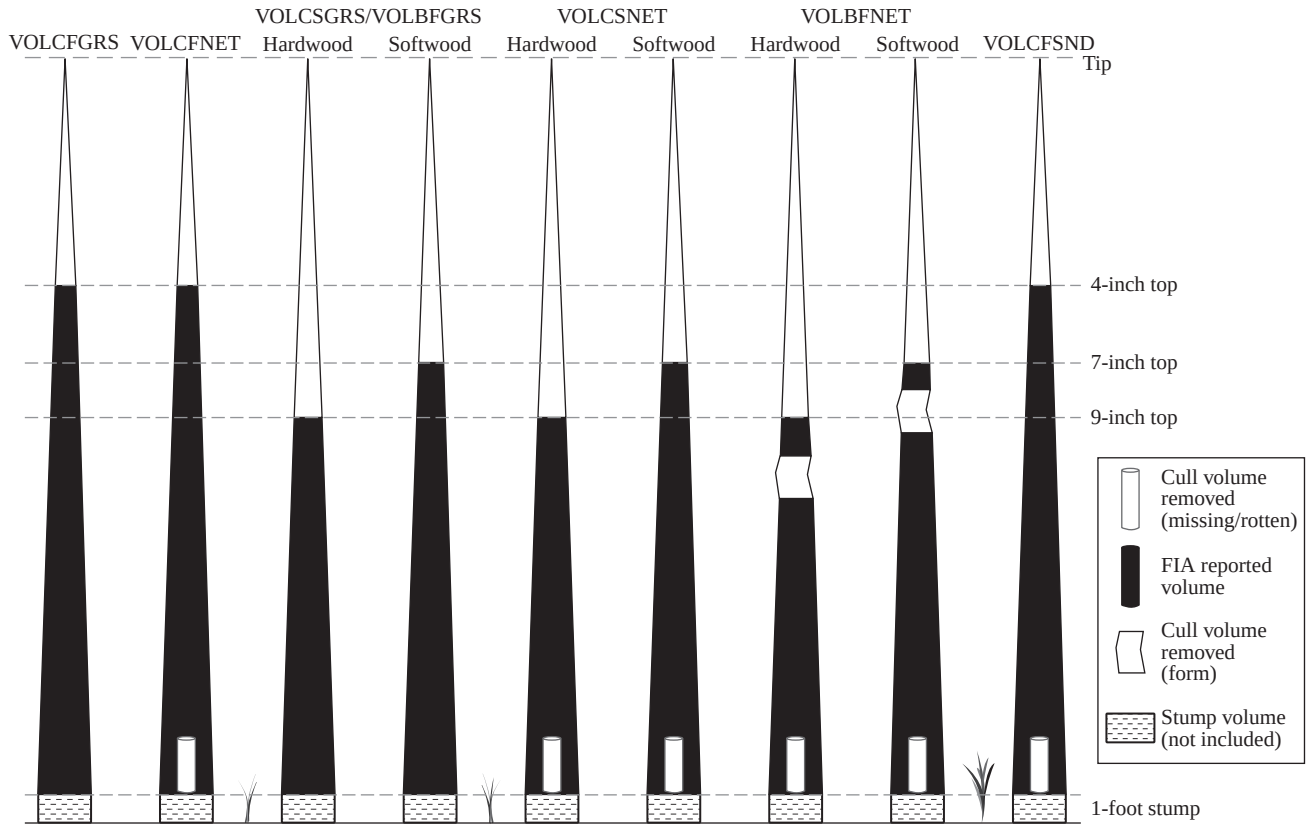

Figure 1—Graphical illustration of the primary volume variables* populated in FIADB 4.0.

* See table 1 for variable definitions.

VOLCFNET Net cubic-foot volume. For timber species (trees where the diameter is measured at breast height [d.b.h.]), this is the net volume of wood in the central stem of a sample tree ≥ 5.0 inches diameter, from a 1-foot stump to a minimum 4-inch top diameter outside bark (d.o.b.), or to where the central stem breaks into limbs all of which are < 4.0 inches d.o.b. For woodland species (trees where the diameter is measured at root collar [d.r.c.]), this is the net volume of wood from the d.r.c. measurement point(s) to a minimum 1.5-inch top. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per acre information. This attribute is blank (null) for trees with DIA < 5.0 inches. All trees measured after 1998 with DIA ≥ 5.0 inches (including dead and cut trees) will have entries in this field. Does not include rotten and missing cull (volume loss due to rotten and missing cull defect has been deducted). ***Note—****VOLCFNET in other FIA regions accounts for additional deductions for form cull.*

VOLCFGRS Gross cubic-foot volume. For timber species, this is the total volume of wood in the central stem of sample trees ≥ 5.0 inches d.b.h., from a 1-foot stump to a minimum 4-inch top d.o.b., or to where the central stem breaks into limbs all of which are < 4.0 inches d.o.b. For woodland species, this is the total volume of wood from the d.r.c. measurement point(s) to a minimum 1.5-inch top. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per acre information. This attribute is blank (null) for trees with DIA < 5.0 inches. All trees measured after 1998 with DIA ≥ 5.0 inches (including dead and cut trees) have entries in this field. Includes rotten, missing and form cull (volume loss due to rotten, missing, and form cull defect has not been deducted).

VOLCSNET Net cubic-foot volume in the saw-log portion. The net volume of wood in the central stem of a sample commercial species tree of sawtimber size (9.0 inches d.b.h. minimum for softwoods, 11.0 inches d.b.h. minimum for hardwoods), from a 1-foot stump to a minimum top d.o.b. (7.0 inches for softwoods, 9.0 inches for hardwoods), or to where the central stem breaks into limbs, all of which are less than the minimum top d.o.b. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per acre information. This attribute is blank (null) for softwood trees with DIA < 9.0 inches (11.0 inches for hardwoods). All larger trees have entries in this field if they are growing-stock trees (TREECLCD = 2 and STATUSCD = 1). All rough and rotten trees (TREECLCD = 3 or 4) and dead and cut trees (STATUSCD = 2 or 3) are blank (null) in this field.

VOLCSGRS Gross cubic-foot volume in the saw-log portion. This is the total volume of wood in the central stem of a sample commercial species tree of sawtimber size (9.0 inches d.b.h. minimum for softwoods, 11.0 inches d.b.h. minimum for hardwoods), from a 1-foot stump to a minimum top d.o.b. (7.0 inches for softwoods, 9.0 inches for hardwoods), or to where the central stem breaks into limbs, all of which are less than the minimum top d.o.b. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per acre information. This attribute is blank (null) for softwood trees with DIA < 9.0 inches (11.0 inches for hardwoods). All larger trees have entries in this field if they are growing-stock trees (TREECLCD = 2 and STATUSCD = 1). All rough and rotten trees (TREECLCD = 3 or 4) and dead and cut trees (STATUSCD = 2 or 3) are blank (null) in this field.

VOLBFNET Net board-foot volume in the saw-log portion. This is the net volume (International ¼-inch rule) of wood in the central stem of a sample commercial species tree of sawtimber size (9.0 inches d.b.h. minimum for softwoods, 11.0 inches d.b.h. minimum for hardwoods), from a 1-foot stump to a minimum top d.o.b. (7.0 inches for softwoods, 9.0 inches for hardwoods), or to where the central stem breaks into limbs all of which are less than the minimum top d.o.b. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per unit area information. Trees with DIA < 9.0 inches (11.0 inches for hardwoods) have zero in this field. All larger trees should have entries in this field if they are growing-stock trees (TREECLCD = 2 and STATUSCD = 1). All rough and rotten trees (TREECLCD = 3 or 4) and dead and cut trees (STATUSCD = 2 or 3) are blank (null) in this field.

VOLBFGRS Gross board-foot volume in the saw-log portion. This is the total volume (International ¼-inch rule) of wood in the central stem of a sample commercial species tree of sawtimber size (9.0 inches d.b.h. minimum for softwoods, 11.0 inches d.b.h. minimum for hardwoods), from a 1-foot stump to a minimum top d.o.b.

