

Supplementary material

Method 1. Estimation of the Stem Cross-Sectional Area at the Crown Base (A_B)

According to some previous studies on tree biomass model or growth model [26-28], coefficient of determination (R^2), total relative error (Rs), mean relative error (EE), mean absolute value of relative error (RMA) and prediction accuracy (P) were used to assess the model in this study. The mathematical expressions of the above statistics were as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2} \quad (S-1)$$

$$Rs = \frac{\sum_{i=1}^n (y_i - \hat{y}_i)}{\sum_{i=1}^n \hat{y}_i} \times 100\% \quad (S-2)$$

$$EE = \frac{1}{n} \sum_{i=1}^n \left(\frac{y_i - \hat{y}_i}{\hat{y}_i} \right) \times 100\% \quad (S-3)$$

$$RMA = \frac{1}{n} \sum_{i=1}^n \left| \frac{y_i - \hat{y}_i}{\hat{y}_i} \right| \times 100\% \quad (S-4)$$

$$P = \left[1 - \frac{t_{\alpha} \sqrt{\sum_{i=1}^n (y_i - \hat{y}_i)^2}}{\bar{\hat{y}} \sqrt{n(n-T)}} \right] \times 100\% \quad (S-5)$$

where y_i is the measured value, \hat{y}_i is the estimated value, \bar{y} is the average measured value, $\bar{\hat{y}}$ is the average estimated value, n is the number of samples, T is the number of parameters of the model, and t_{α} is the t value at the confidence level α .

Table S1 Topography of each plot in the four sites

Site	Plot	Slope(°)	Slope position	Slope aspect	Soil Type
Hailin	HS-01	8	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-02	7	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-03	-	Upper	Sunny slope	Dark-brown soil
Hailin	HS-04	5	Lower	Semi-shady slope	Dark-brown soil
Hailin	HS-05	8	Middle	Shady slope	Dark-brown soil
Hailin	HS-06	9	Upper	Semi-sunny slope	Dark-brown soil
Hailin	HS-07	16	Middle	Sunny slope	Dark-brown soil
Hailin	HS-08	16	Middle	Sunny slope	Dark-brown soil
Hailin	HS-09	4	Upper	Sunny slope	Dark-brown soil
Hailin	HS-10	3	Upper	Sunny slope	Dark-brown soil
Hailin	HS-11	7	Upper	Sunny slope	Dark-brown soil
Hailin	HS-12	-	Lower	Sunny slope	Dark-brown soil
Hailin	HS-13	5	-	Sunny slope	Dark-brown soil
Hailin	HS-14	3	Lower	Sunny slope	Dark-brown soil
Hailin	HS-15	3	Lower	Sunny slope	Dark-brown soil
Hailin	HS-16	7	Middle	Sunny slope	Dark-brown soil
Hailin	HS-17	8	Upper	Sunny slope	Dark-brown soil
Hailin	HS-18	7	Upper	Semi-sunny slope	Dark-brown soil
Hailin	HS-19	8	Upper	Semi-sunny slope	Dark-brown soil
Hailin	HS-20	9	Upper	Semi-sunny slope	Dark-brown soil
Hailin	HS-21	6	Upper	Sunny slope	Dark-brown soil
Hailin	HS-22	8	Middle	Sunny slope	Dark-brown soil
Hailin	HS-23	4	Upper	Sunny slope	Dark-brown soil
Hailin	HS-24	8	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-25	-	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-26	11	Lower	Shady slope	Dark-brown soil
Hailin	HS-27	9	Middle	Shady slope	Dark-brown soil

