



Distribution patterns of the subtropical evergreen broad-leaved forests of southwestern China, as compared with those of the eastern Chinese subtropical regions

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Abstract

DISTRIBUTION PATTERNS OF THE SUBTROPICAL EVERGREEN BROAD-LEAVED FORESTS OF SOUTHWESTERN CHINA, AS COMPARED WITH THOSE OF THE EASTERN CHINESE SUBTROPICAL REGIONS.— This paper analyzes the geographic distribution patterns of the subtropical evergreen broad-leaved forests of southwestern China, and compares with other subtropical regions in the east of China in terms of forest types, pertinent species, and spatial distribution along latitudinal, longitudinal and altitudinal gradients. In general, for both the western and the eastern subtropical regions, the evergreen broad-leaved forests are dominated by species of *Castanopsis*, *Lithocarpus*, *Cyclobalanopsis* (Fagaceae), *Machilus*, *Cinnamomum* (Lauraceae), *Schima* (Theaceae), *Manglietia*, and *Michelia*, (Magnoliaceae), while in southwestern China there are more diverse forest types including semi-humid, monsoon, mid-montane moist and humid evergreen broad-leaved forests, but only monsoon and humid forests in the east. The Yunnan area has more varied species of *Lithocarpus* or *Cyclobalanopsis* or *Castanopsis* as dominants than does eastern China, where the chief dominant genus is *Castanopsis*. The upper limits of the evergreen broad-leaved forests are mainly 2400–2800 m in western Yunnan and western Sichuan, much higher than in eastern China (600–1500, but 2500 m in Taiwan). Also discussed are the environmental effects on plant diversity of the evergreen broad-leaved forest ecosystems exemplified by Yunnan and Taiwan.

Key words: dominant species; environmental gradient; forest type; plant diversity; spatial distribution; succession.

Resumen

PATRONES DE DISTRIBUCIÓN DE LOS BOSQUES SUBTROPICALES PERENNIFOLIOS DE HOJA ANCHA DEL SUROESTE DE CHINA EN COMPARACIÓN CON AQUELLOS DE LAS REGIONES SUBTROPICALES DEL ESTE DE CHINA.— En este trabajo se analiza los patrones de distribución geográfica de los bosques subtropicales perennifolios de hoja ancha del suroeste de china, y se comparan con los de otras regiones subtropicales del este de China en términos de tipología de bosque, especies relevantes, y distribución espacial a lo largo de un gradiente latitudinal, longitudinal y altitudinal. De manera general, los bosques perennifolios de hoja ancha de la regiones subtropicales tanto orientales como occidentales presentan dominancia de especies de *Castanopsis*, *Lithocarpus*, *Cyclobalanopsis* (Fagaceae), *Machilus*, *Cinnamomum* (Lauraceae), *Schima* (Theaceae), *Manglietia* y *Michelia* (Magnoliaceae); sin embargo, mientras que en el suroeste de China hay más diversidad de tipos de bosques perennifolios de hoja ancha —húmedos, semi-húmedos, monzónicos y montanos húmedos—, en el este del país la variedad de tipos se limita a dos: monzónicos y húmedos. El área de Yunnan tiene una mayor variedad de especies dominantes de los géneros *Lithocarpus*, *Cyclobalanopsis* y *Castanopsis*, mientras que en este de China el género dominante es casi invariablemente *Castanopsis*. El límite altitudinal superior de los bosques perennifolios de hoja ancha se sitúa en 2400-2800 m para el oeste de las provincias de Yunnan y Sichuan, muy superior a lo que sucede en el este del país (entre 600 y 1500 m, aunque para Taiwan el límite alcanza los 2500 m). En último lugar se discuten los efectos medioambientales sobre la diversidad de especies vegetales de los bosques perennes de hoja ancha, y se proporcionan ejemplos de Yunnan y Taiwan.

Palabras clave: distribución espacial; diversidad de especies vegetales; especies dominantes; gradiente medioambiental; sucesión; tipo de bosque.