(7.0 inches for softwoods, 9.0 inches for hardwoods), or to where the central stem breaks into limbs all of which are less than the minimum top d.o.b. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per unit area information. Trees with DIA < 9.0 inches (11.0 inches for hardwoods) have zero in this field. All larger trees should have entries in this field if they are growing-stock trees (TREECLCD = 2 and STATUSCD = 1). All rough and rotten trees (TREECLCD = 3 or 4) and dead and cut trees (STATUSCD = 2 or 3) are blank (null) in this field.

VOLCFSND Sound cubic-foot volume. For timber species, the volume of sound wood in the central stem of a sample tree ≥ 5.0 inches d.b.h. from a 1-foot stump to a minimum 4-inch top d.o.b. or to where the central stem breaks into limbs all of which are < 4.0 inches d.o.b. For woodland species, this is the net volume of wood from the d.r.c. measurement point(s) to a minimum 1.5-inch top. This is a per tree value and must be multiplied by TPA_UNADJ to obtain per acre information. This attribute is blank (null) for trees with DIA < 5.0 inches. All trees with DIA ≥ 5.0 inches (including dead trees) have entries in this field. Does not include rotten and missing cull (volume loss due to rotten and missing cull defect has been deducted).

DIA Current diameter. This is the current diameter (in inches) of the sample tree at the point of diameter measurement. For additional information about where the tree diameter is measured, see DIAHTCD or HTDMP in the FIADB manual version 4.0. DIA for live trees contains the measured value. DIA for cut and dead trees presents problems associated with uncertainty of when the tree was cut or died as well as structural deterioration of dead trees. Consult individual FIA units for explanations of how DIA is collected for dead and cut trees.

For tree species in which d.r.c. is collected, equivalent diameter (EDRC) (Chojnacky 1994) is calculated for use in volume equations.

EDRC =

$$\sqrt{\sum_{i=1}^{n} drc_i^2}$$

where

n = number of stems measured for *drc* on individual woodland species
drc = diameter root collar

HT Total height. (*core phase 2: ≥ 5.0-inch d.b.h./d.r.c. live trees; core optional phase 2: ≥ 1.0-inch d.b.h./d.r.c. live trees and ≥ 5.0-inch d.b.h./d.r.c. standing dead trees. Core phase 3: ≥ 1.0-inch d.b.h./d.r.c. live trees; core optional phase 3: ≥ 1.0-inch d.b.h./d.r.c. live trees and ≥ 5.0-inch d.b.h./d.r.c. standing dead trees.*) The total length (height) of a sample tree (in feet) measured from the ground to the tip of the apical meristem. The total length of a tree is not always its actual length. If the main stem is broken, the actual length is measured or estimated and the missing piece is added to the actual length to estimate total length. The amount added is determined by measuring the broken piece if it can be located on the ground; otherwise it is estimated. The minimum height for timber species is 5 feet and for woodland species is 1 foot.

ACTUALHT Actual height. *(core phase 2: live and standing dead trees with broken or missing tops, ≥ 5.0-inch d.b.h./d.r.c.; core optional phase 2: live trees ≥ 1.0-inch d.b.h./d.r.c. and ≥ 5.0-inch d.b.h./d.r.c. standing dead trees [with broken or missing tops]; core phase 3:live trees ≥ 1.0-inch d.b.h./d.r.c. (with broken or missing tops and standing dead trees ≥ 5.0-inch d.b.h./d.r.c. [with broken or missing tops])*. The length (height) of the tree to the nearest foot from ground level to the highest remaining portion of the

tree still present and attached to the bole. If ACTUALHT = HT, then the tree does not have a broken top. If ACTUALHT is < HT, then the tree does have a broken or missing top. The minimum height for timber species is 5 feet and for woodland species is 1 foot.

CULL Rotten and missing cull. The percent of the cubic-foot volume in a live or dead tally tree that is rotten or missing. This is a calculated value that includes field-recorded cull (CULL_FLD) and any additional cull due to broken top.

CULL_FLD Rotten/missing cull. (*core: ≥ 5.0-inch live trees; core optional: ≥ 5.0-inch live trees and standing dead*). The percentage rotten or missing cubic-foot cull volume, estimated to the nearest 1 percent. This estimate does not include any cull estimate above actual length; therefore volume lost from a broken top is not included (see CULL for percent cull including cull from broken top). When field crews estimate volume loss (tree cull), they only consider the cull on the merchantable bole/portion of the tree, from a 1-foot stump to a 4-inch top d.o.b.. For western woodland species, the merchantable portion is between the point of d.r.c. measurement to a 1.5-inch top d.o.b.

At times, separate coefficients exist for saplings, poles, and sawtimber. The specifications for each are:

Saplings— Softwood (SPCD or SPN < 300) = d.b.h. ≥ 1 inch and < 5 inches
Hardwood (SPCD or SPN > 299) = d.b.h. ≥ 1 inch and < 5 inches

Poles— Softwood = d.b.h. ≥ 5 inch and < 9 inches
Hardwood = d.b.h. ≥ 5 inch and < 11 inches

Sawtimber— Softwood = d.b.h. ≥ 9 inches and tree class = 2
Hardwood = d.b.h. ≥ 11 inches and tree class = 2

Additionally, coefficients have been fit for planted slash pine and planted loblolly pine for some equations. While ACTUALHT is used as an explanatory variable of volume, each net cubic-foot volume variable accounts for deductions for missing tops (see broken-top cubic-foot cull), missing volume (see missing cubic-foot cull) and rotten wood (see rotten cubic-foot cull). In the case of estimated net board-foot volume, the estimates account for deductions for missing tops, missing volume, rotten wood and poorly formed wood (for example, sweep and crook, see percent board-foot cull). ***Note—****In the South cull is reported as CULL_FLD and CULL in the FIADB. CULL_FLD represents cubic-foot cull, CULL represents CULL_FLD with the addition of broken-top cull*.

Description of Equations

Cubic and board-foot (inside bark) volumes are calculated for softwood and hardwood stems on forest land. International ¼-inch log rule is used for board-foot equations. Multiple volumes are estimated by utilizing a combination of species- or species-group-specific simple linear equations and ratio-based conversion factors.

All total stem volumes are calculated on all trees in the inventory that are > 1.0-inch (2.5 cm) d.b.h. However, tree-level volume variables in the FIADB are only populated for trees > 5-inch (12.5 cm) d.b.h.

All other volumes (gross, net growing-stock, and sawtimber volumes) are calculated on the merchantable stem. Gross volume is generally the first output from volume equations and has not been adjusted for the presence of cull (rot and defect). Net volume is gross volume minus an estimate of volume lost due to rot, physical defect, and/or other damage.

SRS FIA volume is most often reported as gross board-foot volume, gross cubic-foot volume, net board-foot volume, or net cubic-foot volume. Volume is generally reported for populations of growing-stock (see Definition of Terms) or all-live trees. Each metric and population is defined by individual specifications.

Board-foot volume is referred to as sawtimber (or saw-log) volume; for softwoods it is the volume of a tree from a 1-foot stump to a 7-inch top, calculated for softwood species ≥ 9-inch (22.5 cm) d.b.h.; and for hardwoods, it is the volume of a tree from a 1-foot stump to a 9-inch top, calculated for hardwood species ≥ 11-inch (27.5 cm) d.b.h. (table 2).

Table 2—Description of the types of volume calculated with SRS FIA equations, tree specifications, equation variable name, the FIADB equivalent variable name, equation number, and variables used to perform calculations for each type of volume calculated

Type of volume	Tree specifications	Variable name	FIADB equivalent	Equation	Function
	- - - - inches - - - -				
All softwoods and hardwoods					
Volume of the total stem, ground to tip	≥1 (2.5 cm)				
Volume from ground level to the tip	≥1 and <5 (12.5 cm)	TCU		CU000068	(TF, CV4)
Volume from 1' stump to 4" top d.o.b.	≥5	CV4	VOLCFGRS	CU000067	(SPCD_EQ, DBH, HT)
Softwood saw-log volume					
Volume from 1' stump to 6" top d.o.b.	≥9 (22.5 cm)	CUSAW	VOLCSGRS[a]	CU000069	(R_{CUSAW}, CV4)
Hardwood saw-log volume					
Volume from 1' stump to 8" top d.o.b.	≥11 (27.5 cm)	CUSAW	VOLCSGRS[a]	CU000069	(R_{CUSAW}, CV4)
Softwood saw-log volume (board foot)					
Volume from 1' stump to 6" top d.o.b.	≥9	BD	VOLBFGRS[a]	BD00049	(R_{BD}, CV4)
Hardwood saw-log volume (board foot)					
Volume from 1' stump to 8" top d.o.b.	≥11	BD	VOLBFGRS[a]	BD00049	(R_{BD}, CV4)

SRS FIA= Southern Research Station, Forest Inventory and Analysis; FIADB = Forest Inventory and Analysis Database; TCU = total cubic-foot volume from ground level to tip; TF = total cubic-foot volume from ground level to tip; CV4 = cubic-foot volume; SPCD_EQ = FIA species code and associated equation number; DBH = diameter at breast height; HT = total height; VOLCFGRS = gross cubic-foot volume; CUSAW = cubic-foot volume of the saw-log portion; R_{CUSAW} = ratio of cubic-foot volume of the saw-log portion; VOLCSGRS = gross cubic-foot volume in the saw-log portion; BD = board-foot volume; VOLBFGRS = gross board-foot volume in the saw-log portion; R_{BD} = ratio board-foot volume.

