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The biomass and aboveground net primary productivity of *Schima superba–Castanopsis carlesii* forests in east China

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The biomass and productivity of *Schima superba–Castanopsis carlesii* forests in Tiantong, Zhejiang Province, were determined using overlapping quadrants and stem analyses. The total community biomass was (225.3±30.1) t hm^{-2}, of which the aboveground parts accounted for 72.0% and the underground parts accounted for 28.0%. About 87.2% of biomass existed in the tree layer. The resprouting biomass was small, of which over 95.0% occurred in the shrub layer. The productivity of the aboveground parts of the community was (386.8±98.9) g $m^{-2}a^{-1}$, in which more than 96.0% was present at the tree level. The trunk's contribution to productivity was the greatest, while that of leaves was the smallest. In China, the community biomass of subtropical evergreen broadleaved forests differs significantly with the age of the forest. The community biomass of the 52-year-old *S. superba–C. carlesii* forests in this study was lower than the average biomass of subtropical evergreen broadleaved forests in China, and was lower than the biomass of other subtropical evergreen broadleaved forests elsewhere in the world. Moreover, its productivity was lower than the model estimate, indicating that without disturbance, this community has great developmental potential in terms of community biomass and productivity.

evergreen broadleaved forest, community biomass, net primary productivity, distribution pattern, *Schima superba–Castanopsis carlesii* community

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The biomass and productivity of forests are not only the structural and functional bases of the forest ecosystem but are also the foundations for studies on forests' carbon-fixation capability and are forecasters of global change. Large-scale studies on forest biomass and productivity were initiated in the mid-1960s when the International Biological Program undertook surveys and studies on different types of forests [1–11]. In the late 1980s, as study of the global carbon cycle gained more attention, the quantity of carbon released into the atmosphere caused by land-use changes was estimated using the biomass and area statistics of previous sample plots [12–15]. In the late 1990s, to scientifically evaluate the function of the forest ecosystem in terms of the carbon source and carbon sink of the global atmosphere, scientists began to study the potential biomass of the forest ecosystem and the dynamic changes in its biomass and productivity as a result of human and natural interferences [16–20]. With the advent of the new century and the new emphasis on the role of the forest ecosystem in global change, the total organic matter quantity and net production of forest ecosystems have been proposed [21–24], which include not only the biomass and productivity of plant material in forests but also the quantity and accumulation of organic matter in the soil. Along with the constant progress

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of research on the influence of global climate change on forest ecosystems, estimates of regional and global productivity have also become research hotspots [25–30].

The subtropical evergreen broadleaved forest (EBLF) is a typical vegetation type that is widely distributed in the east coast humid subtropical climate zone of China [31]. The EBLF in Tiantong National Forest Park, located in the eastern hilly regions of Zhejiang Province, is representative of this vegetation type [32]. The determination of its biomass and productivity has important significance in estimating the carbon reserves in the forest ecosystem of the area. In this study, we determine the biomass and aboveground productivity of the community dominated by *Schima superba* and *Castanopsis carlesii* using overlapping quadrants and stem analyses. The data obtained for this forest were compared with those collected from other eastern Chinese EBLFs to elucidate its productivity level and development potential. This study is expected to facilitate the long-term monitoring of Tiantong's, as well as China's, subtropical EBLF ecosystem and serve as a scientific basis for sustainable forestry operations, rational utilization of forest resources, and improvement of the ecological environment. It will also provide additional information to the body of knowledge on China's subtropical, as well as EBLF, productivity and enrich our understanding of EBLFs in eastern China.

1 Study site

Tiantong National Forest Park, located in the south-eastern part of Yinzhou District in Zhejiang Province, is 28 km from Ningbo (29°48′ N, 121°47′ E) and has an area of 349 hm^2. The well-preserved forest vegetation located in this park is representative of the zonal vegetation type in the hilly area of eastern Zhejiang Province. It has a warm and humid subtropical climate with an average annual temperature of 16.2°C. The average temperatures are 28.1°C in the hottest month of July and 4.2°C in the coldest month of January. The annual accumulated temperature above 10°C is 5166.2°C. Its Kira's warmth index [33] is 135°C $month^{-1}$, and its coldness index is –0.8°C $month^{-1}$. The annual precipitation of 1374.7 mm is mostly concentrated in the summer, while the annual average relative humidity is 82% and shows little intra-annual variability. The mean annual evaporation is 1320.1 mm, which is less than the annual precipitation. The soil in the forest park is mostly mountain yellow-red soil. The soil parent material mainly includes Mesozoic sedimentary rocks, some acidic igneous rocks, and granite residual weathered material [32].

