Appendix J. Biomass Estimation in the FIADB

In previous versions of the FIADB, a variety of regional methods were used to estimate tree biomass for live and dead trees in the TREE table. In FIADB 4.0, a new nationally consistent method of estimating tree biomass has been implemented. This new approach, called the component ratio method (CRM) (Heath and others 2009), involves calculating the dry weight of individual components before estimating the total aboveground or belowground biomass. The CRM approach is based on:

- converting the sound volume of wood (VOLCFSND) in the merchantable bole to biomass using a compiled set of wood specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of bark on the merchantable bole using a compiled set of percent bark estimates and bark specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of the entire tree (total aboveground biomass), merchantable bole outside bark, and belowground biomass using equations from Jenkins and others (2003)
- calculating the volume of the stump (wood and bark) based on equations in Raile (1982) and converting this to biomass using the same specific gravities used for the bole wood and bark
- calculating the top biomass (tree tip and all branches) by subtracting all other biomass components from the total aboveground estimate
- calculating an adjustment factor by developing a ratio between bole biomass from VOLCFSND to bole biomass from Jenkins and others (2003)
- applying the adjustment factor to all tree components derived from both Jenkins and Raile

The CRM approach is based on assumptions that the definition of merchantable bole in the volume prediction equations is equivalent to the bole (stem wood) in Jenkins and others (2003), and that the component ratios accurately apply.

The tables in this appendix describe the equations used in FIADB 4.0 to estimate components of tree biomass, including stem wood (bole), top and branches combined, bark, stump, and coarse roots. Most of these components are estimated through a series of ratio equations as described by Jenkins and others (2003). Stem wood biomass is calculated directly from the sound cubic-foot volume of the tree bole, percentage of bark on the bole, and specific gravities of both wood and bark.

Note that component equations are not available for woodland tree species or for saplings because saplings have no volume in FIADB. Because of this, only total aboveground biomass is estimated for saplings (trees from 1 to 4.9 inches in diameter) and woodland species [trees where diameter is measured at the root collar (DRC)]. The individual component biomass values for bole, top, and stump are not available in FIADB. Volume equations for woodland species include all wood and bark from ground to tip. When

converted to biomass, the result is total aboveground biomass excluding foliage for these species. Belowground biomass is estimated for all trees greater than or equal to 1 inch.

Definitions of each biomass component and the equations used to estimate the ovendry weight in pounds are shown in appendix tables J-1 through J-5.

- Appendix table J-1 defines the columns that are stored in the TREE table, and clarifies the set of trees (species, dimensions, live or dead, etc) that are used in each calculation.

- Appendix table J-2 defines the Jenkins component equations and explains how the equation results are used to estimate biomass. The 'Estimate name' in this table is the same name found in the coefficient definitions described in the biomass-related columns 38 to 49 of the REF_SPECIES table.

- Appendix table J-3 contains the Jenkins equations used to estimate each biomass component. The equations use the exact coefficient column names found in the REF_SPECIES table (for example, JENKINS_TOTAL_B1 in appendix table J-3 is the column name in REF_SPECIES that holds the value of the coefficient needed in the total aboveground biomass equation). The Jenkins equations use the measured tree diameter to produce an estimate.

- Appendix table J-4 contains the actual equations used in the FIADB to estimate the biomass components stored in the TREE table. These equations are a blend of Jenkins ratios, calculated bole biomass (based on calculated volume from the TREE table), and adjustment factors. The adjustment factor is an important step because it relates measurement-based bole biomass (DRYBIO_BOLE) to generalized equation-based bole biomass to improve or adjust the computed results of the Jenkins equations.

- Appendix table J-5 contains equations that show the approach described by Heath and others (2009), where the proportion of the biomass component relative to stem volume is calculated first, and then is applied to DRYBIO_BOLE to develop the final estimate in pounds.

For more information please consult the publication by Heath and others (2009), titled *Investigation into calculating tree biomass and carbon in the FIADB using a biomass expansion factor approach*.