[a] Not populated for tree class 3 (rough cull) or 4 (rotten cull).

Equations

Equation Form CU000067 = CV4

The following equations compute total cubic-foot volume for saplings and planted saplings:

$$CV4_{Sapling} = A1 + A2 * (DBH^2 * HT)$$

$$CV4_{Planted\ Sapling} = B1 + B2 * (DBH^2 * HT)$$

The following equations compute cubic-foot volume from a 1-foot stump to a 4-inch top d.o.b. for poles and sawtimber:

$$CV4_{Pole} = C1 + C2 * (DBH^2 * HT)$$

$$CV4_{Sawtimber} = D1 + D2 * (DBH^2 * HT)$$

Equation Form CU000068 = TCU

The following equations compute total cubic-foot volume from ground level to tip:

$$TF_{Pole} = E1 + E2 * \left(\frac{1}{DBH - 3}\right)^2$$

$$TF_{Planted\ Pole} = G1 + G2 * \left(\frac{1}{DBH - 3}\right)^2$$

$$TF_{Sawtimber} = F1 + F2 * \left(\frac{1}{DBH - 3}\right)^2$$

$$TF_{Planted\ Sawtimber} = G1 + G2 * \left(\frac{1}{DBH - 3}\right)^2$$

$$TCU = TF * CV4$$

Equation Form CU000069 = CUSAW

The following equation converts cubic-foot volume from a 1-foot stump to a 4-inch top d.o.b. to cubic-foot volume of the saw-log portion of the tree:

$$R = H1 + H2 * \left(\frac{1}{DBH - 5}\right)^2$$

Ratio is limited to between 0.60 and 0.99

$$CUSAW = R * CV4$$

Equation Form BD000049 = BD

The following equation converts cubic-foot volume from a 1-foot stump to a 4-inch top d.o.b. to board-foot volume:

$$R = I1 + I2 * \left(1 - \frac{1}{DBH}\right)$$

$$BD = R * CV4$$

Board-Foot Cull Defect Equation

Only used in processing for broken-top trees.

$$VOLBFNET = VOLBFGRS - \left(VOLBFGRS * \frac{DEFECT_{BF}}{100}\right)$$

where

$DEFECT_{BF}$ = percent board-foot cull

Note—*Currently* $DEFECT_{BF} = DEFECT_{CF}$ *for SRS FIA processing*

Cubic-Foot Cull Defect Equations

Calculated for all net cubic-foot variables (VOLCFNET, VOLCSNET and VOLCFSND).

$$VOLCFNET = VOLCFGRS - \left(VOLCFGRS * \frac{DEFECT_{CF}}{100}\right)$$

$$VOLCSNET = VOLCSGRS - \left(VOLCSGRS * \frac{DEFECT_{CF}}{100}\right)$$

$$VOLCFSND = VOLCSGRS - \left(VOLCSGRS * \frac{DEFECT_{CF}}{100}\right)$$

where

$DEFECT_{CF}$ = percent cubic-foot cull + missing top cull

NIMS–SRS Implementation

VOLCFGRS = CV4
VOLCFNET = CV4 – cubic-foot cull defect
VOLCFSND = CV4 – cubic-foot cull defect
VOLCSGRS = CUSAW except 0 if tree class = 3 or 4
VOLCSNET = CUSAW – cubic-foot cull defect
VOLBFGRS = CV4 * board-foot conversion ratio
VOLBFNET = CV4 * board-foot conversion ratio – cubic-foot cull defect

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Definition of Terms

The following definitions are taken from the Forest Inventory and Analysis glossary (available from the SRS FIA program). Additional information and definitions are available from the Forest Inventory and Analysis National Core Field Guide, Volume 1: Field Data Collection Procedures for Phase 2 Plots. SRS Version 3.0. October 2005. (http://srsfia2.fs.fed.us/data_acquisition/manual.shtml).

Cull—Portions of a tree that are unusable for industrial wood products because of rot, form, or other defect. Cull is further categorized as the following:

Broken-top cubic-foot cull—The broken-top proportion of a timber species tree's merchantable portion from the break to the actual or projected 4-inch top diameter outside bark, or to where the central stem forks, where all forks are < 4.0 inches diameter. For trees 1.0–4.9 inches diameter this is the proportion of the main stem missing due to a broken top.

Missing cubic-foot cull—The proportion of a tree's merchantable portion that is missing. Does not include any cull deductions above actual length for broken-top timber trees. Does include cull deductions above actual length for broken-top woodland species. Trees with d.b.h./d.r.c. < 5.0 inches have a null value in this field.

Rotten cubic-foot cull—The proportion of a tree's merchantable portion that is in a decayed state. Does not include any cull deductions above actual length for broken-top timber trees. Does include cull deductions above actual length for broken-top woodland species. Trees < 5.0 inches d.b.h. have a null value in this field.

Rotten/missing cull—The part of the tree's merchantable portion that is decayed and/or missing due to other factors.

Diameter at breast height (d.b.h.)—The diameter for tree stem, located at 4.5 feet above the ground (breast height) on the uphill side of a tree. The point of diameter measurement may vary on abnormally formed trees.

Diameter at root collar (d.r.c.)—The diameter of a tree (usually a woodland species), measured outside of the bark at the ground line or stem root collar.

Forest land—Land that is at least 10 percent stocked by forest trees of any size, or land formerly having such tree cover, and is not currently developed for a nonforest use. The minimum area for classification as forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width at least 120 feet wide to qualify as forest land. Unimproved roads and trails, streams and other bodies of water, or natural clearings in forested areas shall be classified as forest, if < 120 feet in width or 1.0 acre in size. Forest land is divided into timberland, reserved forest land, and other forest land (such as woodland).

Growing-stock trees—Live large-diameter timber species (excludes nonsaw-log species) trees with one-third or more of the gross board-foot volume in the entire saw-log portion meeting grade, soundness, and size requirements or the potential to do so for medium-diameter and small-diameter trees. A growing-stock tree must have one 12-foot log or two noncontiguous 8-foot merchantable logs, now (large-diameter) or prospectively (medium-diameter and small-diameter), to qualify as growing stock.

Log—Eight foot (2.4 m) or longer tree segment suitable for processing into lumber, veneer, or other wood products.

Merchantable portion—The portion of the main stem of a timber species tree from a 1-foot stump to a minimum 4-inch top diameter inside or outside bark depending on species. The portion of a woodland species tree from the d.r.c. measurement to the 1.5-inch diameters of all the qualifying stems.

Poletimber-sized tree (i.e., poles)—Softwood timber species 5.0 to 8.9 inches d.b.h. and hardwood timber species 5.0 to 10.9 inches d.b.h. Often referred to as medium-diameter trees.

Sapling—Live trees 1.0 to 4.9 inches d.b.h./d.r.c.

Saw-log portion—That portion of the main stem of a timber species tree of large-diameter size from a 1-foot stump to a minimum top d.o.b. 7.0 inches for softwoods, 9.0 inches for hardwoods (equivalent 6.0 inches diameter inside bark (d.i.b.) for softwoods, 8.0 inches d.i.b. for hardwoods).

Sawtimber-sized trees—Softwood timber species ≥ 9.0 inches d.b.h., and hardwood timber species ≥ 11.0 inches d.b.h. Often referred to as large-diameter trees.

