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–   (12113. 92 Mg C)   (165. 03 Mg C • hm⁻²)

–   (680. 95 Mg C)   101. 26 Mg C • hm⁻².

76. 08 ~ 144. 95

0. 16 ~ 20. 62 Mg C • hm⁻².

23092. 39 Mg C   81. 7%

126. 17 Mg C • hm⁻².   28254. 22 Mg C

96. 73 Mg C • hm⁻².

Estimation for vegetation carbon storage in Tiantong National Forest Park. GUO Chun-zi[1 2 3]   WU Yang-yang[1 2 3]   NI Jian[1 2 3] (¹*Department of Environmental Science   East China Normal University   Shanghai 200241   China*; ²*Zhejiang Tiantong National Forest Ecosystem Observation and Research Station   Ningbo 315114   Zhejiang   China*; ³*State Key Laboratory of Environmental Geochemistry   Institute of Geochemistry   Chinese Academy of Sciences   Guiyang 550002   China*). *-Chin. J. Appl. Ecol.   2014   25*(11): 3099 – 3109.

Abstract: Based on the field investigation and the data combination from literature   vegetation carbon storage   carbon density   and their spatial distribution were examined across six forest community types (*Schima superba – Castanopsis fargesii* community   *S. superba – C. fargesii* with *C. sclerophylla* community   *S. superba – C. fargesii* with *Distylium myricoides* community   *Illicium lanceolatum – Choerospondias axillaris* community   *Liquidambar formosana – Pinus massoniana* community and *Hedyotis auricularia – Phylostachys pubescens* community) in Tiantong National Forest Park   Zhejiang Province   by using the allometric biomass models for trees and shrubs. Results showed that: Among the six communities investigated   carbon storage and carbon density were highest in the *S. superba – C. fargesii* with *C. sclerophylla* community (storage: 12113. 92 Mg C; density: 165. 03 Mg C • hm⁻²)   but lowest in the *I. lanceolatum – C. axillaris* community (storage: 680. 95 Mg C; density: 101. 26 Mg C • hm⁻²). Carbon storage was significantly higher in evergreen trees than in deciduous trees across six communities. Carbon density ranged from 76. 08 to 144. 95 Mg C • hm⁻²   and from 0. 16 to 20. 62 Mg C • hm⁻² for evergreen trees and deciduous trees   respectively. Carbon storage was highest in stems among tree tissues in the tree layer throughout communities. Among vegetation types   evergreen broad-leaved forest had the highest carbon storage (23092. 39 Mg C)   accounting for 81. 7% of the total carbon storage in all forest types   with a carbon density of 126. 17 Mg C • hm⁻². Total carbon storage for all vegetation types in Tiantong Na-

tional Forest Park was 28254. 22 Mg C and the carbon density was 96. 73 Mg C • hm^{-2}.

Key words: biomass; vegetation carbon storage; carbon density; allometric biomass equation; evergreen broad-leaved forest.

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图 1

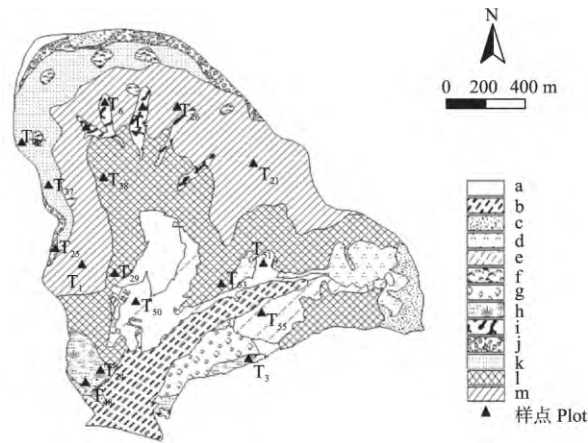**Fig. 1** Vegetation and location of sampling sites in Tiantong National Forest Park.

a) Non-forest area; b) – *Rhododendron simsii* – *Quercus fabric* community; c) *Pinus massoniana* young plantation; d) – *Liquidambar formosana* – *Cunninghamia lanceolata* community; e) – *Hedyotis auricularia* – *Phylostachys pubescens* community; f) – *Lithocarpus henryi* – *Carpinus viminea* community; g) – *Platycarya strobilacea* – *L. formosana* community; h) – *L. formosana* – *P. massoniana* community; i) – *Illicium lanceolatum* – *Choerospondias axillaris* community; j) – *Lithocarpus henryi* – *Cyclobalanopsis sessilifolia* community; k) – *Schima superba* – *Castanopsis fargesii* with *Distylium myricoides* community; l) – *S. superba* – *C. fargesii* with *C. sclerophylla* community; m) *S. superba* – *C. fargesii* community.

