Forest Research

Technical Specification for the Biomass Equations Developed for the 2011 Forecast

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Revised Biomass Equations

Existing crown and root biomass equations overestimate the biomass content of larger trees. Revised equations have therefore been prepared for estimating the crown and root biomass, in oven-dry tonnes, of tree species grown in Great Britain. The form of these equations is presented below, together with the species-specific parameters to be used.

Crown biomass equations

Three separate equations have been developed for estimating the biomass contained in tree crowns. All three equations use diameter at breast height (dbh) as the input variable, and the equation used is dictated by the dbh of the tree being assessed. Crown biomass includes the tip, branches, twigs and foliage.

Crown biomass equation for trees with dbh < 7 cm

A tree of less than 7 cm dbh is assumed to contain no merchantable stem volume. The output of the crown biomass equation for trees of less than 7 cm dbh therefore incorporates the biomass, in oven-dry tonnes, contained in the tree stem in addition to the biomass contained in the crown (*i.e.* all above-ground tree biomass).

The format of the equation is:

$$\text{Above-ground biomass}_{(dbh < 7\text{ cm})} = b \times dbh^{p} \qquad \text{Equation 1}$$

where b and p are species-specific parameters, and dbh is diameter at breast height (1.3 m) less than 7 cm.

The values for the species-specific parameters for use in Equation 1 are presented in Table 1.

Table 1: Species/group-specific coefficients for Equation 1, the above-ground biomass equation for trees less than 7 cm dbh.

Species / species group	*b*	*p*
larches	0.0002855835	1.459047
Corsican pine	0.0002341451	1.459047
lodgepole pine	0.0002693744	1.459047
Scots pine	0.0002694943	1.459047
firs, spruces, cedars and hemlocks	0.0001047720	1.459047
Douglas fir	0.0002710716	1.459047
beech	0.0001172993	2.000000
oak	0.0001136009	2.000000

Crown biomass equation for trees with dbh 7 cm to 50 cm

The output of the crown biomass equation for trees between 7 cm and 50 cm dbh gives an estimate of the biomass, in oven-dry tonnes, contained in the above-ground parts of the tree, excluding the merchantable tree stem biomass (*i.e.* excluding the part of the stem accounted for in M1 and/or Forest Yield in the Forecast System).

The format of the equation is:

$$\text{Crown biomass}_{(7\text{ cm} \le dbh \le 50\text{ cm})} = b \times dbh^{p} \qquad \text{Equation 2}$$

and p are species-specific parameters, and dbh is diameter at breast height (1.3 m) between 7.0 cm and 50.0 cm.

The values for the species-specific parameters for use in Equation 2 are presented in Table 2.

Table 2: Species/group-specific coefficients for Equation 2, the crown biomass equation for trees between 7 cm dbh and 50 cm dbh.

Species / species group	*b*	*p*
larches	0.0000438717	2.0291
Corsican pine	0.0000122645	2.4767
lodgepole pine	0.0000176287	2.4767
Scots pine	0.0000161411	2.4767
firs, spruces, cedars and hemlocks	0.0000144620	2.4767
Douglas fir	0.0000168602	2.4767
beech	0.0000188154	2.4767
oak	0.0000168513	2.4767

Crown biomass equation for trees with dbh > 50 cm

The output of the crown biomass equation for trees with a dbh greater than 50 cm gives an estimate of the biomass, in oven-dry tonnes, contained in the above-ground parts of the tree, excluding the merchantable tree stem biomass (*i.e.* excluding the part of the stem accounted for in M1 and/or Forest Yield in the Forecast System).

The format of the equation is:

$$\text{Crown biomass}_{(dbh > 50\text{ cm})} = a + b \times dbh \qquad \text{Equation 3}$$

where a and b are species-specific parameters, and dbh is diameter at breast height (1.3 m) greater than 50 cm.

The values for the species-specific parameters for use in Equation 3 are presented in Table 3.

Table 3: Species/group-specific coefficients for Equation 3, the crown biomass equation for trees greater than 50 cm dbh.

Species / species group	*a*	*b*
larches	-0.129046967	0.005039011
Corsican pine	-0.299529453	0.009948982
lodgepole pine	-0.430536496	0.014300429
Scots pine	-0.394205622	0.013093685
firs, spruces, cedars and hemlocks	-0.353197843	0.011731597
Douglas fir	-0.411767824	0.013677021
beech	-0.459518648	0.015263082
oak	-0.411550464	0.013669801

Root biomass equations

Two equations have been developed for estimating the biomass contained in tree roots (not differentiated into biomass estimates of coarse and fine roots). Both equations use diameter at breast height (dbh) as the input variable, and the equation used is dictated by the dbh of the tree being assessed.