Appendix table J-1. Definition of Biomass Components stored in the TREE table

Component	**Column name**	**Biomass Component Definition (all are ovendry biomass, pounds)**
Merchantable stem (bole)	DRYBIO_BOLE	Merchantable bole of the tree, includes stem wood and bark, from a 1-foot stump to a 4-inch top diameter outside bark (DOB). Based on VOLCFSND and specific gravity for the species. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees. (note that VOLCFGRS or VOLCFNET might be used after adjustment based on national averages, if VOLCFSND is not available)
Top	DRYBIO_TOP	Top of the tree above 4 inches DOB and all branches; includes wood and bark and excludes foliage. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees.
Stump	DRYBIO_STUMP	Stump of the tree, the portion of a tree bole from ground to 1 foot high, includes wood and bark. For timber species with a DIA $\geq$ 5 inches DBH. Includes live and dead trees.
Belowground	DRYBIO_BG	Coarse roots of trees and saplings with a DIA $\geq$ 1 inch DBH or DRC. Includes timber and woodland species, and live and dead trees.
Saplings	DRYBIO_SAPLING	Total aboveground portion of live trees, excluding foliage. For timber species with a DIA $\geq$ 1 inch and less than 5 inches DBH.
Woodland tree species	DRYBIO_WDLD_SPP	Total aboveground portion of tree, excluding foliage. For woodland species with a DIA $\geq$ 1 inch DRC. Includes live and dead trees. Woodland species can be identified by REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, or TREE.WDLDSTEM > 0

Appendix table J-2. Jenkins Biomass Component Equation Definitions
(Refer to the REF_SPECIES table for equation coefficients and adjustment factors)

Component	**Estimate name**	**Definition**
Total aboveground biomass	total_AG_biomass_ Jenkins	Total biomass of the aboveground portion of a tree. Includes stem wood, stump, bark, top, branches, and foliage. (ovendry biomass, pounds)
Stem wood biomass ratio	stem_ratio	A ratio that estimates biomass of the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins. Includes wood only. This is the portion of the tree from a 1-foot stump to a 4-inch top DOB.
Stem bark biomass ratio	bark_ratio	A ratio that estimates biomass of the bark on the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Foliage biomass ratio	foliage_ratio	A ratio that estimates biomass of the foliage on the entire tree, by applying the ratio to total_AG_biomass_Jenkins.
Coarse root biomass ratio	root_ratio	A ratio that estimates biomass of the belowground portion of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Stump biomass	stump_biomass	An estimate of the stump biomass of a tree, from the ground to 1 foot high. Uses a series of equations that estimate first the diameter inside and outside bark, followed by volume inside and outside bark developed by Raile (1982). Wood and bark volumes are converted to biomass using specific gravity for the species.
Sapling biomass adjustment	JENKINS_SAPLING _ADJUSTMENT	An adjustment factor that is used to estimate sapling biomass for the tree, by applying the factor to the total aboveground estimate excluding foliage. The adjustment factor was computed as a national average ratio of the DRYBIOT (total dry biomass) divided by the Jenkins total biomass for all 5.0-inch trees, which is the size at which biomass based on volume begins.

Appendix table J-3. Jenkins Biomass Equations (Actual B1 and B2 coefficients and adjustment factors are stored in the REF_SPECIES table.) Note: these equations are used in appendix table J-4 to estimate the biomass components stored in the TREE table.