Hailin	HS-28	8	Upper	Shady slope	Dark-brown soil
Hailin	HS-29	14	Middle	Shady slope	Dark-brown soil
Hailin	HS-30	17	Upper	Shady slope	Dark-brown soil
Hailin	HS-31	14	Upper	Shady slope	Dark-brown soil
Hailin	HS-32	4	Upper	Sunny slope	Dark-brown soil
Hailin	HS-33	3	Upper	Sunny slope	Dark-brown soil
Hailin	HS-34	4	Upper	Sunny slope	Dark-brown soil
Hailin	HS-35	3	Middle	Sunny slope	Dark-brown soil
Hailin	HS-36	4	Upper	Sunny slope	Dark-brown soil
Hailin	HS-37	4	Upper	Sunny slope	Dark-brown soil
Hailin	HS-38	3	Middle	Sunny slope	Dark-brown soil
Hailin	HS-39	4	Middle	Sunny slope	Dark-brown soil
Hailin	HS-40	6	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-41	7	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-42	10	Upper	Semi-sunny slope	Dark-brown soil
Hailin	HS-43	11	Upper	Semi-sunny slope	Dark-brown soil
Hailin	HS-44	7	Middle	Sunny slope	Dark-brown soil
Hailin	HS-45	7	Lower	Semi-sunny slope	Dark-brown soil
Hailin	HS-46	12	Middle	Semi-sunny slope	Dark-brown soil
Hailin	HS-47	4	Lower	Sunny slope	Dark-brown soil
Hailin	HS-48	4	Lower	Sunny slope	Dark-brown soil
Hailin	HS-49	4	Lower	Sunny slope	Dark-brown soil
Hailin	HS-50	4	Lower	Sunny slope	Dark-brown soil
Dahailin	CT-3	12	Middle	Shady slope	Dark-brown soil
Dahailin	CT-4	5	Upper	Semi-shady slope	Dark-brown soil
Dahailin	CT-5	7	Lower	Shady slope	Dark-brown soil
Dahailin	CT-6	18	Middle	Shady slope	Dark-brown soil
Dahailin	CT-7	5	Upper	Semi-shady slope	Dark-brown soil
Dahailin	CT-8	6	Upper	Semi-shady slope	Dark-brown soil

Dahailin	CT-9	3	Lower	Semi-sunny slope	Dark-brown soil
Dahailin	CT-10	4	Upper	Semi-shady slope	Dark-brown soil
Dahailin	CT-11	6	Upper	Semi-shady slope	Dark-brown soil
Dahailin	CT-12	7	Upper	Semi-shady slope	Dark-brown soil
Dahailin	CT-13	6	Lower	Shady slope	Dark-brown soil
Dahailin	CT-14	9	Upper	Semi-shady slope	Dark-brown soil
Dahailin	CT-18	8	Middle	Semi-sunny slope	Dark-brown soil
Dahailin	HJ-1	3	Upper	Semi-shady slope	Dark-brown soil
Dahailin	HJ-2	3	Upper	Semi-shady slope	Dark-brown soil
Dahailin	HJ-3	4	Lower	-	Dark-brown soil
Dahailin	HJ-4	9	Lower	-	-
Dahailin	HJ-5	19	Lower	-	Dark-brown soil
Dahailin	HJ-6	4	Lower	-	Dark-brown soil
Dahailin	QJ-1	-	-	-	-
Dahailin	QJ-2	15	Middle	Sunny slope	Dark-brown soil
Dahailin	QJ-3	19	Upper	Shady slope	Dark-brown soil
Dahailin	QJ-4	19	Middle	Semi-sunny slope	Dark-brown soil
Dahailin	QJ-5	5	Middle	Shady slope	Dark-brown soil
Dahailin	QP-1	8	Middle	Shady slope	Dark-brown soil
Dahailin	QP-2	14	Lower	Shady slope	Dark-brown soil
Dahailin	RL-1	8	Lower	Shady slope	Brown coniferous forest soil
Dahailin	RL-2	10	Lower	-	Brown coniferous forest soil
Dahailin	RL-3	5	Lower	Semi-sunny slope	Brown coniferous forest soil
Dahailin	TP-1	4	Lower	Semi-sunny slope	Dark-brown soil
Dahailin	TP-2	10	Middle	-	-
Dahailin	TP-3	18	Lower	Sunny slope	Dark-brown soil
Dahailin	TP-4	14	Lower	Semi-sunny slope	Dark-brown soil
Dahailin	TP-5	4	Lower	Sunny slope	Dark-brown soil
Dahailin	TP-6	7	-	Semi-sunny slope	Dark-brown soil