2 Methods

2.1 Profile of the sample plot

Five 20 m×20 m sample plots with slopes of 25–30° were established 260 m above sea level on the south-eastern slope (SE25°) of Tiantong Fangyang Hill. The trees in the four sample plots were felled [34], and the biomass of three sample plots was determined. The community was divided into three layers: the tree layer ($H>8$ m), the shrub layer (1.5 m$<H<$8 m), and the herb layer ($H<1.5$ m). The dominant tree species were *S. superba* and *C. carlesii*, although some *Lithocarpus glaber*, *Castanopsis fargesii*, and *Cyclobalanopsis myrsinaefolia* were also found. The understory shrubs mainly included plants from the families of Theaceae, Symplocaceae, and Lauraceae. The herb layer was mainly composed of ferns, such as *Woodwardia japonica, Dryopteris erythrosora,* and *Hicriopteris glauca*.

2.2 Biomass measurement

Biomass was determined by the overlapping quadrant method (Figure 1). Measurements were performed sequentially from the herb layer to the tree layer. The biomasses of seedlings and sprouting individuals were measured separately. The experimental treatment was completed in November 2003.

2.2.1 Measurement of biomass in the litter and herb layers

A 5 m×5 m quadrat was randomly selected from each plot. Deadwood and leaf litter within the quadrat were collected and weighed separately. For woody plants, the stems and leaves were collected separately and their fresh weights were determined immediately. For herbs and lianas, the whole-plant weight was determined.

2.2.2 Measurement of biomass in the shrub layer

In a 10 m×10 m quadrat from each plot, the fresh weight of leaves, branches, and stems were weighed separately.

2.2.3 Measurement of biomass in the tree layer

For the tree and shrub layers, 41 tree samples representative of the main tree species were selected from all the sampling plots according to their diameter class (Appendix Table 1) and cut down to measure the fresh weights of their leaves, branches, and stems. The relationships between the biomasses of different organs and diameter at breast height (DBH) were then established for each species (Appendix Table 1). These data were used to estimate the biomass of all

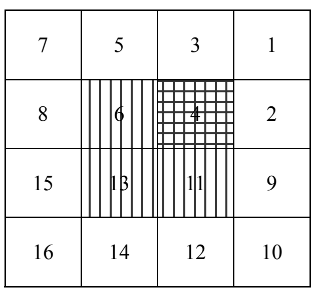

Figure 1 Arrangement of sample plots. Each plot was composed of 16 quadrats each 5 m×5 m in size.

individual main tree species. For other tree species fewer than five in number, all individuals were directly taken for measurement of the fresh weight of the different organs.

2.2.4 Measurement of the biomass of the root system

The biomass of the root system was calculated through the establishment of the relationship between the DBH of trees and the biomasses of their roots (Appendix Table 2). Recovery experiments had to be carried out in the sampling plots, so eight individuals from the main woody species (Appendix Table 2) were selected from the same type of community nearby the plots, according to diameter class. The roots of each tree were then dug up and weighed. In addition, the roots of all plants from three randomly selected 2 m×2 m quadrats from the herb layer were dug up and weighed.

For all fresh weight samples, 5% of the total weight (100% if the total weight was less than 500 g) was brought back to the laboratory, dried in an 80°C oven to a constant weight, and then the dry weights of each sample was measured.

2.3 Tree ring measurement

For all tree and shrub species, a tree ring disc was attached near the base of each sample stem and then sanded with sandpaper to measure the age and annual ring width using the ring analyzer WinDENDROTM2003a. Tree rings were read in four directions for trees and in two directions for shrubs [35] with an accuracy of 0.001 mm. The average reading was taken as the ring width.

2.4 Calculation of aboveground net primary productivity

2.4.1 Tree productivity

The base diameter of a sample tree is directly related to the biomass of its various organs [31]. Therefore, the biomass increment over the previous 5 years and the annual productivity were calculated according to the annual ring widths of the base diameters by establishing a relationship between the two.

2.4.2 Shrub productivity

Solar radiation is the main factor that influences shrub layer productivity, and species with the same vertical height have similar productivity levels. Therefore, to estimate productivity, the shrub layer was further divided into four height levels (i.e., 1.5 m<H⩽2.0 m, 2.1 m<H⩽4.0 m, 4.1 m<H⩽ 6.0 m, and 6.1 m<H⩽8.0 m). Shrub layer species consisted of tree saplings (1.5 m⩽H⩽8.0 m) and other shrub species. The biomass increment of tree saplings was evaluated using the same method as that of trees in the tree layer. Specifically, estimates were based on the relationship between the sample sapling's base diameter and its organ biomass. The recent 5-year average productivity of a shrub species was estimated based on the average organ biomass increment of tree saplings in the same height level.