Seedling—Live trees < 1.0-inch d.b.h./d.r.c. that are ≥ 6 inches in height for softwoods and ≥ 12 inches in height for hardwoods and > 0.5-inch d.b.h./d.r.c. at ground level for longleaf pine.

Species group—A collection of species used for reporting purposes.

Total length—The total length of the tree, recorded to the nearest 1.0 foot from ground level to the tip of the apical meristem. Trees growing on a slope are measured on the uphill side of the tree. If the tree has a broken or missing top, the total length is estimated to what the length would be if there were no missing or broken top. Forked trees are treated the same as unforked trees.

Tree—A woody perennial plant, typically large, with a single well-defined stem carrying a more or less definite crown; sometimes defined as attaining a minimum diameter of 3 inches and a minimum height of 15 feet at maturity. For FIA, any plant on the tree list in the current field manual is measured as a tree.

Tree class—An indication of the general quality of the tree. In the annual inventory, this is the tree class for both live and dead trees at the time of current measurement. In the historical periodic inventory, for cut and dead trees, this is the tree class of the tree at the time it died or was cut. Therefore, cut and dead trees collected in periodic inventory can be growing stock.

Cull species—Species measured at d.r.c. and timber species (measured at d.b.h.) that would not produce saw logs.

Growing stock—Live large-diameter timber species (excludes nonsaw-log species) trees with one-third or more of the gross board-foot volume in the entire saw-log portion meeting grade, soundness, and size requirements or the potential to do so for medium-diameter trees. A growing-stock tree must have one 12-foot log or two noncontiguous 8-foot merchantable logs, now (large diameter) or prospectively (medium diameter), to qualify as growing stock.

Rough cull—Trees that do not contain at least one 12-foot saw log or two 8-foot logs now or prospectively, primarily because of roughness or poor form. Less than one-third of its gross board-foot volume meets size, soundness, and grade requirements and less than one-half of the cubic-foot cull is rotten or unsound.

Rotten cull—Trees that do not contain at least one 12-foot saw log or two 8-foot logs now or prospectively and/or do not meet grade specifications for percent sound primarily because of rot. All species not having one-third or more of its gross board-foot volume meeting size, soundness, and grade requirements, and over one-half of the cubic-foot cull is rotten or unsound.

Volume—A measure of the solid content of the tree stem used to measure wood quantity.

Gross board-foot volume—Total board-foot volume of wood inside bark without deductions for total board-foot cull.

Gross cubic-foot volume—Total cubic-foot volume of wood inside bark without deductions for rotten, missing, or broken-top cull.

Net board-foot volume—Gross board-foot volume minus deductions for total board-foot cull.

Net cubic-foot volume—Gross cubic-foot volume minus deductions for rotten, missing, and broken-top cull.

Metric Equivalents

1 acre = 4,046.86 m^2 or 0.404687 ha
1 cubic foot = 0.028317 m^3
1 inch = 2.54 cm or 0.0254 m
Breast height (4.5 feet) = 1.4 m above the ground
1 square foot = 929.03 cm^2 or 0.0929 m^2
1 square foot of basal area per acre = 0.229568 m^2/ha
1 cubic foot per acre = 0.0699722 m^3/ha
1 pound = 0.454 kg
1 ton = 0.908 metric ton

Appendix

Reading Tables

Identify FIA volume variable(s) of interest. Ascertain needed coefficients. Use table A.1 to identify species of interest by common name (COMMON_NAME) or FIA species code (SPCD) and associated equation number (SPCD_EQ). Use the SPCD_EQ code to identify corresponding coefficients in table A.2 (total gross cubic-foot volume for saplings), table A.3 (total gross cubic-foot volume for planted saplings), table A.4 (VOLCFGRS for poles and sawtimber), table A.5 (total cubic-foot volume from stump to tip for poles and sawtimber), table A.6 (total cubic-foot volume from stump to tip for planted poles and planted sawtimber), table A.7 (conversion of CV4 to CUSAW), and/or table A.8 (conversion of CV4 to board-foot volume).

Guide to Coefficient Tables

Table A.2

A1, A2 Coefficients to compute sapling total cubic-foot volume stump to tip

Table A.3

B1, B2 Coefficients to compute sapling total cubic-foot volume stump to tip for plantation trees

Table A.4

C1, C2 Coefficients to compute pole cubic-foot volume from stump to 4-inch top
D1, D2 Coefficients to compute sawtimber cubic-foot volume from stump to 4-inch top

Table A.5

E1, E2 Coefficients to convert poles from CV4 (cubic volume to a 4-inch top) to total stem
F1, F2 Coefficients to convert sawtimber from CV4 (cubic volume to a 4-inch top) to total stem

Table A.6

G1, G2 Coefficients to convert plantation trees from CV4 (cubic volume to a 4-inch top) to total stem

Table A.7

H1, H2 Coefficients to convert CV4 (cubic volume to a 4-inch top) to CUSAW (cubic saw-log volume)

Table A.8

I1, I2 Coefficients to convert CV4 (cubic volume to a 4-inch top) to board-foot

Table A.1—Species code, common name, and the species code for the equation (or set of coefficients – SPCD_EQ) used for each species

SPCD	Common name	Species number	SPCD_EQ[a]	SPCD	Common name	Species number	SPCD_EQ[a]
10	Fir spp.	10	10	320	Norway maple	320	318
12	Balsam fir	12	10	321	Rocky Mountain maple	321	Chojnacky 1988
16	Fraser fir	16	10	323	Chalk maple	323	317
43	Atlantic white-cedar	43	43	330	Buckeye, horsechestnut	330	330
58	Pinchot juniper	58	Chojnacky 1994	331	Ohio buckeye	331	330
59	Redberry juniper	59	Chojnacky 1994	332	Yellow buckeye	332	330
61	Ashe juniper	61	Chojnacky 1994	334	Texas buckeye	334	330
63	Alligator juniper	63	Chojnacky 1994	341	Ailanthus	341	999
66	Rocky Mountain juniper	66	Chojnacky 1994	345	Mimosa, silktree	345	491
67	Southern redcedar	67	67	356	Serviceberry	356	999
68	Eastern redcedar	68	68	367	Pawpaw	367	999
69	Oneseed juniper	69	Chojnacky 1994	370	Birch spp.	370	370
90	Spruce spp.	90	90	371	Yellow birch	371	371
93	Engelmann spruce	93	90	372	Sweet birch	372	371
97	Red spruce	97	90	373	River birch	373	370
106	Common pinyon	106	Chojnacky 1994	379	Gray birch	379	371
107	Sand pine	107	107	381	Chittamwood, gum bumelia	381	999
110	Shortleaf pine	110	110	391	American hornbeam, musclewood	391	999
111	Slash pine	111	111	400	Hickory spp.	400	400
115	Spruce pine	115	115	401	Water hickory	401	400
121	Longleaf pine	121	121	402	Bitternut hickory	402	400
122	Ponderosa pine	122	Hann and Bare 1978	403	Pignut hickory	403	400
123	Table Mountain pine	123	123	404	Pecan	404	400
126	Pitch pine	126	126	405	Shellbark hickory	405	400
128	Pond pine	128	128	406	Nutmeg hickory	406	400
129	Eastern white pine	129	129	407	Shagbark hickory	407	400
131	Loblolly pine	131	131	408	Black hickory	408	400
132	Virginia pine	132	132	409	Mockernut hickory	409	400
140	Mexican pinyon pine	140	Chojnacky 1994	410	Sand hickory	410	400
202	Douglas-fir	202	Hann and Bare 1978	421	American chestnut	421	999
221	Baldcypress	221	221	422	Allegheny chinkapin	422	999
222	Pondcypress	222	222	423	Ozark chinkapin	423	999
241	Northern white-cedar	241	241	450	Catalpa spp.	450	999
260	Hemlock spp.	260	260	451	Southern catalpa	451	999
261	Eastern hemlock	261	260	452	Northern catalpa	452	999
262	Carolina hemlock	262	260	460	Hackberry spp.	460	460
299	Unknown conifer	299	10	461	Sugarberry	461	460
310	Maple spp.	310	318	462	Hackberry	462	460
311	Florida maple	311	311	463	Netleaf hackberry	463	460
313	Boxelder	313	313	471	Eastern redbud	471	999
314	Black maple	314	317	481	Yellowwood	481	491
315	Striped maple	315	999	491	Flowering dogwood	491	491
316	Red maple	316	316	492	Pacific dogwood	492	491
317	Silver maple	317	317	500	Hawthorn	500	999
318	Sugar maple	318	318	501	Cockspur hawthorn	501	999
319	Mountain maple	319	999				

continued

Table A.1—Species code, common name, and the species code for the equation (or set of coefficients – SPCD_EQ) used for each species (continued)