Dahailin	TP-7	7	Lower	Semi-sunny slope	Dark-brown soil
Dahailin	XC-1	7	Lower	Sunny slope	Brown coniferous forest soil
Dahailin	XC-2	17	Middle	Sunny slope	Brown coniferous forest soil
Dahailin	XC-3	12	Middle	Semi-sunny slope	Brown coniferous forest soil
Dahailin	XC-4	4	Lower	Semi-sunny slope	Brown coniferous forest soil
Dahailin	XL-1	8	Lower	Semi-sunny slope	-
Dahailin	XL-2	8	Lower	Shady slope	-
Dahailin	XL-3	4	Lower	Sunny slope	-
Dahailin	XL-4	10	Lower	Shady slope	-
Dahailin	YG-1	9	Upper	Semi-shady slope	Dark-brown soil
Dahailin	YG-2	11	Upper	Semi-shady slope	Dark-brown soil
Dahailin	YG-3	14	Lower	Semi-sunny slope	Dark-brown soil
Dahailin	YG-4	16	Lower	Semi-sunny slope	Brown coniferous forest soil
Linkou	DL-23	4	Upper	Semi-shady slope	Dark-brown soil
Linkou	DL-35	4	Middle	Semi-shady slope	Meadow soil
Linkou	DL-36	15	Lower	Semi-sunny slope	Dark-brown soil
Linkou	DL-37	10	Upper	Sunny slope	Dark-brown soil
Linkou	HS-3	5	Middle	Sunny slope	Dark-brown soil
Linkou	HS-7	15	Lower	Sunny slope	Dark-brown soil
Linkou	HS-8	12	Middle	Sunny slope	Dark-brown soil
Linkou	HS-9	5	Middle	Semi-shady slope	Dark-brown soil
Linkou	HS-12	5	-	-	Dark-brown soil
Linkou	HS-19	19	Upper	Sunny slope	Dark-brown soil
Linkou	SD-5	20	Lower	Shady slope	Dark-brown soil
Linkou	SD-30	14	Middle	Sunny slope	Dark-brown soil
Linkou	SD-31	16	Lower	Shady slope	Dark-brown soil
Linkou	SD-32	14	Lower	Shady slope	Dark-brown soil
Linkou	SG-1	14	Lower	Shady slope	Dark-brown soil
Linkou	SG-2	13	Lower	Shady slope	Dark-brown soil

Linkou	SG-3	13	Lower	Semi-shady slope	Dark-brown soil
Linkou	SG-4	14	Lower	Semi-sunny slope	Dark-brown soil
Linkou	SG-5	15	Lower	Semi-sunny slope	Dark-brown soil
Linkou	SG-6	15	Lower	Shady slope	Dark-brown soil
Linkou	SG-7	15	Lower	Semi-shady slope	Dark-brown soil
Linkou	SG-8	15	Lower	Semi-shady slope	Dark-brown soil
Linkou	XL-1	3	Lower	-	Dark-brown soil
Linkou	XL-28	13	Lower	Semi-shady slope	Dark-brown soil
Linkou	XL-43	8	Lower	Semi-shady slope	Dark-brown soil
Linkou	YS-22	16	Lower	Shady slope	Dark-brown soil
Linkou	YS-23	17	Lower	Sunny slope	Dark-brown soil
Linkou	YS-25	13	Upper	Semi-sunny slope	Dark-brown soil
Linkou	YS-26	17	Lower	Sunny slope	Dark-brown soil
Linkou	YS-27	18	Lower	Shady slope	Dark-brown soil
Linkou	YS-37	9	Upper	Semi-shady slope	Dark-brown soil
Linkou	ZD-1	11	Lower	Shady slope	Dark-brown soil
Linkou	ZD-2	4	-	-	Marsh soil
Linkou	ZD-3	12	Lower	Shady slope	Dark-brown soil
Linkou	ZD-5	16	Middle	Sunny slope	Dark-brown soil
Linkou	ZD-6	3	Lower	-	Dark-brown soil
Linkou	ZD-7	-	-	-	Dark-brown soil
Linkou	ZD-8	16	Upper	Sunny slope	Dark-brown soil
Linkou	ZD-9	13	Upper	Sunny slope	Dark-brown soil
Linkou	ZD-10	3	-	-	Dark-brown soil
Linkou	ZD-11	8	Lower	-	Dark-brown soil
Linkou	ZD-12	5	Upper	-	Meadow soil
Linkou	ZD-13	16	Upper	Sunny slope	Dark-brown soil
Linkou	ZD-14	18	Lower	Sunny slope	Dark-brown soil
Linkou	ZD-19	16	Middle	Shady slope	Dark-brown soil