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Table 1 Allometric biomass equations for the subtropical evergreen broad-leaved forests in Eastern China

Species/PFTs	Study site	Forest type	Component	Regression model	r	Reference
1) *Loropetalun chinense*	Qianyanzhou Jiangxi	Subtropical plantation	Aboveground Branch Leaf	$W = 0.0024(GH)^{1.0973}$ $W = 0.000796(GH)^{1.1878}$ $W = 0.0114(GH)^{0.7581}$	0.8436 0.8515 0.5713	30
Schima superba	Tiantong Zhejiang	Typical evergreen broad-leaved forest	Aboveground Stem Branch Leaf	$W = 0.1619D^{2.2993}$ $W = 0.0916D^{2.3612}$ $W = 0.0483D^{2.261}$ $W = 0.182e^{0.1672D}$	0.9987 0.9957 0.9933 0.9976	31
Castanopsis carlesii	Tiantong Zhejiang	Typical evergreen broad-leaved forest	Aboveground Stem Branch Leaf	$W = 0.7597e^{0.3518H}$ $W = 0.5113e^{0.3516H}$ $W = 0.1465e^{0.3712H}$ $W = 0.1133e^{0.2627H}$	0.9741 0.9791 0.9496 0.9688	31
Castanopsis fargesii	Tiantong Zhejiang	Typical evergreen broad-leaved forest	Aboveground Stem Branch Leaf	$W = 0.3343e^{0.4064H}$ $W = 0.2393e^{0.404H}$ $W = 0.0503e^{0.4434H}$ $W = 0.0398e^{0.3179H}$	0.9916 0.9868 0.9903 0.9844	31
2) *Lithocarpus glaber*	Tiantong Zhejiang	Typical evergreen broad-leaved forest	Aboveground Stem Branch Leaf	$W = 0.449e^{0.2932D}$ $W = 0.1583D^{2.2171}$ $W = 0.0716e^{0.3136D}$ $W = 0.047e^{0.2393D}$	0.9908 0.9924 0.9845 0.9372	31
3) *Cyclobalanopsis myrsinaefolia*	Tiantong Zhejiang	Typical evergreen broad-leaved forest	Aboveground Stem Branch Leaf	$W = 0.0109H^{3.8461}$ $W = 0.0102H^{3.6991}$ $W = 0.0368e^{0.5097H}$ $W = 0.0109e^{0.1387D}$	0.9887 0.9909 0.9846 0.9854	31
Syzygium buxifolium	Jinggangshan Jiangxi	Middle subtropical moist evergreen broad-leaved forest	Whole plant	$W = 4.299 + 0.004Dr^2H$	0.968	32
Maesa japonica			Whole plant	$W = 0.165Dr^{2.646}$	0.904	
4) *Rhododendron latoucheae*			Whole plant	$W = 27.602 + 0.004Dr^2H$	0.966	
Alniphyllum fortunei			Whole plant	$W = 1.262 + 0.002Dr^2H$	0.941	
5) *Indocalamus tessellatus*			Whole plant	$W = 0.319Dr^{2.552}$	0.950	
6) *Ardisia crenata*			Whole plant	$W = -2.804 - 2.909Dr + 1.41Dr^2$	0.991	
Toxicodendron succedaneum			Whole plant	$W = 1.253 + 0.004Dr^2H$	0.916	
Quercus fabri			Aboveground	$W = 1.1214G$	0.9003	33
7) *Wendlandia uvariifolia*	Changyang Hubei	Subtropical shrubby grass-land	Aboveground	$W = 0.7714G$	0.9662	
Quercus acutissima			Aboveground	$W = 1.0232G$	0.9243	
8) *Dalbergia hupeana*			Aboveground	$W = 1.1464G$	0.9195	
9) *Smilax china*			Aboveground	$W = 0.7915G$	0.9659	
Rhus chinensis	Qianyanzhou Jiangxi	Subtropical plantation	Whole plant	$W = 3.43 + 0.501Dr^2G$	0.991	34
Symplocos paniculate			Whole plant	$W = 8.559 + 0.49Dr^2H$	0.967	
Rubus corchorifolius	Qianyanzhou Jiangxi	Subtropical plantation	Whole plant	$W = 0.1685(Dr^2H)^{0.6165}$	0.843	35
10) *Callicarpa bodinieri*			Whole plant	$W = 4.6484 + 0.0028Dr^2H$	0.942	
11) *Cinnamomum camphora*	Huitong Hunan	Subtropical evergreen broad-leaved forest	Stem Branch Leaf Skin Root	$W = 20.583(D^2H)^{1.069}$ $W = 33.366(D^2H)^{0.6806}$ $W = 29.959(D^2H)^{0.8664}$ $W = 4.6996(D^2H)^{1.1397}$ $W = 26.789(D^2H)^{0.9108}$	0.9775 0.6866 0.7038 0.9501 0.9348	36
12) *Elaeocarpus decipiens*	Huitong Hunan	Subtropical evergreen broad-leaved forest	Stem Branch Leaf Skin Root	$W = 126.55(D^2H)^{0.4929}$ $W = 36.356(D^2H)^{0.5317}$ $W = 51.924(D^2H)^{0.5559}$ $W = 23.391(D^2H)^{0.3742}$ $W = 84.776(D^2H)^{0.4974}$	0.9691 0.7810 0.9892 0.9596 0.9805	36