SPCD	Common name	Species number	SPCD_EQ[a]	SPCD	Common name	Species number	SPCD_EQ[a]
502	Downy hawthorn	502	999	742	Eastern cottonwood	742	740
510	Eucalyptus	510	999	743	Bigtooth aspen	743	741
521	Common persimmon	521	521	744	Swamp cottonwood	744	740
531	American beech	531	531	745	Plains cottonwood	745	740
540	Ash spp.	540	540	755	Mesquite	755	Chojnacky 1988
541	White ash	541	540	756	Western honey mesquite	756	Chojnacky 1988
543	Black ash	543	540	758	Screwbean mesquite	758	Chojnacky 1988
544	Green ash	544	540	760	Cherry and plum spp.	760	999
545	Pumpkin ash	545	540	761	Pin cherry	761	999
546	Blue ash	546	540	762	Black cherry	762	762
548	Carolina ash	548	999	763	Chokecherry	763	762
551	Waterlocust	551	999	765	Canada plum	765	999
552	Honeylocust	552	552	766	Wild plum	766	999
555	Loblolly-bay	555	555	800	Oak deciduous	800	812
571	Kentucky coffeetree	571	999	802	White oak	802	802
580	Silverbell	580	580	804	Swamp white oak	804	804
591	American holly	591	591	806	Scarlet oak	806	806
600	Walnut	600	601	808	Durand oak	808	808
601	Butternut	601	601	809	Northern pin oak	809	830
602	Black walnut	602	602	810	Emery oak	810	Chojnacky 1988
605	Texas walnut	605	601	812	Southern red oak	812	812
611	Sweetgum	611	611	813	Cherrybark oak	813	813
621	Yellow-poplar	621	621	816	Bear oak, scrub oak	816	842
641	Osage-orange	641	999	817	Shingle oak	817	817
650	Magnolia spp.	650	652	819	Turkey oak	819	817
651	Cucumbertree	651	651	820	Laurel oak	820	820
652	Southern magnolia	652	652	822	Overcup oak	822	822
653	Sweetbay	653	653	823	Bur oak	823	823
654	Bigleaf magnolia	654	651	824	Blackjack oak	824	824
655	Mountain magnolia	655	651	825	Swamp chestnut oak	825	825
660	Apple spp.	660	999	826	Chinkapin oak	826	826
680	Mulberry spp.	680	680	827	Water oak	827	827
681	White mulberry	681	999	828	Nuttall oak	828	813
682	Red mulberry	682	680	830	Pin oak	830	830
691	Water tupelo	691	691	831	Willow oak	831	831
692	Ogechee tupelo	692	999	832	Chestnut oak	832	832
693	Blackgum	693	693	833	Northern red oak	833	833
694	Swamp tupelo	694	694	834	Shumard oak	834	834
701	Eastern hophornbeam	701	999	835	Post oak	835	835
711	Sourwood	711	999	836	Delta post oak	836	836
712	Paulownia, empress-tree	712	999	837	Black oak	837	837
721	Redbay	721	999	838	Live oak	838	838
722	Water-elm, planertree	722	999	840	Dwarf post oak	840	840
731	Sycamore	731	731	841	Dwarf live oak	841	840
740	Cottonwood and poplar spp.	740	740	842	Bluejack oak	842	842
741	Balsam poplar	741	741	843	Silverleaf oak	843	Chojnacky 1988

continued

Table A.1—Species code, common name, and the species code for the equation (or set of coefficients – SPCD_EQ) used for each species (continued)

SPCD	Common name	Species number	SPCD_EQ[a]	SPCD	Common name	Species number	SPCD_EQ[a]
844	Oglethorpe oak	844	842	970	Elm spp.	970	970
845	Dwarf chinakapin oak	845	842	971	Winged elm	971	970
846	Gray oak	846	Chojnacky 1988	972	American elm	972	970
901	Black locust	901	901	973	Cedar elm	973	970
911	Palmetto spp.	911	999	974	Siberian elm	974	970
919	Western soapberry	919	999	975	Slippery elm	975	970
920	Willow	920	920	976	September elm	976	970
921	Peachleaf willow	921	920	977	Rock elm	977	970
922	Black willow	922	920	989	Mangrove	989	999
927	White willow	927	920	992	Melaleuca	992	999
931	Sassafras	931	999	993	Chinaberry	993	999
935	American mountain-ash	935	999	994	Chinese tallowtree	994	999
950	Basswood spp.	950	950	995	Tung-oil-tree	995	999
951	American basswood	951	950	996	Smoketree	996	999
952	White basswood	952	950	997	Russian-olive	997	999
953	Carolina basswood	953	950	999	Unknown hardwood	999	999

Note: Some species will require the use of equations built by other regions and are denoted by the appropriate citation.
SPCD = Forest Inventory and Analysis species code; SPCD_EQ = species code equation.
[a] Citation listed when published equations available.

Table A.2—Species code equation and associated coefficients for use in SRS FIA gross volume equations (total) for saplings (use equation form CU000067)

	Coefficients			Coefficients			Coefficients	
SPCD_EQ	A1	A2	SPCD_EQ	A1	A2	SPCD_EQ	A1	A2
10	0.065755	0.002813	400	0.047620	0.002192	808	0.080702	0.002467
43	0.010169	0.002839	460	0.054564	0.002565	812	0.080702	0.002467
60	0.052928	0.002853	491	0.037005	0.002729	813	0.041238	0.002603
67	0.052928	0.002853	521	0.034641	0.002546	817	0.041238	0.002603
68	0.052928	0.002853	531	0.058647	0.002378	820	0.024511	0.002637
90	0.065755	0.002813	540	0.064004	0.002410	822	0.041238	0.002603
107	0.079225	0.002490	552	0.058647	0.002378	823	0.041238	0.002603
110	0.066654	0.002168	555	0.012745	0.003005	824	0.053215	0.002475
111	0.070229	0.002111	580	0.054564	0.002565	825	0.041238	0.002603
115	0.081287	0.002219	591	0.058647	0.002378	826	0.041238	0.002603
121	0.058586	0.002429	601	0.054564	0.002565	827	0.030987	0.002670
123	0.081287	0.002219	602	0.058647	0.002378	830	0.041238	0.002603
126	0.081287	0.002219	611	0.045146	0.002357	831	0.041238	0.002603
128	0.047587	0.002354	621	0.019361	0.002514	832	0.014284	0.002521
129	0.074791	0.002881	651	0.051279	0.002641	833	0.041238	0.002603
131	0.060342	0.002197	652	0.051279	0.002641	834	0.041238	0.002603
132	0.034943	0.002569	653	0.057904	0.002603	835	0.051922	0.002631
221	0.094132	0.002743	680	0.058647	0.002378	836	0.053210	0.002475
222	0.101432	0.002744	691	0.062785	0.002458	837	0.042519	0.002613
241	0.065755	0.002813	693	0.048582	0.002498	838	0.050820	0.002776
260	0.065755	0.002813	694	0.088427	0.002681	840	0.053210	0.002475
311	0.058647	0.002378	731	0.054564	0.002565	842	0.053210	0.002475
313	0.054564	0.002565	740	0.054564	0.002565	899	0.053215	0.002475
316	0.023326	0.002860	741	0.054564	0.002565	901	0.058647	0.002378
317	0.054564	0.002565	762	0.155471	0.002461	920	0.054564	0.002565
318	0.058647	0.002378	802	0.044339	0.002539	950	0.054564	0.002565
330	0.054564	0.002565	804	0.041238	0.002603	970	0.032199	0.002589
370	0.058647	0.002378	806	0.067831	0.002660	999	0.062125	0.002494
371	0.058647	0.002378						

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; A1 = coefficient to compute sapling total cubic-foot volume stump to tip; A2 = coefficient to compute sapling total cubic-foot volume stump to tip.