Linkou	ZD-20	16	Middle	Shady slope	Dark-brown soil
Linkou	ZD-21	17	Upper	Sunny slope	Dark-brown soil
Linkou	ZD-22	14	Lower	Sunny slope	Dark-brown soil
Linkou	ZD-23	16	Middle	Sunny slope	Dark-brown soil
Linkou	ZD-24	16	Lower	Sunny slope	Dark-brown soil
Linkou	ZD-26	9	Middle	Shady slope	Dark-brown soil
Huanan	MS-01	3	Upper	Semi-shady slope	Dark-brown soil
Huanan	MS-02	3	Upper	Shady slope	Dark-brown soil
Huanan	MS-03	4	Upper	Shady slope	Dark-brown soil
Huanan	MS-04	2	Upper	Shady slope	Dark-brown soil
Huanan	MS-05	3	Upper	Shady slope	Dark-brown soil
Huanan	MS-06	3	Middle	Sunny slope	Dark-brown soil
Huanan	MS-07	3	Upper	Shady slope	Dark-brown soil
Huanan	MS-08	5	Middle	Shady slope	Dark-brown soil
Huanan	MS-09	-	Lower	Shady slope	Dark-brown soil
Huanan	MS-10	4	Lower	Shady slope	Dark-brown soil
Huanan	MS-11	4	Lower	Semi-shady slope	Dark-brown soil
Huanan	MS-12	-	Lower	Semi-shady slope	Dark-brown soil
Huanan	MS-13	4	Middle	Semi-shady slope	Dark-brown soil
Huanan	MS-14	3	Middle	Semi-shady slope	Dark-brown soil
Huanan	MS-15	5	Middle	Sunny slope	Dark-brown soil
Huanan	MS-16	3	Middle	Sunny slope	Dark-brown soil
Huanan	MS-17	3	Lower	Sunny slope	Dark-brown soil
Huanan	MS-18	3	Lower	Sunny slope	Dark-brown soil
Huanan	MS-19	4	Lower	Sunny slope	Dark-brown soil
Huanan	MS-20	3	Lower	Sunny slope	Dark-brown soil
Huanan	MS-21	-	Middle	Semi-shady slope	Dark-brown soil
Huanan	MS-22	3	Lower	Semi-shady slope	Dark-brown soil
Huanan	MS-23	3	Lower	Semi-shady slope	Dark-brown soil

Huanan	MS-24	3	Middle	Semi-shady slope	Dark-brown soil
Huanan	MS-25	-	Middle	Semi-shady slope	Dark-brown soil
Huanan	MS-26	-	Lower	Sunny slope	Dark-brown soil
Huanan	MS-27	-	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-28	-	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-29	-	Middle	Semi-shady slope	Dark-brown soil
Huanan	MS-30	2	Lower	Semi-sunny slope	Dark-brown soil
Huanan	MS-31	-	Lower	Semi-sunny slope	Dark-brown soil
Huanan	MS-32	3	Lower	Semi-sunny slope	Dark-brown soil
Huanan	MS-33	3	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-34	3	Lower	Semi-shady slope	Dark-brown soil
Huanan	MS-35	3	Lower	Semi-shady slope	Dark-brown soil
Huanan	MS-36	3	Lower	Semi-shady slope	Dark-brown soil
Huanan	MS-37	3	Middle	Sunny slope	Dark-brown soil
Huanan	MS-38	3	Lower	Sunny slope	Dark-brown soil
Huanan	MS-39	3	Lower	Sunny slope	Dark-brown soil
Huanan	MS-40	3	Lower	Sunny slope	Dark-brown soil
Huanan	MS-41	-	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-42	3	Lower	Semi-sunny slope	Dark-brown soil
Huanan	MS-43	2	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-44	2	Upper	Semi-sunny slope	Dark-brown soil
Huanan	MS-45	2	Upper	Semi-sunny slope	Dark-brown soil
Huanan	MS-46	-	Upper	Semi-sunny slope	Dark-brown soil
Huanan	MS-47	-	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-48	4	Upper	-	Dark-brown soil
Huanan	MS-49	3	Middle	Semi-sunny slope	Dark-brown soil
Huanan	MS-50	-	Upper	Semi-sunny slope	Dark-brown soil

Table S2 Estimation of the stem area at the crown base (A_B) (318 trees)

Site	Sample trees number	$A_{1.3}$ (m ²)			Measured A_B (m ²)			Estimated A_B (m ²)		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Hailin	81	0.0607	0.0026	0.0181	0.0272	0.0020	0.0099	0.0297	0.0028	0.0102
Dahailin	89	0.0560	0.0052	0.0162	0.0305	0.0011	0.0091	0.0298	0.0015	0.0095
Linkou	73	0.0523	0.0020	0.0212	0.0423	0.0015	0.0117	0.0454	0.0022	0.0129
Huanan	75	0.0688	0.0020	0.0257	0.0343	0.0013	0.0132	0.0432	0.0017	0.0143
Total	318	0.0688	0.0020	0.0201	0.0423	0.0011	0.0109	0.0454	0.0015	0.0116

