

Supplementary Information

Supplementary Table S1 Permanent sample plots and observations of each natural uneven-aged pure stand (Spruce, Korean Larch, Mongolian Oak, and White Birch) within five site types (see Table 1)

Site type	Spruce		Korean Larch		Mongolian Oak		White Birch	
	No. of plots	No. of observations	No. of plots	No. of observations	No. of plots	No. of observations	No. of plots	No. of observations
1	16	192	19	258	15	189	24	201
2	25	284	21	287	23	307	16	129
3	23	271	12	168	28	390	17	141
4	20	235	14	213	18	249	16	129
5	11	128	6	90	21	270	4	30
Total	95	1110	72	1016	105	1405	77	630

Supplementary Table S2 Summary statistics for model-fitting and validation data sets. Min, minimum; Max, maximum; SD, standard deviation; D, diameter at breast height of dominant tree; and H, total height of dominant tree

Stands	Model-fitting data				Validation data			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Spruce								
D (cm)	3.9	99.0	25.9	15.2	3.9	100.6	25.9	14.9
H (m)	3.4	32.6	15.4	6.2	4.0	32.6	15.6	6.0
Korean Larch								
D (cm)	2.0	37.6	13.8	7.3	2.4	35.3	14.8	7.4
H (m)	3.0	21.3	12.3	4.9	2.2	20.8	12.8	4.9
Mongolian Oak								
D (cm)	3.2	107.8	27.4	13.3	3.2	109.3	8.0	12.3
H (m)	1.9	22.6	14.6	3.4	1.9	22.6	14.8	3.2
White Birch								
D (cm)	3.5	57.0	24.6	9.6	4.2	55.9	24.0	9.8
H (m)	1.6	22.6	16.8	3.6	6.0	22.5	16.7	3.7

Supplementary Table S3 Root mean square error for candidate base equations 1–3.

Tree species	Model-fitting data			Validation data		
	Eq.1	Eq.2	Eq.3	Eq.1	Eq.2	Eq.3
Spruce	0.9417	0.9421	0.9421	1.3916	1.3909	1.4005
Korean Larch	0.8812	0.8765	0.8598	0.9517	0.9505	0.9480
Mongolian Oak	0.8233	0.8091	0.7031	0.8533	0.8390	0.7391
White Birch	0.6203	0.6150	0.5840	0.5421	0.5453	0.5771

Supplementary Table S4 Parameter estimates of Eqs. 9–11. $\beta_2 - \beta_3$, fixed-effects parameters; and σ^2 , variance-covariance parameter of error term

Tree Species	Eq.9			Eq.10			Eq.11		
	β_2	β_3	σ^2	β_1	β_3	σ^2	β_1	β_2	σ^2
Spruce	-1352.6390	38.6290	0.2845	35.8199	39.1656	0.2453	16.5756	-0.1803	0.5749
Korean Larch	-687.4287	18.4909	0.1475	33.2912	18.1771	0.1846	15.8923	-0.7460	0.5016
Mongolian Oak	-269.5374	9.7199	0.1234	21.7024	9.6197	0.1429	14.9194	-0.3900	0.3881
White Birch	-453.0400	14.4576	0.0501	27.8177	14.3976	0.0421	16.5553	-0.0636	0.3770

Supplementary Table S5 Evaluation indexes of Eqs. 9–11 for algebraic difference approach. *RMSE*, root mean square error; and *AIC*, Akaike's information criterion

Tree species	Evaluation indexes	Eq.9	Eq.10	Eq. 11
Spruce	<i>RMSE</i>	0.2844	0.2452	3.5649
	<i>AIC</i>	363.4339	34.0772	703.6876
Korean Larch	<i>RMSE</i>	0.1845	0.1474	5.6386
	<i>AIC</i>	-545.5373	-1001.6690	616.4019
Mongolian Oak	<i>RMSE</i>	0.1428	0.1234	4.5108
	<i>AIC</i>	-1476.9070	-1887.6250	780.2137
White Birch	<i>RMSE</i>	0.0501	0.0421	4.4956
	<i>AIC</i>	-1980.5721	-2198.3020	346.3939

Supplementary Table S6 Parameter estimates of Eqs. 12-14. β_k , $\beta_k^{(1)}$, $\beta_k^{(2)}$, $\beta_k^{(3)}$, $\beta_k^{(4)}$ and β_l = fixed-effects parameters; $k = 2$ and $l = 3$ for Eq. 12, $k = 1$ and $l = 3$ for Eq. 13, $k = 1$ and $l = 2$ for Eq. 14; and σ^2 , parameters of variance-covariance for error term

