A Comprehensive Database of Diameter-Based Biomass Regressions for North American Tree Species*

***available online at http://www.fs.fed.us/ne/global/ or http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/pdfs/2004/ne_gtr319.pdf**

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ABSTRACT

Estimates of national-scale forest carbon (C) stocks and fluxes are typically based on allometric regression equations developed using dimensional analysis techniques. However, the published literature can be inconsistent and incomplete with respect to large-scale forest C estimation and few off-the-shelf sources have been available for comprehensive, large-scale allometric estimation of tree biomass. In this project, we used primary sources whenever possible to **compile all available (2600+) diameter-based allometric regression equations for estimating total aboveground and component biomass, defined in dry weight terms, for trees found in the United States.** The database includes information on the numbers of trees sampled to develop each equation, the maximum and minimum dbh values over which the equation is valid, regression statistics as published by the original authors, and other information valuable for users of the equations. The compilation is published as a database and is available in both paper and electronic (pdf and spreadsheet) format (Jenkins, JC, DC Chojnacky, LS Heath, and RA Birdsey. 2004. Comprehensive Database of Diameter-based Biomass Regressions for United States Tree Species. Gen. Tech. Rep. NE-319. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. Also available at http://www.fs.fed.us/ne/global/). This database is the underlying source of material for our 2003 paper entitled "Consistent National-Scale Biomass Estimators for United States Tree Species" (Forest Science 49(1): 12-35). In addition to its value as a source for our generalized national-scale equations, we envision this database as a user-friendly and comprehensive resource for researchers and practitioners interested in quantifying standing stocks of biomass based on forest mensuration data.

Biomass components

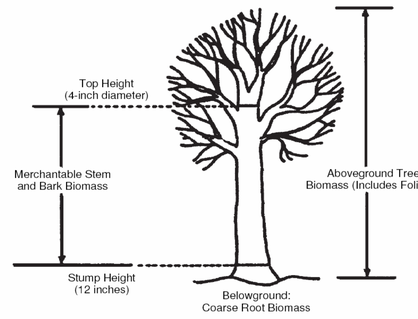


Figure 1.—Tree component biomass definitions.

Table 5.—Tree component key

Component description	Component abbreviation*	Component ID
Complete tree (above + belowground)	BTT	1
Whole tree (aboveground)	BAT	2
Whole tree (above stump)		3
Stem (wood only)	BSW	4
Stem (bark only)	BSB	5
Stem (wood + bark)	BST	6
Stem top		7
Branches live	BBL	8
Branches live < 2.5 cm	BBL_1	9
Branches live 2.5-7.6 cm	BBL_2	10
Branches live > 7.6 cm	BBL_3	11
Branches dead	BBD	12
Branches total (live + dead)	BBT	13
Stem + branches (bark only)		14
Stem + branches (wood only)		15
Stem + branches (live)	BAP	16
Wood, bark, branches (live + dead; no twigs or foliage)	BAE	17
Foliage total	BFT	18
Foliage new	BFN	19
Foliage old	BFO	20
Twigs total	BBG	21
Twigs old	BBG_O	22
Foliage + twigs	BFG	23
Crown (branches + foliage + twigs)	BCT	24
Roots, coarse > 3 mm dia	BKL	25
Coarse stump roots	BSR	26
Coarse lateral roots	BLR	27
Fine roots	BFR	28
Roots total	BRT	29
Stump wood		30
Stump bark		31
Stump total		32
Stump + roots		33
Cones		34
Live crown (branches + foliage + twigs)	BCL	35
Dead crown (branches + foliage + twigs)	BCD	36
Small branches	BBS	37

*See BIOPAK compilation in Means et al. (1994).

Species-specific information

Table 4.—Species key, suggested assignments for species groups to apply generalized equations, and specific gravity information (see Appendix A)