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Table 1   Continued

Species/PFTs	Study site	Forest type	Component	Regression model	r	Reference
[13] Evergreen companion subtrees	Jiande Zhejiang	Subtropical evergreen broad-leaved forest	Whole plant	$W = 136.175(D^2H)^{0.7897}$	0.9987	37
			Aboveground	$W = 248.253 + 33.3112D^2H$	0.9992	
			Underground	$W = 68.564(D^2H)^{0.643}$	0.9971	
			Stem	$W = 40.756(D^2H)^{0.9199}$	0.9978	
			Branch	$W = D/(0.022 - 0.0032D)$	0.9951	
			Leaf	$W = 20.335e^{0.5544D}$	0.9840	
			Root	$W = 35.07(D^2H)^{0.6499}$	0.9966	
[14] Deciduous subtrees	Jiande Zhejiang	Subtropical evergreen broad-leaved forest	Whole plant	$W = 86.589(D^2H)^{0.8699}$	0.9876	37
			aboveground	$W = -22.704 + 35.686D^2H$	0.9926	
			Underground	$W = 74.066(D^2H)^{0.5827}$	0.9950	
			Stem	$W = 28.579(D^2H)e^{-0.000309D^2H}$	0.9915	
			Branch	$W = 2.222(D^2H)^{1.1548}$	0.9897	
			Leaf	$W = 4.551D^{2.3727}$	0.9946	
			Root	$W = 38.031(D^2H)^{0.5902}$	0.9925	
[15] Chinese sweet gum	Zhejiang	Subtropical evergreen broad-leaved forest	Aboveground	$W = 34.514(D^2H)^{1.0037}$	0.9549	38
Castanopsis sclerophylla			Aboveground	$W = 60.143(D^2H)^{0.9274}$	0.9608	
[16] Other species in the evergreen broad-leaved forest in Zhejiang			Aboveground	$W = 94.594(D^2H)^{0.8666}$	0.9053	
Ⅱ [17] Hardwood (Ⅱ)	Zhejiang	Evergreen broad-leaved forest	Stem	$W = 0.0803H^{0.7815}D^{1.8056}$		39
			Crown	$W = 0.286D^{1.0968}G^{0.945}$		
			Root	$W = 0.247H^{0.1745}D^{1.7954}$		
Phyllostachys pubescens	Zhejiang	Evergreen broad-leaved forest	Stem	$W = 0.0398H^{0.5778}D^{1.854}$		39
			Crown	$W = 0.28D^{0.8357}G^{0.274}$		
			Root	$W = 0.371H^{0.1357}D^{0.9817}$		
Other species of Bambusoideae	Zhejiang	Evergreen broad-leaved forest	Whole plant	$W = 0.015189Dr^{0.6305}H^{2.0687}$		39
Herb	Zhejiang	Evergreen broad-leaved forest	Total amount per unit area	$W = 0.05492H^{0.803}C^{1.0877}$		39
[18] *Wookwardia japonica*	Qianyanzhou Jiangxi	Subtropical conifer plantation	Aboveground	$W = 2.518(Dr^2H)^{0.616}$		40