Param	Spruce			Korean Larch			Mongolian Oak			White Birch		
eters	Eq. 12	Eq.13	Eq. 14	Eq. 12	Eq.13	Eq. 14	Eq. 12	Eq.13	Eq. 14	Eq. 12	Eq.13	Eq. 14
β_k	-1308.5801	36.5668	18.2609	-678.3999	32.7556	13.6407	270.7054	22.0175	13.8262	-459.4833	28.1610	14.4685
$\beta_k^{(1)}$	99.4264	-2.6926	-4.2182	6.0656	0.25	-0.7648	34.6428	-1.2701	-1.5432	-5.2273	0.0068	0.3552
$\beta_k^{(2)}$	-16.8375	0.2154	-2.8453	-6.8742	0.8537	0.4300	24.6414	-0.7715	-1.4778	16.7285	-0.8156	0.7305
$\beta_k^{(3)}$	-11.8633	-0.2456	-3.9805	-0.3143	0.691	0.0587	1.7508	-0.1205	-0.0641	12.0513	-0.5443	1.0555
$\beta_k^{(4)}$	183.1765	-3.8469	-4.7360	22.072	-0.1954	-0.7236	15.5495	-0.3734	0.3085	1.8337	-0.0854	0.2781
β_l	36.0608	36.6683	0.1673	18.2329	18.0272	-0.2621	9.0282	9.1467	-0.0112	14.5324	14.5329	0.1112
σ^2	0.2696	0.2307	0.5282	0.1439	0.1815	0.4201	0.1154	0.1397	0.3195	0.0461	0.0365	0.3584

Supplementary Table S7 Evaluation indexes of Eqs. 12–14. *RMSE*, root mean square error; and AIC, Akaike's information criterion

Tree species	Evaluation indexes	Eq. 12	Eq. 13	Eq. 14
Spruce	<i>RMSE</i>	0.2690	0.2302	5.2702
	AIC	248.0649	-97.6808	685.2845
Korean Larch	<i>RMSE</i>	0.1811	0.1435	4.1906
	AIC	-575.9567	-1048.465	580.7856
Mongolian Oak	<i>RMSE</i>	0.1394	0.1152	3.1897
	AIC	-1535.7610	-2071.7480	725.9576
White Birch	<i>RMSE</i>	0.0459	0.0364	3.5702
	AIC	-2081.3040	-2374.4870	340.4352

Supplementary Table S8 Parameter estimates of Eqs. 15 and 16. β_k , $\beta_k^{(1)}$, $\beta_k^{(2)}$, $\beta_k^{(3)}$, $\beta_k^{(4)}$ and β_l = fixed-effects parameters; $k = 2$ and $l = 3$ for Eq. 15, $k = 1$ and $l = 3$ for Eq. 16; ψ , parameter of variance-covariance for random effects; and ρ , λ and σ^2 , parameters of variance-covariance for error term

Parameters	Spruce		Korean Larch		Mongolian Oak		White Birch	
	Eq.15	Eq. 16	Eq. 15	Eq. 16	Eq. 15	Eq. 16	Eq. 15	Eq. 16
β_k	-1377.5370	38.9523	-752.4783	34.9875	-274.0674	22.0713	-450.9703	27.8648
$\beta_k^{(1)}$	-399.5588	4.0942	73.3851	-1.5871	-66.4534	0.9170	-33.4431	0.5308
$\beta_k^{(2)}$	-654.0083	6.1516	58.8904	-0.7647	-12.5191	0.7170	-0.6498	-0.0526
$\beta_k^{(3)}$	-683.4097	5.7594	45.5517	-0.5550	-59.0001	1.5419	1.3211	-0.2837
$\beta_k^{(4)}$	-576.5436	6.2669	70.6408	-1.9881	-16.1019	0.6582	-15.9688	0.3525
β_l	48.0217	58.4896	18.6861	19.9357	11.5152	15.8445	14.8714	14.6709
ψ	10.60552	26.6711	1.6317	3.7712	2.2937	6.8966	1.0114	3.8585
ρ	0.3773	0.4279	0.1582	0.2224	0.6517	0.6031	0.0172	0.0550
λ	-2.8394	-2.5740	0.4782	0.5924	-2.2465	-1.7161	-3.4834	-2.1050
σ^2	2.5136	2.7005	0.0115	0.0068	6.1419	2.8368	2.2326	2.6663

Supplementary Table S9 Evaluation indexes of Eqs. 15 and 16. *RMSE*, root mean square error; and AIC, Akaike's information criterion

Tree species	Equation	<i>RMSE</i>	AIC
Spruce	Eq. 15	0.2060	-3096.7430
	Eq. 16	0.1912	-3588.7920
Korean Larch	Eq. 15	0.0366	-3456.9370
	Eq. 16	0.0290	-3954.9940
Mongolian Oak	Eq. 15	0.0468	-5720.700
	Eq. 16	0.0417	-7463.5090
White Birch	Eq. 15	0.0208	-3750.3310
	Eq. 16	0.0135	-4494.6690