Root biomass equation for trees with dbh ≤ 30 cm

The output of the root biomass equation for trees up to and including 30 cm dbh estimates the total biomass, in oven-dry tonnes, contained in tree roots (*i.e.* not differentiated into biomass estimates of coarse and fine roots).

The format of the equation is:

$$\text{Root biomass}_{(dbh \leq 30\ \text{cm})} = b \times dbh^{2.5} \qquad \text{Equation 4}$$

where b is a species-specific parameter, and dbh is diameter at breast height (1.3 m) in centimetres.

The values for the species-specific parameter for use in Equation 4 are presented in Table 4.

Table 4: Species/group-specific coefficients for Equation 4, the root biomass equation for trees up to and including 30 cm dbh.

Species / species group	*b*
western red cedar, noble fir, Corsican pine	0.000010722
Norway spruce	0.000011883
grand fir, Scots pine, western hemlock	0.000015404
Douglas fir, Japanese larch, lodgepole pine	0.000017326
Sitka spruce	0.000020454
red alder	0.000022700

Root biomass equation for trees with dbh > 30 cm

The output of the root biomass equation for trees greater than 30 cm dbh estimates the total biomass, in oven-dry tonnes, contained in tree roots (*i.e.* not differentiated into biomass estimates for coarse and fine roots).

The format of the equation is:

$$\text{Root biomass}_{(dbh > 30\text{ cm})} = a + b \times dbh \qquad \text{Equation 5}$$

where *a* and *b* are species-specific parameters, and *dbh* is diameter at breast height (1.3 m) greater than 30 cm.

The values for the species-specific parameters for use in Equation 5 are presented in Table 5.

Table 5: Species/group-specific coefficients for Equation 5, the root biomass equation for trees greater than 30 cm dbh.

Species / species group	*a*	*b*
western red cedar, noble fir, Corsican pine	-0.082602857	0.004515233
Norway spruce	-0.091547262	0.005004152
grand fir, Scots pine, western hemlock	-0.118673233	0.006486910
Douglas fir, Japanese larch, lodgepole pine	-0.133480423	0.007296300
Sitka spruce	-0.157578701	0.008613559
red alder	-0.174882004	0.009559391

Species mapping

The quantities of data available for calibrating revised biomass equations for use in Great Britain are generally insubstantial, variable, and do not cover all species commonly grown as forest trees. In order to satisfactorily calibrate the revised biomass equations, it has been necessary to pool data according to apparent statistical similarities. This approach has resulted in slightly different species groupings for crown and root biomass.

The revised biomass equations were subsequently subjectively assigned ("mapped") to species for which no suitable calibration data existed, on the basis of perceived similarities in silvicultural and morphological characteristics. The resultant species mappings are presented in Tables 6 and 7. This approach is entirely consistent with mapping exercises that have previously been carried out for other growth and yield models applied to tree species in Great Britain.

Table 6: Species mappings for broadleaves.

PF Code	FC Code	Species name	Mapping for Crown Biomass Functions	Mapping for Root Biomass Functions
34	OK	Oak	oak	red alder
35	POK	Pedunculate oak	oak	red alder
36	SOK	Sessile oak	oak	red alder
37	ROK	Red oak	oak	red alder
38	BE	Beech	beech	red alder
39	SY	Sycamore	beech	red alder
40	NOM	Norway maple	beech	red alder
41	AH	Ash	oak	red alder
42	BI	Birch	oak	red alder
43	PO	Poplar	oak	red alder
44	SC	Sweet chestnut	beech	red alder
45	HCH	Horse Chestnut	oak	red alder
46	AR	Alder	oak	red alder
47	CAR	Common alder	oak	red alder
48	GAR	Grey alder	oak	red alder
49	RAR	Red alder	oak	red alder
50	SAR	Sitka alder	oak	red alder
51	VAR	Green alder	oak	red alder
52	LI	Lime	oak	red alder
53	CLI	Common Lime	oak	red alder
54	SLI	Small-leaved lime	oak	red alder

Table 6 (continued): Species mappings for broadleaves.