3 Results

3.1 Community biomass

The total community biomass was (225.3±30.1) t hm^{-2} (Table 1). The aboveground biomass measured (162.3±19.9) t hm^{-2}, accounting for 72.0% of the total community biomass, while the underground biomass measured (63.0±12.3) t hm^{-2}, accounting for 28.0% of the total community biomass. The ratio of aboveground biomass to underground biomass was 2.58. About 90.8% of the aboveground biomass in the community was concentrated in the tree layer, measuring (147.3±14.3) t hm^{-2}. The shrub and litterfall layers (dead standing trees, deadwood, and leaf litter) showed relatively small biomasses, accounting for only 5.5% and 3.0% of the total forest biomass, respectively. Both the herb and liana plant layers, on the other hand, accounted for less than 0.5% of the total biomass.

As seen from the biomasses of the plant organs in the entire community, the biomasses of organs are arranged in the following sequence: stem>root>branch>leaf. The stem biomass of the tree layer accounted for over 50.0% of the layer's biomass (Table 2), and its branch biomass (22.0%) was smaller than its root biomass (25.0%). In the shrub layer, the root biomass was highest (43.0%). From the tree layer to the herb layer, the biomasses of stems and branches gradually decreased, while the root biomass gradually increased.

The total sprout biomass was (2.1±1.5) t hm^{-2} (Table 3), accounting for about 0.3% of the total biomass in the community, and over 95% was in the shrub layer. The sprout biomass only accounted for 0.1% of the total biomass in the herb layer. In the shrub layer, 58.4% of the sprout biomass

Table 1 Distribution of biomass in different layers of the community (biomass data are the mean±SD)

Layer	Biomass (t hm^{-2})	Percentage (%)
Aboveground part		
Tree layer	147.3±14.3	65.4 (90.8)
Shrub layer	8.9±5.6	4.0 (5.5)
Herb layer	0.7±0.2	0.3 (0.4)
Litterfall	4.9±1.8	2.2 (3.0)
Lianas	0.5±0.7	0.2 (0.3)
Total aboveground parts	162.3±19.9	72.0
Underground part	63.0±12.3	28.0
Total	225.3±30.1	100

Table 2 Distribution of organ biomass in the community (data are the mean±SD)

Vegetation	Aboveground part (t hm^{-2})			Underground part (t hm^{-2})	Total (t hm^{-2})
	Leaf	Branch	Stem	Root	
Tree layer	5.0±1.2	43.3±5.9	98.9±20.5	49.1±16.8	196.4±18.2[a]
Percentage (%)	2.5	22.0	50.4	25.0	
Shrub layer	0.9±0.6	1.8±1.1	6.1±3.9	6.8±2.1[b]	15.7±7.5
Percentage (%)	5.9	11.7	39.2	43.2	
Herb layer	0.1±0.1	0.4±0.2		7.2±5.9	7.9±5.9[c]
Percentage (%)	1.6	4.7		91.3	

a, Includes the biomass of fruits. b, Includes the biomass of the root system of lianas. c, Includes the biomass of herbs.

originated from the dominant species, *C. carlesii*, followed in rank by *Myrica rubra* (18.5%), *S. superba* (5%), *C. myrsinaefolia* (3.8%), and *Symplocos sumuntia* (4.7%). Other species each contributed less than 1% to the sprout biomass. Of the herb layer sprout biomass, 88.0% was contributed by *C. carlesii,* followed by *C. fargesii*, which contributed 7.50%.

3.2 Aboveground net primary productivity

The combined aboveground net primary productivity (ANPP) for the tree and shrub layers was (386.8±98.9) g m^{-2} a^{-1} (Table 4), of which over 96% was from the tree layer, amounting to about (373.0±104.8) g m^{-2} a^{-1}. Tree stems contributed the most to productivity (64.9%), while leaves contributed the least (6.6%).

Table 3 Distribution of sprouting stem biomass in aboveground layers in the community (data are the mean±SD)

Vegetation layer	Biomass (t hm^{-2})			Total
	Leaf	Branch	Stem	
Shrub	0.1±0.1	0.4±0.3	1.5±1.1	2.0±1.4
Percentage (%)	6.9	20.0	73.1	100
Herb	0.027±0.016	0.068±0.048		0.095±0.064
Percentage (%)	28.2	71.8		100

Table 4 Aboveground net primary production in aboveground layers (data are the mean±SD)

Vegetation layer	Aboveground net primary productivity (g m^{-2} a^{-1})			Total
	Leaf	Branch	Stem	
Tree	24.5±15.0	98.4±31.1	242.1±63.5	373.0±104.8[a]
Percentage (%)	6.6	26.4	64.9	100[b]
Shrub	3.1±2.1	2.5±2.0	8.2±5.7	13.8±9.8
Percentage (%)	21.8	20.0	58.2	100

a,b) Includes fruits.