Table A.3—Species code equation and associated coefficients for use in SRS FIA gross volume equations (total) for planted saplings (use equation form CU000067)

	Coefficients	
SPCD_EQ	B1	B2
111	0.132056	0.002113
131	0.150292	0.001994

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; B1 = coefficient to compute sapling total cubic-foot volume stump to tip for plantation trees; B2 = coefficient to compute sapling total cubic-foot volume stump to tip for plantation trees.

Table A.4—Species code equation and associated coefficients for use in SRS FIA gross volume equations for poles and sawtimber (use equation form CU000067)

	Coefficients					Coefficients			
	Pole		Sawtimber			Pole		Sawtimber	
SPCD_EQ	C1	C2	D1	D2	SPCD_EQ	C1	C2	D1	D2
10	-0.099920	0.002097	0.879371	0.001845	651	-0.198410	0.001901	0.735415	0.001775
43	0.247418	0.002161	1.668389	0.001822	652	-0.198410	0.001901	0.735415	0.001775
60	-0.315878	0.002207	-0.104252	0.002145	653	-0.198410	0.001901	0.735415	0.001775
67	-0.315878	0.002207	-0.104252	0.002145	680	-0.347844	0.001837	-0.202284	0.001818
68	-0.315878	0.002207	-0.104252	0.002145	691	-0.267107	0.001904	1.749738	0.001659
90	-0.099920	0.002097	0.879371	0.001845	693	-0.225146	0.001902	0.690730	0.001767
107	-0.514855	0.002472	0.377006	0.002239	694	-0.466949	0.001972	1.284413	0.001760
110	-0.706167	0.002215	-0.687060	0.002211	731	0.229691	0.001901	2.326908	0.001649
111	-0.797881	0.002128	-0.611225	0.002088	740	-0.451948	0.001921	0.518892	0.001802
115	0.248714	0.002143	0.118241	0.002168	741	-0.451948	0.001921	0.518892	0.001802
121	-0.944222	0.002265	-0.443190	0.002165	762	-0.547200	0.001948	-0.607326	0.001957
123	-0.013552	0.002453	0.870587	0.002205	802	-0.376980	0.001948	0.148434	0.001880
126	-0.470660	0.002194	-0.379670	0.002171	804	-0.279035	0.001894	0.248363	0.001823
128	-0.632942	0.002177	-0.279600	0.002093	806	-0.225632	0.001917	0.003343	0.001887
129	-0.040964	0.002011	0.604023	0.001857	808	-0.316577	0.001817	-0.085426	0.001783
131	-0.819681	0.002140	-0.658316	0.002107	812	-0.316577	0.001817	-0.085426	0.001783
132	-0.284955	0.002264	0.333364	0.002118	813	0.046929	0.001950	1.212451	0.001791
221	0.241431	0.002047	1.757944	0.001752	817	-0.279035	0.001894	0.248363	0.001823
222	-0.296106	0.002037	1.044195	0.001712	820	-0.351135	0.002014	0.846919	0.001840
241	-0.099920	0.002097	0.879371	0.001845	822	-0.279035	0.001894	0.248363	0.001823
260	-0.259181	0.001808	-0.216081	0.001798	823	-0.279035	0.001894	0.248363	0.001823
311	-0.347844	0.001837	-0.202284	0.001818	825	0.343571	0.001822	0.376354	0.001818
313	-0.451948	0.001921	0.518892	0.001802	826	-0.279035	0.001894	0.248363	0.001823
316	-0.104018	0.001850	0.680247	0.001742	827	-0.265687	0.001986	1.195722	0.001795
317	-0.451948	0.001921	0.518892	0.001802	830	-0.279035	0.001894	0.248363	0.001823
318	-0.052827	0.001891	0.352087	0.001838	831	-0.383480	0.001893	-0.460755	0.001904
330	-0.439762	0.001940	0.218924	0.001833	832	-0.377981	0.001859	-0.069945	0.001818
370	0.371605	0.001773	0.543581	0.001751	833	-0.095806	0.001889	0.793996	0.001779
371	0.998628	0.001765	0.169526	0.001893	834	-0.279035	0.001894	0.248363	0.001823
400	-0.665929	0.001868	-0.793179	0.001884	835	-0.361464	0.001892	0.301286	0.001791
460	-0.193680	0.001770	0.500522	0.001670	837	-0.513128	0.001775	-0.515373	0.001775
491	-0.347844	0.001837	-0.202284	0.001818	838	0.459129	0.001560	0.344387	0.001580
521	-0.402944	0.001931	-1.173042	0.002028	899	-0.183950	0.001841	-0.035319	0.001807
531	-0.398996	0.002026	1.468854	0.001765	824	-0.183950	0.001841	-0.035319	0.001807
540	-0.392822	0.001921	0.172701	0.001851	840	-0.183950	0.001841	-0.035319	0.001807
552	-0.347844	0.001837	-0.202284	0.001818	842	-0.183950	0.001841	-0.035319	0.001807
555	-0.198410	0.001901	0.735415	0.001775	836	-0.183950	0.001841	-0.035319	0.001807
580	-0.451948	0.001921	0.518892	0.001802	901	-0.206213	0.001592	0.603856	0.001483
591	-0.172555	0.002151	0.762909	0.001965	920	-0.451948	0.001921	0.518892	0.001802
601	-0.451948	0.001921	0.518892	0.001802	950	0.198966	0.001860	0.034400	0.001882
602	-0.033805	0.001656	0.421890	0.001596	970	-0.155066	0.001828	-0.316500	0.001851
611	-0.936122	0.001991	-0.629168	0.001955	999	-0.378830	0.001855	0.823520	0.001630
621	-0.553182	0.001922	0.485232	0.001807					

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; C1 = coefficient to compute pole cubic-foot volume from stump to 4-inch top; C2 = coefficient to compute pole cubic-foot volume from stump to 4-inch top; D1 = coefficient to compute sawtimber cubic-foot volume from stump to 4-inch top; D2 = coefficient to compute sawtimber cubic-foot volume from stump to 4-inch top.

Table A.5—Species code equation and associated coefficients for use in SRS FIA total cubic-foot volume equations for poles and sawtimber (use equation form CU000068)