1) Distylium myricoides; 2) Lithocarpus henryi; 3) Cyclobalanopsis stewardiana、 Cyclobalanopsis glauca、 Cyclobalanopsis nubium; 4) Rhododendron ovatum、 Vaccinium mandarinorum; 5) Pleioblastus amarus、 Miscanthus floridulus; 6) Ardisia crenata、 Ardisia crenata; 7) Tricalysia dubia、 Damnacanthus indicus、 Elaeagnus pungens; 8) Ormosia henryi; 9) Dioscorea opposite; 10) Clerodendrum cyrtophyllum、 Premna microphylla; 11) Machilus thunbergii、 Machilus leptophylla、 Cinnamomum subavenium、 Litsea coreana、 Litsea elongata、 Phoebe sheareri、 Cinnamomum japonicum; 12) Elaeocarpus japonicus; 13) Helicia cochinchinensis、 Daphniphyllum oldhamii、 Myrica rubra、 Neolitsea aurata、 Photinia glabra、 Illicium lanceolatum、 Michelia figo、 Symplocos sumuntia、 Symplocos lancifolia、 Symplocos setchuensis、 Symplocos heishanensis、 Symplocos anomala、 Symplocos laurina、 Symplocos stellaris、 Eurya loquaiana、 Eurya muricata、 Eurya rubiginosa、 Camellia fraterna、 Camellia oleifera、 Camellia japonica、 Ternstroemia gymnanthera、 Cleyera japonica; 14) Euscaphis japonica、 Boehmeria nivea、 Ficus erecta、 Helicteres angustifolia、 Euonymus alatus、 Euonymus centidens、 Lindera rubronervia、 Mallotus tenuifolius、 Styrax confusus、 Styrax japonicus、 Litsea cubeba、 Tarenna mollissima; 15) Acer olivaceum、 Acer acutum、 Acer buergerianum; 16) Sassafras tzumu、 Castanea seguinii、 Platycarya strobilacea、 Sapindus mukorossi、 Kalopanax septemlobus、 Vernicia fordii、 Carpinus viminea、 Ehretia thyrsiflora、 Choerospondias axillaris、 Juglans cathayensis; 17) Ilex purpurea、 Ilex latifolia、 Ilex hylonoma、 Ilex elmerrilliana、 Michelia maudiae、 Osmanthus cooperi、 Fraxinus insularis; 18) Pteridium aquilinum、 Diplopterygium glaucum、 Cyrtomium fortunei、 Lygodium japonicum. *W*: Biomass; *D*: Diameter at breast height; *Dr*: Basal diameter; *H*: Height; *G*: Crown diameter; *C*: Coverage.

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Table 2　Biomass，carbon storage and carbon density of different communities in Tiantong National Forest Park（mean ± SD）