4 Discussion

4.1 Chinese evergreen broadleaved forest biomass

The measured biomass of China's natural EBLFs is grouped into different types of EBLFs [36,37], as shown in Table 5. The same table shows that the measured EBLFs include 19 types of communities, including eight eastern typical EBLFs, four western typical EBLFs, and seven seasonal-type EBLFs, mainly involving communities dominated by *Castanopsis* spp., *Cyclobalanopsis glauca*, *S. superba*, and *L. glaber*. The *Erythrophleum fordii* forest on Dinghu Mountain has the greatest living biomass of 568.2 t hm^{-2}, and the 12-year-old *Castanopsis echidnocarpa* forest has the smallest living biomass of 87.8 t hm^{-2}. The eastern typical EBLF has an average biomass of 251.6 t hm^{-2} and an average age of about 40 years. The seasonal and western typical EBLFs have separate average biomasses of 331.7 t hm^{-2}, 335.8 t hm^{-2}, respectively; most of them are mature forests. Although the biomass of the 52-year-old *S. superba–C. carlesii* forest in this study was larger than that of the 35-year old *C. glauca*, *C. fargesii* and *S. superba* forests, and the 42-year old *C. echidnocarpa* forest, it was significantly lower than that of the 35-year old *Castanopsis hystrix* and *Cylobalanopsis chungii* forests, indicating that in addition to the difference in age, a forest's dominant species, ecological habits, regional climates, and site conditions, among other considerations, are important factors that influence a community's biomass.

4.2 Estimate of China's total EBLF biomass

At present, there are two main methods used to study the biomass and productivity of a forest ecosystem. In one method, the biomass and productivity of a forest ecosystem are calculated using existing measured data. In the other method, biomass and productivity are estimated using climate data, remote sensing, and generalized ecological models. To better understand the overall biomass of EBLFs in China, the total biomass of EBLFs in China was estimated based on existing community biomass data and Chinese

Table 5 Aboveground biomass allocation of evergreen broadleaved forests in eastern China