FIA ID	Common name	Family	Genus	Species	Species group	Wood specific gravity	Bark specific gravity	Bark specific gravity source	Stump volume equation
#	conifers (general)								
10	fir spp.	Pinaceae	*Abies*	*spp.*	tf	0.367	0.375	94	
11	Pacific silver fir	Pinaceae	*Abies*	*amabilis*	tf	0.4			
12	balsam fir	Pinaceae	*Abies*	*balsamea*	tf	0.34	0.375	94	12
13	silver fir (Himalaya)	Pinaceae	*Abies*	*pindrow*	tf				
14	Bristlecone fir	Pinaceae	*Abies*	*bracteata*	tf				
15	White fir	Pinaceae	*Abies*	*concolor*	tf	0.37			
16	Fraser fir	Pinaceae	*Abies*	*fraseri*	tf	0.34	0.4	12	
17	Grand fir	Pinaceae	*Abies*	*grandis*	tf	0.35			
18	Corkbark fir	Pinaceae	*Abies*	*lasiocarpa var. arizonica*	tf	0.28			
19	Subalpine fir	Pinaceae	*Abies*	*lasiocarpa*	tf	0.31			
20	California red fir	Pinaceae	*Abies*	*magnifica*	tf	0.37			
21	Shasta red fir	Pinaceae	*Abies*	*magnifica var. shastensis*	tf	0.37			
22	Noble fir	Pinaceae	*Abies*	*procera*	tf	0.37			
41	Port-Orford-cedar	Pinaceae	*Chamaecyparis*	*lawsoniana*	cl	0.39			
42	Alaska-cedar	Pinaceae	*Chamaecyparis*	*nootkatensis*	cl	0.42			
43	Atlantic white-cedar	Pinaceae	*Chamaecyparis*	*thyoides*	cl	0.31	0.4	241	
50	Cypress	Cupressaceae	*Cupressus*	*spp.*	wo				
51	Arizona cypress	Cupressaceae	*Cupressus*	*arizonica*	wo				
58	Pinchot juniper	Cupressaceae	*Juniperus*	*pinchotii*	wo				
59	Redberry juniper	Cupressaceae	*Juniperus*	*erythrocarpa*	wo				
60	Common juniper	Cupressaceae	*Juniperus*	*communis*	wo	0.44	0.4	94	
60	redcedar	Cupressaceae	*Juniperus*	*spp.*	cl	0.44	0.4	241	
62	California juniper	Cupressaceae	*Juniperus*	*californica*	wo				
63	Alligator juniper	Cupressaceae	*Juniperus*	*deppeana*	wo	0.48			
64	Western juniper	Cupressaceae	*Juniperus*	*occidentalis*	wo				
65	Utah juniper	Cupressaceae	*Juniperus*	*osteosperma*	wo				
66	Rocky Mountain juniper	Cupressaceae	*Juniperus*	*scopulorum*	wo	0.44	0.4	94	
67	southern redcedar	Cupressaceae	*Juniperus*	*silicicola*	cl	0.44	0.4	241	
68	eastern redcedar	Cupressaceae	*Juniperus*	*virginiana*	cl	0.44	0.4	241	
69	Oneseed juniper	Cupressaceae	*Juniperus*	*monosperma*	wo				
70	larch (introduced)	Pinaceae	*Larix*	*spp.*	cl	0.48	0.4	125	
71	tamarack (native)	Pinaceae	*Larix*	*laricina*	cl	0.49	0.4	125	
72	Subalpine larch	Pinaceae	*Larix*	*lyallii*	cl	0.48			
73	Western larch	Pinaceae	*Larix*	*occidentalis*	cl	0.48			
81	Incense-cedar	Cupressaceae	*Calocedrus*	*decurrens*	cl	0.35			
90	spruce	Pinaceae	*Picea*	*spp.*	sp	0.366	0.3	94	
91	Norway spruce	Pinaceae	*Picea*	*abies*	sp	0.38	0.4	94	
92	Brewer spruce	Pinaceae	*Picea*	*breweriana*	sp				
93	Engelmann spruce	Pinaceae	*Picea*	*engelmannii*	sp				
94	white spruce	Pinaceae	*Picea*	*glauca*	sp				
95	black spruce	Pinaceae	*Picea*	*mariana*	sp				
96	blue spruce	Pinaceae	*Picea*	*pungens*	sp				
97	red spruce	Pinaceae	*Picea*	*rubens*	sp				
98	Sitka spruce	Pinaceae	*Picea*	*sitchensis*	sp				

Range in published allometric equations for one species

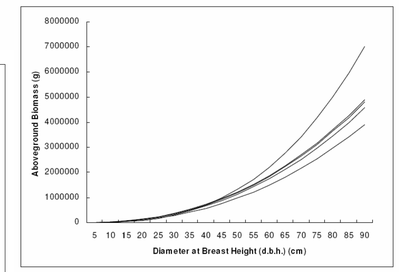


Figure 2.—Total aboveground biomass as predicted from five allometric regression equations for Douglas-fir.