Component	**Equation**
total_AG_biomass_Jenkins (pounds) (total aboveground biomass, includes wood and bark for stump, bole, top, branches, and foliage)	= exp(JENKINS_TOTAL_B1 + JENKINS_TOTAL_B2 * ln(DIA*2.54)) * 2.2046
stem_ratio	= exp(JENKINS_STEM_WOOD_RATIO_B1 + JENKINS_STEM_WOOD_RATIO_B2 / (DIA*2.54))
bark_ratio	= exp(JENKINS_STEM_BARK_RATIO_B1 + JENKINS_STEM_BARK_RATIO_B2 / (DIA*2.54))
foliage_ratio	= exp(JENKINS_FOLIAGE_RATIO_B1 + JENKINS_FOLIAGE_RATIO_B2 / (DIA*2.54))
root_ratio	= exp(JENKINS_ROOT_RATIO_B1 + JENKINS_ROOT_RATIO_B2 / (DIA*2.54))
stem_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * stem_ratio
bark_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * bark_ratio
bole_biomass_Jenkins (pounds)	= stem_biomass_Jenkins + bark_ biomass_Jenkins
foliage_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * foliage_ratio
root_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * root_ratio
stump_biomass (pounds)	Volumes of wood and bark are based on diameter inside bark (DIB) and DOB equations from Raile, 1982. DIB = (DIA * RAILE_STUMP_DIB_B1) + (DIA * RAILE_STUMP_DIB_B2 * (4.5-HT) / (HT+1)) DOB = DIA + (DIA * RAILE_STUMP_DOB_B1 * (4.5-HT) / (HT+1)) Volume is estimated for 0.1ft (HT) slices from ground to 1 foot high (HT), and summed to compute stump volume. Bark_volume = Volume_outside_bark – Volume_inside_bark Bark and wood volumes are multiplied by their respective specific gravities and added together to estimate biomass
top biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins – stem_biomass – bark_biomass – foliage_biomass – stump_biomass

Appendix table J-4. Equations used to calculate Biomass Components stored in the TREE table

Column name	Equation (refer to Appendix J-3 for details on variables found in equations below)
	AdjFac = DRYBIO_BOLE / bole_biomass_Jenkins **AdjFac_woodland** = DRYBIO_BOLE / (total_AG_biomass_Jenkins – foliage_biomass_Jenkins)
DRYBIO_BOLE (wood and bark) (see note below)	VOLUME = VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound) = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + (VOLUME * (WOOD_SPGR_GREENVOL_DRYWT * 62.4)) Note: For woodland species, volume equations produce volume outside bark, from ground to tip including branches, therefore DRYBIO_BOLE is the biomass from ground to tip. Wood and bark volumes need to be estimated before converting to biomass as follows: = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + ((VOLUME – (VOLUME * (BARK_VOL_PCT/100.0))) * (WOOD_SPGR_GREENVOL_DRYWT * 62.4))
DRYBIO_TOP	= top_biomass_Jenkins * **AdjFac**
DRYBIO_STUMP	= stump_biomass * **AdjFac**
DRYBIO_SAPLING	= (total_AG_biomass_Jenkins – foliage_biomass_Jenkins) * JENKINS_SAPLING_ADJUSTMENT
DRYBIO_WDLD_SPP	= DRYBIO_BOLE (trees>= 5 inches DIA_) = DRYBIO_SAPLING (trees < 5 inches DIA) For tree species where REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, and/or TREE.WDLDSTEM > 0 Note: volume equations produce volume from ground to tip, including branches; DRYBIO_BOLE is the biomass of all wood from ground to tip
DRYBIO_BG	= root_biomass_Jenkins * **AdjFac** (for timber spp >= 5 inches DIA) = root_biomass_Jenkins * **AdjFac_woodland** (for woodland spp >= 5 inches DIA) = root_biomass_Jenkins * JENKINS_SAPLING_ADJUSTMENT (for all trees < 5 inches DIA)
Note: If DIA >= 5.0 and VOLCFSND > 0 then VOLUME = VOLCFSND If DIA >= 5.0 and VOLCFSND = (0 or null) and VOLCFGRS > 0 then VOLUME = VOLCFGRS * Percent Sound If DIA >= 5.0 and VOLCFSND and VOLCFGRS = (0 or null) then VOLUME = VOLCFNET * (Ratio of cubic foot sound to cubic foot net vol)	

Appendix table J-5. Alternative method to calculate Biomass Components, following Heath and others, 2009

Component	**Equation**
DRYBIO_BOLE (wood and bark)	VOLUME = VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound) = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + (VOLUME * (WOOD_SPGR_GREENVOL_DRYWT * 62.4))
TOP_proportion	= top_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_TOP	= TOP_proportion * DRYBIO_BOLE
STUMP_proportion	= stump_biomass / bole_biomass_ Jenkins
DRYBIO_STUMP	= STUMP_proportion * DRYBIO_BOLE
BG_proportion	= root_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_BG	= BG_proportion * DRYBIO_BOLE
BARK_proportion	= bark_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_BARK	= BARK_proportion * DRYBIO_BOLE