Partition	Community	Place	Latitude and longitude	Age (year)	Biomass ($t\ hm^{-2}$)	Tree	Shrub	Herb	Liana	Litterfall	Total ($t\ hm^{-2}$)	Source
Seasonal EBLF	*Cryptocarya concinna*	Dinghu Mountain	23°08′N 112°35′E	400	Quantity	346.1	21.7	12.7			380.7	[38]
					%	90.9	5.7	3.3				
	Cryptocarya concinna	Dinghu Mountain	23°08′N 112°35′E	400	Quantity	203.6	1.7	0.1	3.0		208.4	[39]
					%	97.7	0.8	0.0	1.4			
	Castanopsis chinensis- Cryptocarya chinensis	Dinghu Mountain	23°08′N 112°35′E	400	Quantity	286.1	8.9	0.3	0.3		295.6	[40]
					%	96.7	3.0	0.1	0.1			
	Erythrophloeum ferdii	Dinghu Mountain	23°08′N 112°35′E	400	Quantity	566.5	1.4	0.2	0.1		568.17	[41]
					%	99.6	0.2	0.2	0.0			
	Ixonanthes chinensis	Heishiding	23°27′N 111°19′E	100	Quantity	353.5	3.8	0.6			358	[42]
					%	98.8	1.1	0.2				
	Castanopsis echidnocarpa	Pu 'er, Yunnan	23°12′N 100°51′E	12	Quantity	80.4	6.6	0.2	0.6		87.8	[43]
					%	91.5	7.5	0.3	0.7			
				42	Quantity	159.0	2.4	0.8	0.4		162.6	
					%	97.8	1.5	0.5	0.2			
	Castanopsis hystrix	Hua'an	24°55′N 117°33′E	34	Quantity	385.5	17.2	2.1		4.6	404.8	[44]
					%	94.2	4.2	0.5		1.1		
				38	Quantity	507.9	8.5	2.7		5.6	519	
					%	96.8	1.6	0.5		1.1		
Eastern typical EBLF	*Cyclobalanopsis glauca*	Jiande	29°24′N 119°31′E	30–35	Quantity	107.5	3.2	0.2	0.5		111.2	[45]
					%	96.6	2.8	0.2	0.4			
	Schima superba	Hangzhou	30°15′N 120°10′E	35	Quantity	107.5	12.8	6.4		7.5	126.6	[46]
					%	80.2	9.5	4.8		5.6		
	Schima superba–Castanopsis carlesii	Tiantong	29°48′N 121°47′E	52	Quantity	196.4	15.7	7.9	0.5	4.9	220.4	This study
					%	87.2	7.0	3.1	0.2	2.2		
	Castanopsis eyrei	Wuyi Mountain	27°42′N 117°41′E	51	Quantity	404.5	2.4	04			407.3	[47]
					%	99.3	0.6	0.1				
	Castanopsis fargesii	Gongcheng	24°37′N 110°38′E	30	Quantity	192.0	2.4	1.5		6.7	195.9	[48]
					%	94.8	1.2	0.7		3.3		
	Castanopsis hystrix–Cyclobalanopsis glauca–Machilus pauhoi	Huitong	26°40′N 109°26′E	70	Quantity	426.8	17.8		1.8	4.7	446.3	[49]
					%	94.6	3.9		0.4	1.0		
	Cyclobalanopsis glauca–Cinnamomum calcareum	Maolan	25°09′N 107°52′E	Middle aged	Quantity	111.5	3.0	0.3	2.8	6.5	117.5	[50]
					%	89.9	2.4	0.2	2.3	5.2		
	Cylobalanopsis chungii	Minqing	26°15′N 118°40′E	35	Quantity	355.3	30.2	2.1		7.4	387.6	[51]
					%	90.0	7.7	0.5		1.9		
Western typical EBLF	*Lithocarpus variolosus*	Ailao Mountain	24°10′N 101°25′E	Nearly mature	Quantity	491.2	7.4	1.1			499.7	[52]
					%	98.3	1.5	0.2				
	Lithocarpus variolosus	Ailao Mountain	24°10′N 101°25′E	Mature	Quantity	494.7	7.4	1.2		5.4	503.2	[53]
					%	97.3	1.5	0.2		1.1		
				Mature	Quantity	243.3	38.4	3.5		7.9	285.1	
					%	83.0	13.1	1.2		2.7		
	Castanopsis arthacantha	Songming	25°24′N 102°45′E	Middle aged	Quantity	260.2	0.5	0.1		8.9	260.8	[54]
					%	96.5	0.2	0.0		3.3		
	Cylobalanopsis delavayii.	Fumin	25°19′N 103°33′E	20	Quantity	125.3	5.1	0.2		5.3	130.6	[55]
					%	92.2	3.7	02		3.9		

vegetation maps [56]. In accordance with a Chinese EBLF forest classification scheme [57], EBLF formations in China (including Taiwan island) were divided into different clusters; however, these are not classification units, and are larger than formation groups. Actual sampling point data exist for each cluster. Depending on the average biomass values and distribution areas of each cluster, the total biomass of each type can be calculated, thus allowing the subsequent calculation of the total biomass of EBLFs (Table 6). The results were as follows: (i) The eastern typical EBLF is divided into three clusters: the *Cyclobalanopsis–Lithocarpus* cluster, the *Castanopsis–Schima* cluster, and the *Cinnamomum–Machilus* cluster. The *Cyclobalanopsis–Lithocarpus* cluster includes dominant species such as *Cyclobalanopsis glauca* and *Lithocarpus harlandii*. The community biomasses of *C. glauca*, *C. glauca–Cinnamomum calcareum*, and *C. chungii* were measured. The *Castanopsis–Schima* cluster includes dominant species such as *C. fargesii*, *C. carlesii*, *Castanopsis eyrei* and *S. superba*. The community biomasses of *S. superba*, *C. eyrei*, *S. superba–C. carlesii*, *C. fargesii*, *C. hystrix–C. glauca–Machilus pauhoi* were measured. Among the dominant species in the *Cinnamomum–Machilus* cluster, which includes the species of *Cinnamomum*, *Machilus*, *Phoebe*, and *Michelia,* only the biomass of *Phoebe bournei* artificial forest [58–60] was determined. (ii) The western typical EBLF is divided into the *Castanopsis–Cyclobalanopsis* cluster and the *Schima–Lithocarpus* cluster. In the former, the dominant species are *Cyclobalanopsis glaucoides*, *Cylobalanopsis delavayii*, *Castanopsis arthacantha* and *C. delavyii*. The biomasses of *C. arthacantha* [54] *and C. delavayii* [55] were measured. In the latter, the dominant species in the cluster are *Lithocarpus*, *Manglietia* and *Schima noronhae*, and the biomass of *Lithocarpus variolosus* [52,53] was measured. (iii) The seasonal EBLF, as one cluster, includes eastern mainland seasonal EBLFs, western mainland seasonal EBLFs, and Taiwan seasonal EBLFs. The biomasses of *Cryptocarya concinna* [38,39], *Cryptocarya chinensis* [40], *Ixonanthes chinensis* [42] and *C. echidnocarpa* [43] were measured. (iv) The *Kandelia–Eucalyptus–Casuarina* cluster includes *Kandelia candel*, *Casuarina equisetifolia* and Eucalyptus forests in the mainland southeast costal area and the western area, in which most *C. equisetifolia* and *Eucalyptus urophylla* are artificial forests, and counted into the distribution area of EBLF. The biomasses of natural *Kandelia candel* [60], *Casuarina equisetifolia* [61], and *Eucalyptus urophylla* [62] were measured.