Some key parameters included for users of allometric biomass regressions:

- Corrected for bias (logarithmic equation forms) (Baskerville 1972)
- Stump height and merchantable top diameter
- Sample size and regression statistics
- Geographic origin of sample trees
- Minimum and maximum diameter values of sample trees
- Literature citations for all equations

Equation forms

Table 6.—Equation form key

Equation form description	Equation form ID
log10 biomass = a + b * (log10(dia^c))	1
ln biomass = a + b * dia + c * (ln(dia^d))	2
ln biomass = a + b * ln(dia) + c * (d + (e * ln(dia)))	3
biomass = a + b * dia + c * (dia ^ d)	4
biomass = a + (b * dia) + c * (dia ^ 2) + d * (dia ^ 3)	5
biomass = a * (exp(b + (c * ln(dia)) + (d * dia)))	6
biomass = a + ((b * (dia ^ c))/((dia ^ c) + d))	7
log100 biomass = a + (b * log10(dia))	8
ln biomass = ln(a) + (b * ln(dia))	9

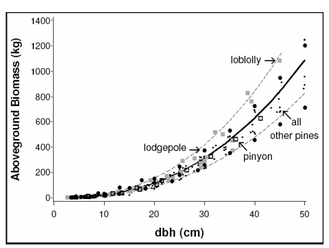
National-scale biomass estimation

National-Scale Biomass Estimators for United States Tree Species

Jennifer C. Jenkins, David C. Chojnacky, Linda S. Heath, and Richard A. Birdsey

ABSTRACT. Estimates of national-scale forest carbon (C) stocks and fluxes are typically based on allometric regression equations developed using dimensional analysis techniques. However, the literature is inconsistent and incomplete with respect to large-scale forest C estimation. We compiled all available diameter-based allometric regression equations for estimating total aboveground and component biomass, defined in dry weight terms, for trees in the United States. We then implemented a modified meta-analysis based on the published equations to develop a set of consistent, national-scale aboveground biomass regression equations for U.S. species. Equations for predicting biomass of tree components were developed as proportions of total aboveground biomass for hardwood and softwood groups. A comparison with recent equations used to develop large-scale biomass estimates from U.S. forest inventory data for eastern U.S. species suggests general agreement (±30%) between biomass estimates. The comparison also shows that differences in equation forms and species groupings may cause differences at small scales depending on tree size and forest species composition. This analysis represents the first major effort to compile and analyze all available biomass literature in a consistent national-scale framework. The equations developed here are used to compute the biomass estimates used by the model FORCARB to develop the U.S. C budget. For. Sci. 49(1):12–35.

Key Words: Allometric equations, forest biomass, forest inventory, global carbon cycle.



Generalized equations for 10 US tree species groups based on published allometric equations

Variability in allometry within species groups

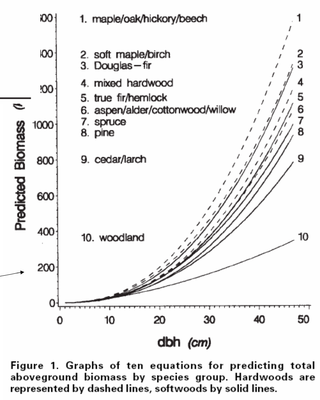


Figure 1. Graphs of ten equations for predicting total aboveground biomass by species group. Hardwoods are represented by dashed lines, softwoods by solid lines.

List of parameters

Table 3.—Equations and parameters for diameter-based biomass equations (first 10 pages only; complete version is available online)