Community type	Area (hm²)	Tree			Shrub			Herb			Community			
		Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C·hm⁻²)	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C·hm⁻²)	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C·hm⁻²)	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C·hm⁻²)	CV (%)
A	76.65	17204.66 ±7598.24	8602.33 ± 3799.12	112.23 ± 49.57	885.99 ±420.49	442.99 ± 210.24	5.78 ± 2.74	202.41 ±150.10	101.20 ± 75.05	1.32 ± 0.98	18293.06	9146.53	119.33ab	40
B	73.40	22610.68 ±12582.70	11305.34 ± 6291.35	154.02 ± 85.71	988.34 ±424.05	494.17 ± 212.03	6.73 ± 2.89	628.82 ±188.83	314.41 ± 94.42	4.28 ± 1.29	24227.84	12113.92	165.03b	54
C	25.02	4253.50 ±1489.83	2126.75 ± 744.92	85.00 ± 29.77	246.30 ±101.84	123.15 ± 50.92	4.92 ± 2.04	210.72 ±49.70	105.36 ± 24.85	4.21 ± 0.99	4710.52	2355.26	94.14ab	30
D	6.73	1286.88 ±759.89	643.44 ± 379.94	95.68 ± 56.50	54.85 ±5.02	27.42 ± 2.51	4.08 ± 0.37	20.16 ±7.93	10.08 ± 3.97	1.50 ± 0.59	1361.90	680.95	101.26ab	56
E	8.69	1793.44 ±588.58	896.72 ± 294.29	103.19 ± 33.87	38.77 ±7.73	19.39 ± 3.86	2.23 ± 0.44	107.20 ±21.28	53.60 ± 10.64	6.17 ± 1.22	1939.41	969.71	111.59ab	30
F	26.06	2124.34 ±245.70	1062.17 ± 122.85	40.76 ± 4.71	42.37 ±5.29	21.19 ± 2.64	0.81 ± 0.10	79.15 ±42.59	39.58 ± 21.29	1.52 ± 0.82	2245.86	1122.93	43.09a	9

A：　　　　－　　　Schima superba－Castanopsis fargesii community；B：　　　　－　　　　Schima superba－Castanopsis fargesii with C. sclerophylla community；C：　　　　－　　　Schima superba－Castanopsis fargesii with Distylium myricoides community；D：　－　　Illicium lanceolatum－Choerospondias axillaris community；E：　　　－　　　Liquidambar formosana－Pinus massoniana community；F：　　　－　　Hedyotis auricularia－Phylostachys pubescens community.　　　　　（P < 0.05）Different small letters in the same column meant significant difference at 0.05 level.　　The same below.

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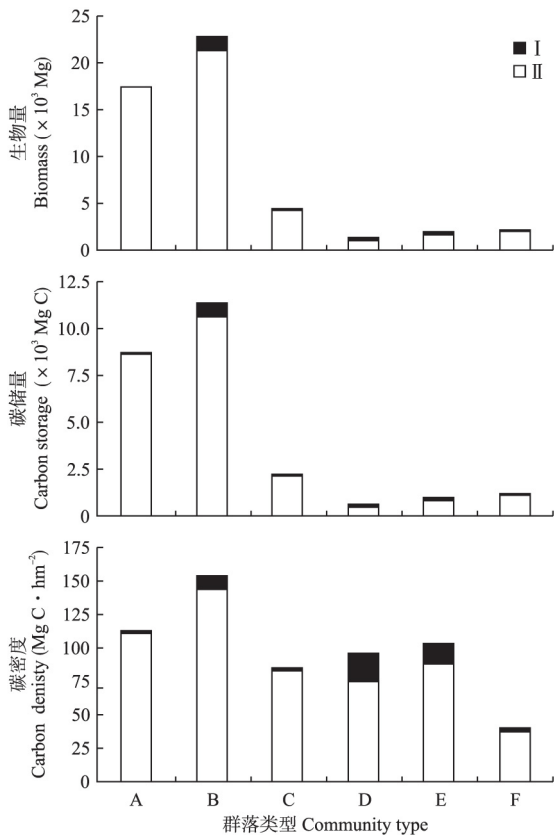**Fig. 2　Biomass，carbon storage and carbon density of evergreen and deciduous trees of different communities in Tiantong National Forest Park.**

A ~ F：　　　　（　　2）Community type（Saw Table 2）. Ⅰ：　　　Deciduous tree；Ⅱ：　　　　Evergreen tree.

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Table 3 Biomass carbon storage and carbon density in tree layer of different communities in Tiantong National Forest Park (mean ± SD)