The total EBLF biomass in China was estimated to be 4.05 Pg (Table 6) after it was divided in accordance with the above clusters (the supposed carbon amount is 50%, converted into 2.02 Pg C). This result is less than half of the total EBLF biomass estimated by Zhao [64] using the CENTURY model (4.50 Pg C), 0.8–1.6 times the estimates of Luo [65] (2.54 Pg C), Fang [66] (1.39 Pg C), and Zhou *et al.* [67] (1.33 Pg C) using national forest investigation data, and over 10 times the estimate (0.20 Pg C) of Wang [68] using biomass sample plot report data before 1994. These differences are likely a result of the different research techniques used. Moreover, the time span during which the existing community investigation data were gathered was quite large. As such, uncertainties with regard to the estimate of the EBLF biomass exist. These variations bring about difficulties in data comparisons. Furthermore, previous studies paid little attention to the difference between community types, and the total biomass was mostly estimated using the average biomass method. Generally speaking, there are several diverse types of EBLFs, and the site conditions of each type are highly heterogeneous, thus causing large differences between the biomasses of different types of communities. To increase the precision with which estimates of EBLF biomass is obtained, clarifications regarding the various biomasses of each type of EBLF are required.

4.3 EBLF community biomass in the world

EBLFs are mainly distributed in China, Japan, and the Korean Peninsula of East Asia, the Florida Peninsula and Cali-

Table 6 Chinese evergreen broadleaved forest classification scheme and biomass

Cluster		Area ($\times10^6$ hm)	Mean community biomass (t hm^{-2})	Biomass (Pg)
East area	*Castanopsis–Schima*	27.7	336.3	0.93
	Cyclobalanopsis–Lithocarpus	33.7	210.1	0.71
	Cinnamomum–Machilus	0.5	179.9	0.01
West area	*Schima–Lithocarpus*	11.8	433.8	0.51
	Castanopsis–Cyclobalanopsis	18.7	202.8	0.38
Seasonal EBLF		50.6	294.5	1.49
Kandelia–Eucalyptus–Casuarina		1.1	125.6	0.01
Total				4.05

fornia in North America, Chile in South America, Australia and New Zealand in Oceania, and Madeira and the Canary Islands in the North Atlantic Ocean [69]. Previous research on EBLF biomasses has been carried out, for example, in Japan, United States, New Zealand, Australia, and Chile. The aboveground biomass determinations of several typical global EBLF communities are shown in Table 7. China and other areas in world have different biomass measurement methods. Direct harvest methods (bush and herb layers) and allometric methods (tree layer) are often adopted in China to determine EBLF community biomasses. Allometric methods (all tree species), on the other hand, are adopted overseas. The unified regression model of the organic biomasses and DBH was adopted during the determination of the community biomass of *Nothofagus truncata* in New Zealand. With regard to aboveground biomass, the biomass of *N. truncata* in New Zealand at the mature forest stage was the greatest (442.2 t hm^{-2}), followed by Australia's *Eucalyptus* forest (435.5 t hm^{-2}). In comparison, the biomass of the 52-year old S*chima superba–Castanopsis carlesii* forest in this research is relatively small. With regard to the biomass of the entire global community, the biomass of *Eucalyptus regnans,* located in New South Wales in Australia, was the greatest, reaching 585.4 t hm^{-2}, followed by *Castanopsis cuspidata* in Minimata, Japan, with a biomass reaching 378.6 t hm^{-2}. The biomass of *Quercus laurifolia* in South Carolina, USA, was the smallest (217.6 t hm^{-2}). Generally, the more mature standing forests have higher biomasses and are closer to one another. The biomasses of mature forests in China and overseas are about 295.0–568.0 t hm^{-2} and 242.0–585.0 t hm^{-2}, respectively.