A_B : stem area at crown base; $A_{1.3}$: stem area at 1.3m

Table S3 Slope and intercept of the model for estimating A_B

Site	Slope(a)		Intercept(b)		R^2	R^2_{adj}
	a	95% CI	b	95% CI		
Hailin	1.067	(1.008,1.125)	0.211	(-0.052,0.474)	0.943	0.942
Dahailin	0.960	(0.901,1.020)	-0.254	(-0.533,0.024)	0.940	0.939
Linkou	1.000	(1.010,1.115)	0.288	(0.043,0.533)	0.960	0.960
Huanan	0.977	(0.934,1.020)	-0.176	(-0.378,0.026)	0.958	0.958
Total	0.999	(0.974,1.026)	-0.065	(-0.186,0.055)	0.949	0.949

A_B : stem area at crown base; $A_{1.3}$: stem area at 1.3m; H: tree height; H_B : height at crown base; $H_{1.3}$: breast height; R^2 : coefficient of determination; R^2_{adj} : adjusted R -squared; CI: confidence interval. $\ln(A_B) = a \cdot \ln[A_{1.3}(H-H_B)/(H-H_{1.3})] + b$.

Table S4 The 20% individual trees to test the suitability of the estimation of the stem areaat the crown base (A_B)

Site	Sample trees number	$A_{1.3}$ (m^2)			Measured A_B (m^2)			Estimated A_B (m^2)		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Hailin	19	0.029	0.011	0.024	0.023	0.006	0.013	0.024	0.007	0.014
		9	3	4	0	1	5	0	3	5
Dahailin	7	0.035	0.015	0.026	0.016	0.007	0.012	0.018	0.007	0.013
		6	6	4	5	2	8	0	5	7
Linkou	29	0.051	0.005	0.025	0.024	0.003	0.012	0.026	0.003	0.013
		5	8	4	6	4	0	9	9	2
Huanan	25	0.056	0.005	0.023	0.029	0.003	0.012	0.031	0.003	0.013
		0	8	2	3	5	1	2	4	1
Total	80	0.056	0.005	0.024	0.029	0.003	0.012	0.031	0.003	0.013
		0	8	5	3	4	5	2	4	5

 A_B : stem area at crown base; $A_{1.3}$: stem area at 1.3m

Table S5 Results of Analysis of Co-Variance (ANCOVA)

Dependent Variable	Covariate	Fixed factor	Effects(p)			R^2	R^2_{adj}
			Covariate	Fixed factor	Interaction		
LB	A _B	Site	<0.001	0.662	<0.001	0.951	0.950
BB	A _B	Site	<0.001	0.077	0.003	0.952	0.951
CB	A _B	Site	<0.001	0.180	0.005	0.954	0.953
LB	D ² H	Site	<0.001	<0.001	0.000	0.827	0.823
BB	D ² H	Site	<0.001	0.017	0.001	0.834	0.831
CB	D ² H	Site	<0.001	0.010	0.001	0.835	0.831
LB	A _B	Density	<0.001	0.103	<0.001	0.949	0.948
BB	A _B	Density	<0.001	0.178	0.005	0.943	0.942
CB	A _B	Density	<0.001	0.169	0.002	0.946	0.945
LB	D ² H	Density	<0.001	0.004	0.033	0.817	0.814
BB	D ² H	Density	<0.001	0.000	0.000	0.841	0.839
CB	D ² H	Density	<0.001	0.000	0.000	0.840	0.838
LB	A _B	Age	<0.001	0.006	0.001	0.946	0.945
BB	A _B	Age	<0.001	0.041	0.002	0.945	0.944
CB	A _B	Age	<0.001	0.024	0.001	0.947	0.946
LB	D ² H	Age	<0.001	0.010	<0.001	0.810	0.807
BB	D ² H	Age	<0.001	0.006	0.001	0.831	0.829
CB	D ² H	Age	<0.001	0.002	<0.001	0.830	0.827

LB: leaf biomass; BB: branch biomass; CB: crown biomass; A_B: stem area at crown base;

D: diameter at breast height; H: tree height; R^2 : coefficient of determination; R^2_{adj} : adjusted

R -squared; CI: confidence interval. $p < 0.05$ indicates that the effect of variables is significant.