PF Code	FC Code	Species name	Mapping for Crown Biomass Functions	Mapping for Root Biomass Functions
55	LLI	Large-leaved lime	oak	red alder
56	EM	Elm	oak	red alder
57	EEM	English elm	oak	red alder
58	WEM	Wych elm	oak	red alder
59	SEM	Smooth-leaved elm	oak	red alder
60	WCH	Wild cherry, gean	oak	red alder
61	BCH	Bird cherry	oak	red alder
62	HBM	Hornbeam	beech	red alder
63	RON	Roble	beech	red alder
64	RAN	Raoul	beech	red alder
65	DUM	Dummy	oak	red alder
66	XB	Other broadleaves	oak	red alder
67	MB	Mixed broadleaves	oak	red alder
68	HAZ	Hazel	oak	red alder
1014	WWL	White willow	oak	red alder
1015	WPO	White poplar	oak	red alder
1016	GPO	Grey poplar	oak	red alder
1017	XB2	Aspen	oak	red alder
1018	BPO	Black poplar	oak	red alder
1019	XB9	Hybrid black poplar	oak	red alder
1020	XB5	Eastern cottonwood	oak	red alder
1021	IAR	Italian alder	oak	red alder
1022	XB12	Pin oak	oak	red alder
1023	QIL	Holm oak	oak	red alder
1024	XB4	Cork oak	oak	red alder
1025	XB17	Turkey oak	oak	red alder
1026	XB15	Small-leaved elm	oak	red alder
1027	TUL	Tulip tree	beech	red alder
1028	LPL	London plane	beech	red alder
1029	XB14	Service tree	oak	red alder
1030	XB13	Rowan	oak	red alder
1031	WHI	Common whitebeam	oak	red alder
1032	FM	Field maple	beech	red alder
1033	WL	Willow	oak	red alder
1034	ROW	Rowan	oak	red alder
1035	ASP	Aspen	oak	red alder
1037	HOL	Holly	beech	red alder
1039	HAW	Hawthorn	oak	red alder
1053	QCE	Turkey oak	oak	red alder
1054	QFR	Hungarian oak	oak	red alder

Table 6 (continued): Species mappings for broadleaves.

PF Code	FC Code	Species name	Mapping for Crown Biomass Functions	Mapping for Root Biomass Functions
1055	QPY	Pyrenean oak	oak	red alder
1056	QPU	Downy oak	oak	red alder
1057	JRE	Common walnut	oak	red alder
1058	QAL	White oak	oak	red alder
1059	XOK	Other oak	oak	red alder
1060	XWA	Other walnut	oak	red alder
1061	JNI	Black walnut	oak	red alder
1062	ENI	Shining gum	oak	red alder
1063	XEU	Other eucalyptus	oak	red alder
1064	XPO	Other poplar	oak	red alder
1065	NPU	Lenga	beech	red alder
1066	XNO	Other Nothofagus	beech	red alder
1067	FAM	White ash/american ash	oak	red alder
1068	ASA	Silver maple	beech	red alder
1069	BPA	Paper bark birch	oak	red alder
1070	SCI	Grey willow	oak	red alder
1071	CAP	Crab apple	oak	red alder
1072	FPE	Red ash	oak	red alder
1073	BOX	Box	beech	red alder
1074	EGU	Cider gum	oak	red alder
1075	PBI	Downy birch	oak	red alder
1076	CWL	Crack willow	oak	red alder
1077	FM	Field maple	beech	red alder
1078	GWL	Goat willow	oak	red alder
1079	AMA	Big leaf maple	beech	red alder
1080	WST	Wild service tree	oak	red alder
1081	FAN	Narrow-leafed ash	oak	red alder
1082	PSP	Blackthorn	oak	red alder
1083	SBI	Silver birch	oak	red alder
1084	XWL	Other willows	oak	red alder
1085	XBI	Other birch	oak	red alder
1086	XCH	Other cherry	oak	red alder
1087	XPL	Other plane	beech	red alder
1088	COV	Shagbark hickory	oak	red alder
1090	FOR	Oriental beech	beech	red alder

Table 7: Species mappings for conifers.