4.4 Community net primary productivity

Data on the measured productivity of eastern China's EBLFs is lacking and only model-based estimations are available. The ANPP measured in this study was 386.8 g m^{-2} a^{-1}. Existing studies in China show that the underground net primary productivity (NPP) value is about 8.6%–24.3% of the total community NPP value [39,42,43,45–47,54,55]. As such, the total community NPP value in this study is estimated to be 423.2–511.0 g m^{-2} a^{-1} (the carbon content is estimated to be 50%, which converts to 211.6–255.5 g C m^{-2} a^{-1}), which is closest to the minimum NPP value (590.0 g m^{-2} a^{-1}; the carbon content is estimated to be 50%, which converts to 295 g C m^{-2} a^{-1}) of EBLFs in China's subtropical northern subzone as estimated by Ni [76] using the Chikugo model. Our NPP value differs markedly from the average NPP of China's EBLFs in the Yangzi River region as estimated separately by Ke *et al*. [77] (365.0 g C m^{-2} a^{-1}) and Piao [78] (525.0 g C m^{-2} a^{-1}) using the Carnegie-Ames-Stanford approach. More interestingly, our value is only one-quarter of the minimum NPP value of subtropical EBLFs in the northern subzone as estimated by Zhou *et al*. [79] based on a comprehensive model.

Overall, the estimated NPP values of subtropical EBLFs are higher than our measured NPP. The *S. superba–C. carlesii* forest studied herein is located in north-central Asia's EBLF zone, and the dominant species, *C. carlesii*, reached the northern boundary of its distribution. Therefore, the NPP calculated for such forest may be lower than the average NPP values of eastern China's EBLFs. In addition, most NPP estimation models are based mainly on environmental factors, such as solar radiation, temperature, and precipitation, thus NPP estimates are likely to be the potential NPP in the area or the maximal NPP that can be attained by the vegetation under ideal conditions. In reality, however, communities are affected by human and/or natural disturbances. In particular, the study area in this work is affected by frequent human activities and seasonal typhoons. Thus, achieving maximum NPP estimates for this locale was difficult.

Table 7 Evergreen broadleaved forest community biomass in the world and its distribution

Community	Location	Latitude and longitude	Age (year)	Biomass (t hm^{-2})			Source
				Aboveground	Underground	Total	
Schima superba–Castanopsis carlesii	Tiantong, China	29°48′N 121°47′E	52	162.3	63.0	225.3	This study
Quercus laurifolia	South Carolina, USA	33°N 82°W	60	207.0	10.6	217.6	[70]
Castanopsis cuspidata	Minimata, Japan	32°10′N 130°28′E	65	330.3	48.3	378.6	[71]
Nothofagus truncata	Nelson, New Zealand	41°31′S 172°45′E	Mature forest	442.2	143.2	585.4	[72]
Erica arborea–Laurus azorica	Canary Islands	28°19′N 16°34′W	Mature forest	242.5			[73]
Nothofagus truncata	Chile Island	42°30′S 74°W	Mature forest	381.0			[74]
Eucalyptus regnans	New South Wales, Australia	37°S 149°30′E	Mature forest	435.5			[75]

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Appendix Table 1 Sample stems and regression equations for measurement of aboveground biomass and productivity