	Coefficients					Coefficients			
	Pole		Sawtimber			Pole		Sawtimber	
SPCD_EQ	E1	E2	F1	F2	SPCD_EQ	E1	E2	F1	F2
10	1.146541	2.146242	1.146541	2.146242	651	1.158363	2.382274	1.158363	2.382274
43	1.152171	1.259555	1.152171	1.259555	652	1.158363	2.382274	1.158363	2.382274
60	1.176439	2.550195	1.176439	2.550195	653	1.166687	2.242538	1.166687	2.242538
67	1.176439	2.550195	1.176439	2.550195	680	1.186636	2.417775	1.186636	2.417775
68	1.176439	2.550195	1.176439	2.550195	691	1.264347	1.821700	1.264347	1.821700
90	1.146541	2.146242	1.146541	2.146242	693	1.156640	2.035818	1.156640	2.035818
107	1.112564	2.775872	1.112564	2.775872	694	1.187896	2.444066	1.187896	2.444066
110	1.113788	2.208955	1.113788	2.208955	731	1.150504	1.590116	1.150504	1.590116
111	1.109247	2.429713	1.109247	2.429713	740	1.145017	2.255001	1.145017	2.255001
115	1.116228	2.142989	1.116228	2.142989	741	1.145017	2.255001	1.145017	2.255001
121	1.107343	2.384360	1.107343	2.384360	762	1.164183	1.513173	1.164183	1.513173
123	1.127272	1.123936	1.127272	1.123936	802	1.223605	2.051445	1.223605	2.051445
126	1.139310	1.300282	1.139310	1.300282	804	1.218003	2.181659	1.218003	2.181659
128	1.125409	1.877110	1.125409	1.877110	806	1.216303	1.553713	1.216303	1.553713
129	1.145631	1.610693	1.145631	1.610693	808	1.206835	3.453587	1.206835	3.453587
131	1.111780	2.473630	1.111780	2.473630	812	1.206835	3.453587	1.206835	3.453587
132	1.134089	1.531460	1.134089	1.531460	813	1.223374	1.367666	1.223374	1.367666
221	1.188594	2.394869	1.188594	2.394869	817	1.218003	2.181659	1.218003	2.181659
222	1.237591	3.561137	1.237591	3.561137	820	1.237288	2.395208	1.237288	2.395208
241	1.146541	2.146242	1.146541	2.146242	822	1.218003	2.181659	1.218003	2.181659
260	1.131783	2.320512	1.131783	2.320512	823	1.218003	2.181659	1.218003	2.181659
311	1.186636	2.417775	1.186636	2.417775	825	1.237249	1.578554	1.237249	1.578554
313	1.145017	2.255001	1.145017	2.255001	826	1.218003	2.181659	1.218003	2.181659
316	1.179791	1.882807	1.179791	1.882807	827	1.224892	2.664642	1.224892	2.664642
317	1.145017	2.255001	1.145017	2.255001	830	1.218003	2.181659	1.218003	2.181659
318	1.190063	1.712613	1.190063	1.712613	831	1.202078	3.487957	1.202078	3.487957
330	1.172535	1.535447	1.172535	1.535447	832	1.205365	1.671724	1.205365	1.671724
370	1.216170	1.355783	1.216170	1.355783	833	1.224449	1.277306	1.224449	1.277306
371	1.212153	1.359713	1.212153	1.359713	834	1.218003	2.181659	1.218003	2.181659
400	1.189261	3.074669	1.189261	3.074669	835	1.237511	2.241176	1.237511	2.241176
460	1.188803	1.641479	1.188803	1.641479	837	1.214240	2.375921	1.214240	2.375921
491	1.186636	2.417775	1.186636	2.417775	838	1.193954	4.298451	1.193954	4.298451
521	1.214404	1.834798	1.214404	1.834798	899	1.218003	2.181659	1.218003	2.181659
531	1.219447	2.401295	1.219447	2.401295	824	1.218003	2.181659	1.218003	2.181659
540	1.128655	2.349280	1.128655	2.349280	840	1.218003	2.181659	1.218003	2.181659
552	1.186636	2.417775	1.186636	2.417775	842	1.218003	2.181659	1.218003	2.181659
555	1.152686	2.649964	1.152686	2.649964	836	1.218003	2.181659	1.218003	2.181659
580	1.145017	2.255001	1.145017	2.255001	901	1.194258	1.609426	1.194258	1.609426
591	1.203433	1.865955	1.203433	1.865955	920	1.145017	2.255001	1.145017	2.255001
601	1.145017	2.255001	1.145017	2.255001	950	1.135107	1.257835	1.135107	1.257835
602	1.173659	1.863595	1.173659	1.863595	970	1.159555	2.270106	1.159555	2.270106
611	1.122118	2.802714	1.122118	2.802714	999	1.218003	2.181659	1.218003	2.181659
621	1.115123	1.788864	1.115123	1.788864					

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; E1 = coefficient to convert poles from CV4 (cubic volume to a 4-inch top) to total stem; E2 = coefficient to convert poles from CV4 (cubic volume to a 4-inch top) to total stem; F1 = coefficient to convert sawtimber from CV4 (cubic volume to a 4-inch top) to total stem; F2 = coefficient to convert sawtimber from CV4 (cubic volume to a 4-inch top) to total stem.

Table A.6—Species code equation and associated coefficients for use in SRS FIA total cubic-foot volume equations for planted poles and planted sawtimber (use equation form CU000068)

	Coefficients	
SPCD_EQ	G1	G2
111	1.081908	2.607333
131	1.081556	3.659920

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; G1 = coefficient to convert plantation trees from CV4 (cubic volume to a 4-inch top) to total stem; G2 = coefficient to convert plantation trees from CV4 (cubic volume to a 4-inch top) to total stem.

Table A.7—Species code equation and associated coefficients for use in SRS FIA equation to convert cubic-foot volume to a 4-inch top to cubic-foot volume of the saw-log portion (use equation form CU000069)

	Coefficients			Coefficients	
SPCD_EQ	H1	H2	SPCD_EQ	H1	H2
10	0.987226	-4.396825	651	1.016073	-15.025004
43	1.006045	-4.962611	652	1.016073	-15.025004
60	0.987563	-4.027958	653	1.005781	-14.518615
67	0.987563	-4.027958	680	0.970888	-12.114880
68	0.987563	-4.027958	691	0.973498	-12.868316
90	0.987226	-4.396825	693	0.967984	-13.248708
107	1.005598	-4.595382	694	0.975950	-12.390384
110	1.017129	-5.035009	731	0.977294	-16.118257
111	1.018317	-5.202751	740	0.993648	-14.095485
115	1.012739	-5.021693	741	0.993648	-14.095485
121	1.007357	-4.383530	762	0.967082	-11.074226
123	1.019967	-3.831951	802	0.984900	-12.754068
126	0.990799	-4.465552	804	0.970577	-11.942936
128	1.015474	-4.750206	806	0.985882	-12.214161
129	0.985634	-4.484123	808	1.004199	-14.775319
131	1.018534	-5.661877	812	1.004199	-14.775319
132	0.988876	-4.339684	813	1.011594	-16.475117
221	0.976887	-6.372196	817	0.970577	-11.942936
222	0.982780	-4.980440	820	0.962858	-10.854013
241	0.987226	-4.396825	822	0.970577	-11.942936
260	0.979075	-4.860084	823	0.970577	-11.942936
311	0.970888	-12.114880	825	1.022046	-16.551048
313	0.993648	-14.095485	826	0.970577	-11.942936
316	0.957247	-12.838405	827	0.951738	-10.055145
317	0.993648	-14.095485	830	0.970577	-11.942936
318	0.986670	-13.285690	831	0.976525	-12.140112
330	0.993648	-14.095485	832	0.968616	-11.614055
370	0.990427	-14.816790	833	0.925404	-10.109039
371	0.970888	-12.114880	834	0.970577	-11.942936
400	0.975054	-11.967499	835	0.981927	-11.738632
460	0.884844	-10.966955	837	0.973573	-13.391067
491	0.970888	-12.114880	838	0.956531	-10.588513
521	1.017439	-13.174563	899	0.970577	-11.942936
531	0.939240	-10.377629	824	0.970577	-11.942936
540	0.990354	-13.866570	840	0.970577	-11.942936
552	0.970888	-12.114880	842	0.970577	-11.942936
555	1.016073	-15.025004	836	0.970577	-11.942936
580	0.993648	-14.095485	901	0.920003	-9.999206
591	0.970888	-12.114880	920	0.993648	-14.095485
601	0.993648	-14.095485	950	0.977669	-12.161698
602	0.939211	-10.789604	970	0.944758	-11.243663
611	1.013706	-14.690715	999	0.970577	-11.942936
621	1.015683	-15.253771			

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; H1 = coefficient to convert CV4 (cubic volume to a 4-inch top) to CUSAW (cubic saw-log volume); H2 = coefficient to convert CV4 (cubic volume to a 4-inch top) to CUSAW (cubic saw-log volume).