Community type	Branch			Stem			Leaf			Underground			Total carbon storage (Mg C)
	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C · hm⁻²)	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C · hm⁻²)	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C · hm⁻²)	Biomass (Mg)	Carbon storage (Mg C)	Carbon density (Mg C · hm⁻²)	
]A	4489.53 ± 2944.78	2244.77 ± 1472.39	29.29 ± 19.21	9301.45 ± 3166.83	4650.72 ± 1583.41	60.68 ± 20.66	528.30 ± 268.30	264.15 ± 134.15	3.45 ± 1.75	2867.16 ± 1333.68	1433.58 ± 666.84	18.70 ± 8.70	8593.22
B	6068.62 ± 5496.84	3034.31 ± 2748.42	41.34 ± 37.44	8420.07 ± 6496.48	4210.04 ± 3248.24	57.36 ± 44.25	2323.17 ± 1948.29	1161.58 ± 974.14	15.82 ± 13.27	3434.77 ± 1543.47	1717.39 ± 771.74	23.40 ± 10.51	10123.32
C	949.22 ± 486.30	474.61 ± 243.15	18.97 ± 9.72	2285.15 ± 904.48	1142.58 ± 452.24	45.67 ± 18.08	81.95 ± 46.85	40.98 ± 23.42	1.64 ± 0.94	880.44 ± 206.57	440.22 ± 103.28	17.59 ± 4.13	2098.38
D	255.70 ± 210.99	127.85 ± 105.49	19.01 ± 15.69	355.66 ± 95.32	177.83 ± 47.66	26.44 ± 7.09	238.22 ± 297.86	119.11 ± 148.93	17.71 ± 22.15	208.49 ± 113.61	104.24 ± 56.81	15.50 ± 8.45	529.04
E	136.09 ± 33.44	68.05 ± 16.72	7.83 ± 1.92	840.94 ± 388.07	420.47 ± 194.04	48.39 ± 22.33	46.83 ± 46.47	23.41 ± 23.23	2.69 ± 2.67	554.12 ± 224.39	277.06 ± 112.19	31.88 ± 12.91	788.99
F	246.30 ± 41.92	123.15 ± 20.96	4.73 ± 0.80	1256.44 ± 130.44	628.22 ± 65.22	24.11 ± 2.50	–	–	–	502.55 ± 29.81	251.27 ± 14.90	9.64 ± 0.57	1002.64

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Table 4 Carbon storage and carbon density of different forest types in Tiantong National Forest Park

Forest type	Area (hm²)	Carbon storage (Mg C)	Carbon density (Mg C · hm⁻²)	Percentage
Evergreen broad-leaved forest	183.03	23092.39	126.17	81.7
Evergreen and deciduous broad-leaved mixed forest	9.71	983.20	101.26	3.5
Deciduous broad-leaved forest	8.39	208.39	24.83	0.7
Evergreen coniferous forest	20.13	2246.56	111.59	8.0
Moso bamboo forest	26.06	1122.93	43.09	4.0
Shrubland	24.27	239.76	9.88	0.9
Pinus massoniana artificial young forest	7.98	212.69	26.67	0.8
Non-forest	12.52	148.30	11.85	0.5
Total	292.08	28254.22	96.73	100

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　　270～330 m　　　　[42 – 43]　. Fang　[9]

　　　　　　　　　　　44. 91 Mg C · hm⁻²

　　　．　－　　　[40]

；　　　－　　42. 82 Mg C · hm⁻²　　[44]

　　　　　　　　57. 07 Mg C · hm⁻²．

　　　　　　　　96. 73 Mg C · hm⁻²

　　[21]　　　¹ (86. 00 Mg C · hm⁻²) ．

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5
Table 5　Vegetation carbon density of different study areas in subtropical and tropical China

Study site	Forest type	Altitude (m)	Geographical location	Slope (°)	Vegetation carbon density (Mg C·hm⁻²)	Reference
Xishuangbanna	Tropical seasonal rain forest	730	21°57′39.4″ N 101°12′00.4″ E	22	154.67	45
Dinghu Mountain	Evergreen broad-leaved forest	300	23°10′9.9″ N 112°32′22.64″ E	30	149.45	45
Ailao Mountain	Moist evergreen broad-leaved forest	2488	24°32′53″ N 101°01′41″ E	15	239.40	45
Tiantong Zhejiang Province	Subtropical evergreen broad-leaved forest	300	29°48′ N 121°47′ E	10～30	96.73	This study
The Three Gorges Reservoir Area	Subtropical evergreen broad-leaved forest	1080～1920	30°10′58″—31°24′14″ N 108°23′28″—110°30′51″ E	5～40	42.80	46
Central Jiangxi Province	Subtropical evergreen broad-leaved forest	83～1041	26°29′17″—26°51′49″ N 114°06′39″—115°04′10″ E	15～35	43.00	42

3.3

47

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0.5

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