No.	Species	Height (m)	Diameter at breast height (cm)	Base diameter (cm)	Organ biomass (kg)			Regression equation[a)]
					Leaf	Branch	Stem	
1	*Castanopsis carlesii*	4.3	2.7	4.4	0.1	0.8	1.1	$W_L=0.0453D^{1.716}$ $W_B=0.037D^{2.4599}$ $W_S=0.1565D^{2.2772}$ $W_L=0.0079Dr^{2.1658}$ $W_B=0.0033Dr^{3.0943}$ $W_S=0.0179Dr^{2.8362}$
2		2.0	2.8	4.3	0.2	0.5	1.4	
3		5.5	5.0	6.6	0.7	1.4	4.0	
4		5.0	4.3	7.3	0.5	1.4	2.6	
5		5.0	4.5	–	0.7	1.2	3.7	
6		16.0	23.5	21.6	5.9	21.9	169.1	
7		18.0	24.0	22.7	9.8	85.3	156.7	
8		17.0	26.5	26.1	11.1	117.6	196.6	
9		16.0	28.5	43.9	15.3	317.1	428.5	
10		18.0	28.5	28.5	10.9	79.4	207.7	
11		18.0	8.0	24.3	11.5	83.8	256.3	
12	*Castanopsis fargesii*	2.7	2.8	3.6	0.2	0.3	1.0	$W_L=4.1741\ln D-3.3449$ $W_B=52.7863\ln D-43.6809$ $W_S=0.1392D^{2.1917}$ $W_L=0.0616e^{0.1166Dr}$ $W_B=0.0905e^{0.1643 Dr}$ $W_S=0.4181e^{0.1479 Dr}$
13		3.3	1.8	12.2	0.1	0.2	0.5	
14		4.5	2.3	3.7	0.2	0.4	1.2	
15		2.5	2.5	3.0	0.1	0.1	1.1	
16		18.0	36.0	43.4	11.8	147.5	365.8	
17	*Lithocarpus glaber*	4.2	1.3	1.6	0.1	0.2	0.3	$W_L=0.047e^{0.2393D}$ $W_B=0.0716e^{0.3165D}$ $W_S=0.1583D^{2.2171}$ $W_L=0.0114Dr^{2.1107}$ $W_B=0.0114Dr^{2.7743}$ $W_S=0.0576Dr^{2.5539}$
18		2.4	1.2	2.6	0.1	0.2	0.3	
19		5.0	3.6	3.4	0.3	0.4	1.2	
20		16.0	18.5	20.6	1.1	15.7	101.6	
21		17.0	19.5	15.5	5.5	24.6	101.5	
22		17.0	24.0	25.2	15.5	126.2	218.6	
23		17.0	24.0	24.8	18.4	168.3	212.0	
24		16.0	17.0	18.2	5.7	32.8	92.2	
25	*Cyclobalanopsis myrsinaefolia*	2.8	2.2	3.3	0.1	0.1	0.8	$W_L=0.1019e^{0.1387D}$ $W_B=0.0358D^{2.4556}$ $W_S=0.3152D^{2.016}$ $W_L=0.0045Dr^{2.2879}$ $W_B=0.0024Dr^{3.262}$ $W_S=0.0315Dr^{2.717}$
26		3.5	1.8	4.7	0.2	0.2	0.9	
27		4.2	2.0	3.4	0.1	0.31	1.3	
28		11.0	21.5	17.6	3.6	37.35	99.6	
29		8.5	4.5	9.2	0.2	1.28	21.5	
30		20.0	45.0	43.7	40.7	681.96	699.3	
31	*Schima superba*	4.3	3.5	4.3	0.3	0.82	1.9	$W_L=0.1820e^{0.1672D}$ $W_B=0.0483D^{2.261}$ $W_S=0.0916D^{2.3612}$ $W_L=0.0183Dr^{1.9429}$ $W_B=0.0282Dr^{2.4126}$ $W_S=0.0443Dr^{2.5772}$
32		14.0	17.5	15.5	3.9	37.9	56.4	
33		15.0	21.0	22.5	6.2	36.4	136.0	
34		17.0	25.0	26.1	10.3	86.8	189.3	
35		17.0	25.5	24.1	13.0	79.2	199.3	
36		18.0	23.0	26.5	8.9	46.4	166.8	
37	*Alniphyllum fortunei*	11.0	11.5	12.2	0.4	3.3	31.7	$W_L=0.3223D-2.5441$ $W_B=0.5505D-0.6728$ $W_S=0.2371D^{1.962}$ $W_L=0.296Dr-2.4199$ $W_B=12.973\ln Dr-27.237$ $W_S=0.1128Dr^{2.1103}$
38	*Liquidambar formosana*	14.0	15.0	–	0.7	4.8	48.4	
39	*Sassafras tzumu*	8.5	8.0	11.2	1.5	3.6	13.5	
40	*Castanopsis sclerophylla*	10.0	15.5	17.8	3.1	13.5	47.3	
41	*Castanea seguinii*	18.0	40.0	44.2	10.7	20.9	332.2	

a) W_L, leaf biomass; W_B, branch biomass; W_S, stem biomass; Dr, base diameter; D, Diameter at breast height; ln, napierian logarithm.

Appendix Table 2 Sample stems and regression equations for measurement of underground biomass

No.	Species	Height (m)	Diameter at breast height (cm)	Root biomass (kg)	Regression equations[a)]
1	*Machilus thunbergii*	5.8	3.6	0.8	$W_R=0.0481D^{2.1506}$
2	*Schima superba*	7.3	8.6	3.3	
3	*Symplocos sumuntia*	4.6	4.6	1.1	
4	*Eurya muricata*	3.2	1.7	0.3	
5	*Camellia fraterna*	6.1	2.9	0.6	
6	*Castanopsis carlesii*	2.6	1.5	0.1	
7	*Castanopsis fargesii*	11.5	19.5	24.0	
8	*Castanopsis fargesii*	17.3	28	91.4	

a) W_R, root biomass; D, Diameter at breast height.