Table A.8—Species code equation and associated coefficients for use in SRS FIA equation to convert cubic-foot volume to a 4-inch top to board-foot volume (use equation form BD000049)

	Coefficients			Coefficients	
SPCD_EQ	I1	I2	SPCD_EQ	I1	I2
10	-32.968494	40.900754	651	-43.831114	51.473501
43	-36.443637	44.723860	652	-43.831114	51.473501
60	-31.928229	40.082406	653	-32.151472	38.751286
67	-31.928229	40.082406	680	-33.469593	40.320487
68	-31.928229	40.082406	691	-62.218744	70.635109
90	-32.968494	40.900754	693	-42.670508	50.056472
107	-39.657770	48.447531	694	-45.206541	53.020202
110	-40.778119	49.493703	731	-45.419797	53.050199
111	-44.573295	53.682127	740	-46.585716	54.641538
115	-30.697896	38.676749	741	-46.585716	54.641538
121	-37.533739	46.221683	762	-46.585716	54.641538
123	-36.169514	44.588514	802	-40.853917	48.314853
126	-47.178011	56.153368	804	-39.207446	46.599115
128	-39.081750	47.663171	806	-41.609919	49.261334
129	-38.021863	46.299422	808	-39.405006	46.869861
131	-45.233296	54.320184	812	-39.405006	46.869861
132	-30.487486	37.943803	813	-57.253809	66.161822
221	-39.852794	47.638868	817	-39.207446	46.599115
222	-37.780331	45.512476	820	-39.258381	46.972932
241	-32.968494	40.900754	822	-39.207446	46.599115
260	-35.837266	43.682868	823	-39.207446	46.599115
311	-33.469593	40.320487	825	-52.928852	61.522970
313	-46.585716	54.641538	826	-39.207446	46.599115
316	-37.873060	44.918110	827	-33.821051	41.219217
317	-46.585716	54.641538	830	-39.207446	46.599115
318	-23.292189	29.478650	831	-46.836658	55.060205
330	-46.585716	54.641538	832	-37.716845	44.770685
370	-23.210675	29.141604	833	-34.016058	40.773236
371	-33.469593	40.320487	834	-39.207446	46.599115
400	-43.385922	51.122382	835	-41.637640	49.438943
460	-46.585716	54.641538	837	-42.235900	49.659282
491	-33.469593	40.320487	838	-32.557196	39.284646
521	-33.469593	40.320487	899	-39.207446	46.599115
531	-7.036861	11.665187	824	-39.207446	46.599115
540	-44.046785	51.632536	840	-39.207446	46.599115
552	-33.469593	40.320487	842	-39.207446	46.599115
555	-43.831114	51.473501	836	-39.207446	46.599115
580	-46.585716	54.641538	901	-7.456203	11.992934
591	-33.469593	40.320487	920	-46.585716	54.641538
601	-46.585716	54.641538	950	-37.777411	44.944982
602	-16.280751	21.457858	970	-33.168491	39.961348
611	-50.712592	59.264535	999	-39.207446	46.599115
621	-54.639851	63.549737			

SRS FIA = Southern Research Station, Forest Inventory and Analysis; SPCD_EQ = species code equation; I1 = coefficient to convert CV4 (cubic volume to a 4-inch top) to board foot; I2 = coefficient to convert CV4 (cubic volume to a 4-inch top) to board foot.

Examples

We present three examples for using the Southern FIA Volume Equations User's Guide:

Example 1) Volume of interest—VOLCFGRS
Species—white oak
Diameter—18 inches
Height—78 feet
Defect—3 percent

Step 1—Use table 1 and figure 1 to identify the volume variable of interest. For example 1, we will use VOLCFGRS.

Step 2—From table A.1., locate the species equation code (SPCD_EQ) that corresponds to white oak (SPCD_EQ = 802).

Step 3—Use table 2 to identify the ultimate equation necessary for calculating the desired volume—Equation = CU000067

Step 4—Use tree size specifications to identify the necessary set of coefficients. The example tree is a hardwood species with a d.b.h. > 11 inches, and is therefore a sawtimber tree—Coefficients set = D1 and D2.

Step 5—Use the Guide to Coefficients Tables to identify the individual coefficients for plugging into the appropriate equation—Coefficients table = table A.4.

Step 6—Pull individual coefficients from table A.4 for SPCD_EQ code 802—Coefficients = 0.148434 (D1) and 0.00188 (D2).

Step 7—Use equation CU000067 along with d.b.h., HT, and coefficients D1 and D2 to calculate cubic-foot volume from a 1-foot stump to a 4-inch top.

$$\textit{Sawtimber Cubic Volume} = 0.148434 + 0.00188 * (18^2 * 78)$$

$$\textit{Sawtimber Cubic Volume} = 47.70$$

Example tree 1 has a total of **47.70 gross cubic feet**.

Example 2) Volume of interest—VOLBFNET
Species—loblolly pine
Diameter—10 inches
Height—48 feet
Defect—2 percent

Step 1—Use table 1 and figure 1 to identify the volume variable of interest. For example 2, we will use VOLBFNET.

Step 2—From table A.1, locate the species equation code (SPCD_EQ) that corresponds to loblolly pine (SPCD_EQ = 131).

Step 3—Use table 2 to identify the ultimate equation necessary for calculating the desired volume—Equation = BD000049*

> ***Note—**Equation BD000049 calculates a conversion ratio that is applied to cubic-foot volume calculated with equation CU000067 to calculate board-foot volume.

Step 4—Use tree size specifications to identify the necessary set of coefficients. The example tree is a softwood species with a d.b.h. > 9 inches, and is therefore a sawtimber tree—Coefficients set = D1, D2, I1, and I2.

Step 5—Use the Guide to Coefficients Tables to identify the individual coefficients for plugging into the appropriate equation—Coefficients table = tables A.4 and A.8.

Step 6—Pull individual coefficients from table A.4 for SPCD_EQ code 131 for equation CU000067—Coefficients = –0.658316 (D1) and 0.002107 (D2) and table A.8 for SPCD_EQ code 131 for equation BD000049—Coefficients = –45.233296 (I1) and 54.320184 (I2).

Step 7—Use equation CU000067 along with d.b.h., HT, and coefficients D1 and D2 to calculate cubic-foot volume from a 1-foot stump to a 4-inch top.

$$\textit{Sawtimber Cubic Volume} = -0.658316 + 0.002107 * (10^2 * 48)$$

So,

$$\textit{Sawtimber Cubic Volume} = 9.46$$

Step 8—Use equation BD000049 along with d.b.h. and coefficients I1 and I2 to calculate board-foot volume from a 1-foot stump to a 4-inch top.

$$R = -45.233296 + 54.320184 * \left(1 - \frac{1}{10}\right)$$

So,

$$R = 3.65$$

Step 9—Multiply the sawtimber cubic volume from step 7 by the conversion factor in step 8.

$$\textit{Board-foot volume} = 9.46 * 3.65$$

$$\textit{Board-foot volume} = 34.58$$

$$\textit{VOLBFGRS} = 34.58$$

Step 10—The example tree was recorded as having a total defect of 2 percent. Therefore, use the cubic-foot cull defect equation to deduct for missing and/or rotten material.

$$\textit{VOLBFNET} = 34.58 - \left(34.58 * \frac{2.0}{100}\right)$$

$$\textit{VOLBFNET} = 33.89$$

Example tree 2 has a total of **33.89 board feet**.

Example 3) Volume of interest—VOLCFGRS
Species—Emory oak
Diameter—20 inches (d.r.c.)
Height—35 feet
Defect—not applicable

Step 1—Use table 1 and figure 1 to identify the volume variable of interest. For example 1, we will use VOLCFGRS.

Step 2—From table A.1, locate the species equation code (SPCD_EQ) that corresponds to Emory oak (SPCD_EQ = 810).

> ***Note—**Table A.1 provides a citation (Chojnacky 1988) instead of a species equation code. In some cases, particularly tree species collected in western Texas, SRS FIA utilizes volume equations developed outside of the southern region. When applicable, table A.1 provides the citation for the publication where the appropriate volume equation(s) can be found.

Step 3—Use the citation provided to locate the appropriate equation. In this case Chojnacky (1988) provides the following equation for single-stem oaks:

$$\textit{Gross Cubic – foot Volume} = 6.571 + (2.4048 * X) - \left(\frac{17.704}{X}\right)$$

where

$$X = \left(\frac{DRC^2}{1000}\right)$$

Example tree 3 has a total of **38.97 gross cubic feet**.

> ***Note—**Chojnacky (1988) states that gross cubic volume includes all wood and bark of all stems and branches > 1.5 inches.

Oswalt, Christopher M.; Conner, Roger C. 2011. Southern forest inventory and analysis volume equation user's guide. Gen. Tech. Rep. SRS–138. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 22 p.

Reliable volume estimation procedures are fundamental to the mission of the Forest Inventory and Analysis (FIA) program. Moreover, public access to FIA program procedures is imperative. Here we present the volume estimation procedures used by the southern FIA program of the U.S. Department of Agriculture Forest Service Southern Research Station. The guide presented includes a description of the relevant variables populated in the public FIA database, a description of the set of equations used to estimate tree volume in the south, the volume equations, definition of terms, species-specific (or species group) coefficients for each equation, and examples of estimating individual tree volume.

Keywords: Biomass, FIA, volume, volume equation, volume estimation.

The Forest Service, U.S. Department of Agriculture (USDA), is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.