Species	Common name	Component ID	Equation form ID	a	b	c	d	e	Diameter	Corrected for bias	Bias correction (CF)	r	R^2	MinDiameter	MaxDiameter	Sample size	Stump height	Top d.o.b.	Units diameter	Units biomass	Component	Component sum	Ratio equation	Segmented equation	Equation number	Source	Notes
0	eastern conifers	2	7	0.5	15000	2.7	364946		d.b.h.	no	0	0	0.98	1.00	72.00	83	0		cm	kg	na	a			1	140	assume 0-inch stump height, but data from other studies so stump heights are probably mixed: 45 pine, 30 spruce, 10 fir
0	softwoods (general)	3	1	-1.01	2.41	1			d.b.h.	no	0	0	0.99	0.80	34.10	108	6		cm	kg	na				1	51	no stump height; tree data also used for ref 52
0	softwoods (general)	3	4	4.5966	-0.2364	0.00411	2		d.b.h.	no	0	0	0.96	2.50	25.00	131	12		mm	kg	na				1	107	12-inch stump
0	softwoods (general)	6	4	4.142	-0.227	0.003	2		d.b.h.	no	0	0	0.97	12.50	55.00	131	12	0	mm	kg	na				1	107	12-inch stump including entire bole (no branches)
0	softwoods (general)	6	4	-6.221	-0.227	0.003	2		d.b.h.	no	0	0	0.97	12.50	55.00	131	12	4	mm	kg	na				1	107	12-inch stump to 10 cm (4-inch) top
0	softwoods (general)	6	2	-3.787	0	2.767	1		d.b.h.	yes	1.08	0	0.96	1.00	60.00	51	6	0	cm	kg	na	t			1	149	some tree data points may overlap with ref 23 because data sources were from same compilation; assume 6-inch stump; bias correction described as "K"; d.b.h. range estimates from text
0	softwoods (general)	13	2	-3.461	0	2.292	1		d.b.h.	yes	1.26	0	0.95	1.00	60.00	51			cm	kg	na	t			1	149	some tree data points may overlap with ref 23 because data sources were from same compilation; bias correction described as "K"; d.b.h. range estimates from text
0	softwoods (general)	18	4	4.597	-0.236	0.004	2		d.b.h.	no	0	0	0.96	12.50	55.00	131	12	0	mm	kg	na				1	107	12-inch stump aboveground (whole tree including branches and foliage)
0	softwoods (general)	18	2	-2.907	0	1.674	1		d.b.h.	yes	1.34	0	0.91	1.00	60.00	65			cm	kg	na	t			1	149	some tree data points may overlap with ref 23 because data sources were from same compilation; bias correction described as "K"; d.b.h. range estimates from text
10	fir sp.	4	2	-3.7389	0	2.6825	1		d.b.h.	yes	0	0	0.97	8.7	111.0	20	6	0	cm	kg	na				1	55	includes data from published and unpublished sources, as well as original work; coefficients corrected for bias; assume 6-inch stump
10	fir sp.	5	2	-6.1918	0	2.8796	1		d.b.h.	yes	0	0	0.98	8.7	111.0	20	6	0	cm	kg	na				1	55	includes data from published and unpublished sources, as well as original work; coefficients corrected for bias; assume 6-inch stump
10	fir sp.	8	2	-4.8287	0	2.5585	1		d.b.h.	yes	0	0	0.95	8.7	111.0	26			cm	kg	na				1	55	includes data from published and unpublished sources, as well as original work; coefficients corrected for bias
10	fir sp.	18	2	-3.4662	0	1.9287	1		d.b.h.	yes	0	0	0.94	8.7	111.0	25			cm	kg	fl				1	55	equation originally from ref 166; coefficients corrected for bias in ref 55
11	Pacific silver fir	3	4	-2029.05	6775.64	0	0		d.b.h.	no	0	0	0.98	31.00	90.40	7	12		cm	kg	agm	a			1	91	logarithmic equation also presented based on the same data; equations presented here do not require additional variables (additional equations in original reference)
11	Pacific silver fir	1	1	3.779	2.473	0			d.b.h.	no	0	0	0.99	31.00	90.40	7	12		cm	kg	agm				1	91	equations presented here do not require additional variables (additional equations in original reference)
11	Pacific silver fir	4	2	-3.5057	0	2.5744	1		d.b.h.	yes	0	0	0.99	11.7	90.4	14	6	0	cm	kg	na				1	55	includes data from published and unpublished sources, as well as original work; coefficients corrected for bias; assume 6-inch stump
11	Pacific silver fir	4	4	-1467.72	4769.21	0	0		d.b.h.	no	0	0	0.97	31.00	90.40	7	12	1	cm	kg	na				1	91	logarithmic equation also presented based on the same data; equations presented here do not require additional variables (additional equations in original reference)
11	Pacific silver fir	4	1	3.636	2.618	0			d.b.h.	no	0	0	0.99	31.00	90.40	7	12	1	cm	kg	na				1	91	equations presented here do not require additional variables (additional equations in original reference)
														8.1	109.3	143	6	0	cm	Mg	na				1	104	see ref 68 for original bibliographic source; no mention of bias correction; assume 6-inch stump
11	Pacific silver fir	4	1	3.636	2.618	0			d.b.h.	no	0	0	0.99	8.1	109.3	75	6	0	cm	Mg	na				1	104	see ref 68 for original bibliographic source; no mention of bias correction; assume 6-inch stump