PF Code	FC Code	Species name	Mapping for Crown Biomass Functions	Mapping for Root Biomass Functions
1	SP	Scots pine	Scots pine	grand fir, Scots pine, western hemlock
2	CP	Corsican pine	Corsican pine	western red cedar, noble fir, Corsican pine
3	LP	lodgepole pine	lodgepole pine	Douglas fir, Japanese larch, lodgepole pine
4	AUP	Austrian pine	Corsican pine	western red cedar, noble fir, Corsican pine
5	MAP	maritime pine	lodgepole pine	Douglas fir, Japanese larch, lodgepole pine
6	WEP	Weymouth pine	Corsican pine	western red cedar, noble fir, Corsican pine
7	MOP	mountain pine	lodgepole pine	Douglas fir, Japanese larch, lodgepole pine
8	BIP	Bishop pine	Corsican pine	western red cedar, noble fir, Corsican pine
9	RAP	Monterey/Radiata pine	Corsican pine	western red cedar, noble fir, Corsican pine
10	PDP	ponderosa pine	Corsican pine	western red cedar, noble fir, Corsican pine
11	MCP	Macedonian pine	Corsican pine	western red cedar, noble fir, Corsican pine
12	XP	other pines	Scots pine	grand fir, Scots pine, western hemlock
13	SS	Sitka spruce	firs, spruces, cedars and hemlocks	Sitka spruce
14	NS	Norway spruce	firs, spruces, cedars and hemlocks	Norway spruce
15	OMS	Omorika spruce	firs, spruces, cedars and hemlocks	Norway spruce
16	XS	other spruces	firs, spruces, cedars and hemlocks	Norway spruce
17	EL	European larch	larches	Douglas fir, Japanese larch, lodgepole pine
18	JL	Japanese larch	larches	Douglas fir, Japanese larch, lodgepole pine
19	HL	hybrid larch	larches	Douglas fir, Japanese larch, lodgepole pine
20	DF	Douglas fir	Douglas fir	Douglas fir, Japanese larch, lodgepole pine
21	WH	western hemlock	firs, spruces, cedars and hemlocks	grand fir, Scots pine, western hemlock
22	RC	western red cedar	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
23	LC	Lawsons cypress	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
24	LEC	Leyland cypress	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
25	GF	grand fir	firs, spruces, cedars and hemlocks	grand fir, Scots pine, western hemlock
26	NF	noble fir	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
27	ESF	silver fir	firs, spruces, cedars and hemlocks	grand fir, Scots pine, western hemlock
28	XF	other firs (abies)	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
29	JCR	Japanese cedar	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
30	RSQ	coast redwood	firs, spruces, cedars and hemlocks	grand fir, Scots pine, western hemlock
31	WSQ	Wellingtonia	firs, spruces, cedars and hemlocks	grand fir, Scots pine, western hemlock
32	XC	other conifers	firs, spruces, cedars and hemlocks	Norway spruce

Table 7 (continued): Species mappings for conifers.

PF Code	FC Code	Species name	Mapping for Crown Biomass Functions	Mapping for Root Biomass Functions
33	MC	mixed conifers	firs, spruces, cedars and hemlocks	Norway spruce
1001	XF2	Siberian fir	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1002	NMF	Nordmann/Caucasian fir	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1003	ORS	oriental spruce	firs, spruces, cedars and hemlocks	Norway spruce
1004	XS2	white spruce	firs, spruces, cedars and hemlocks	Norway spruce
1005	XS4	Engelmann spruce	firs, spruces, cedars and hemlocks	Norway spruce
1006	XS1	blue spruce	firs, spruces, cedars and hemlocks	Norway spruce
1007	XC3	deodar cedar	Scots pine	grand fir, Scots pine, western hemlock
1008	XC1	Atlantic cedar	Scots pine	grand fir, Scots pine, western hemlock
1009	PMO	western white pine	Corsican pine	western red cedar, noble fir, Corsican pine
1010	MET	dawn redwood	firs, spruces, cedars and hemlocks	grand fir, Scots pine, western hemlock
1011	XC4	Monterey cypress	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1012	XC5	Nootka cypress	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1013	XC6	yew	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1036	JUN	juniper	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1038	YEW	yew	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1040	CAT	Atlas cedar	Scots pine	grand fir, Scots pine, western hemlock
1041	XCD	other cedar	Scots pine	grand fir, Scots pine, western hemlock
1042	PAY	Mexican white pine	Scots pine	grand fir, Scots pine, western hemlock
1043	PBR	Calabrian pine	lodgepole pine	Douglas fir, Japanese larch, lodgepole pine
1044	PKO	Korean pine	Scots pine	grand fir, Scots pine, western hemlock
1045	PWA	Bhutan pine	Corsican pine	western red cedar, noble fir, Corsican pine
1046	PYU	Yunnan pine	Scots pine	grand fir, Scots pine, western hemlock
1048	BMF	Bornmuller's fir	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1049	LCD	cedar of Lebanon	Scots pine	grand fir, Scots pine, western hemlock
1051	GKF	Greek fir	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1089	PAR	Armand's pine	Scots pine	grand fir, Scots pine, western hemlock
1091	PTA	loblolly pine	Corsican pine	western red cedar, noble fir, Corsican pine
1092	XL	other larches	larches	Douglas fir, Japanese larch, lodgepole pine
1093	RF	red (pacific silver) fir	firs, spruces, cedars and hemlocks	western red cedar, noble fir, Corsican pine
1094	PEL	slash pine	lodgepole pine	Douglas fir, Japanese larch, lodgepole pine