摘要

中国西南部亚热带常绿阔叶林分布格局，并与中国东部亚热带常绿阔叶林之比较。— 本文分析了中国西南部亚热带常绿阔叶林类型，植物群落及优势物种在经度、纬度、海拔梯度上的分布格局，并且与中国亚热带东部（此文把中国西南部以东的中国亚热带均称为中国东部）的常绿阔叶林进行了深入比较。西南部及东部亚热带常绿阔叶林一般是以栲属、石栎属、青冈属（壳斗科），润楠属、樟属（樟科），木荷属（茶科），木莲属、含笑属（木兰科）的物种为优势种。西南部有更多样的森林类型，含半湿润，季风，中山湿性和湿润亚热带常绿阔叶林，而东部只有季风和湿润亚热带常绿阔叶林。位于西南部的云南比中国东部有更多样的石栎属、青冈属及栲属优势物种，而东部的优势属只有栲属。在滇西和川西，常绿阔叶林分布的海拔上限主要是在2400-2800 m，比中国东部常绿阔叶林分布的海拔上限（600-1500 m，台湾例外在2500 m）高很多。本文还以云南与台湾为例，阐述了西南部及东部常绿阔叶林生态系统中植物多样性在环境及植物演替梯度上的分布格局。

关键词：优势种；环境梯度；森林类型；植物多样性；空间分布；演替。

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INTRODUCTION

Subtropical evergreen broad-leaved forests (hereafter EBLFs) refer to lauro-fagaceous evergreen forests, also known as lucidophylls or laurophylls, referring to their often glossy leaves. These forests, dominated by the genera *Castanopsis* (D. Don) Spach, *Lithocarpus* Blume, *Cyclobalanopsis* Oerst. (Fagaceae), *Machilus* Rumph. ex Nees (Lauraceae), *Schima* Reinw. ex Blume (Theaceae), *Manglietia* Blume, *Michelia* L. (Magnoliaceae), and *Distylium* Siebold & Zucc. (Hamamelidaceae) are almost exclusively confined to southern, southwestern, and southeastern mainland China, Taiwan, southwestern Japan, southern Korea, and some mountain regions of Vietnam, Laos, Thailand, Myanmar, India, Bhutan, and Nepal (Kira, 1991; Ohsawa, 1993; Tagawa, 1995; Song, 1995; Li, 1997; Tang & Ohsawa, 2009; Song, 2013; Tang *et al.*, 2013). Climatic delimitation of Asian regions has been discussed by investigators (Wolfe, 1979; Ohsawa, 1990, 1993; Kira, 1991; Box, 1995) who have emphasized the seasonal variations in temperature of the monsoon system as the principal determinant of plant distribution patterns. Ohsawa (1995) has provided an explicit template to depict zonal climate-forest patterns along latitudinal and altitudinal gradients in East Asia. As to latitude, southwestern China (SW China including Yunnan, Sichuan, Guizhou provinces and Chongqing Municipality, 21° 08' 32"–34° 20' N, 97° 30'–110° 10' E)

(Fig. 1) falls into the transitional forest zone from tropical mountain to temperate mountain zonation (Fig. 2).

Primary EBLFs once covered most of the subtropical areas of East Asia, but are now greatly diminished as a result of human activities. A recent study found only 5% of China's total land area to be covered by natural EBLFs (Chen, 1995). In the subtropical regions of China, extensive secondary forests have recently been grown on land used for agriculture or firewood production from the 19th to the middle 20th century, but remnants of the natural EBLFs are still found in remote isolated areas, on steep slopes, in nearly inaccessible or protected areas in nature reserves, and around temples. China, especially Yunnan, is home to the most diversified subtropical EBLFs to be found in East Asia (Tang & Ohsawa, 2009; Tang, 2010; Tang *et al.*, 2013).

In this paper the aim is to present an overview of the distribution patterns of the subtropical EBLFs across SW China as compared with all the Chinese subtropical regions to the east.

CLIMATE OF THE SUBTROPICAL EBLFs

China's subtropical regions are bounded to the north by a line running between the Huai River and the Qinling Mountains (35° N), with a southern limit

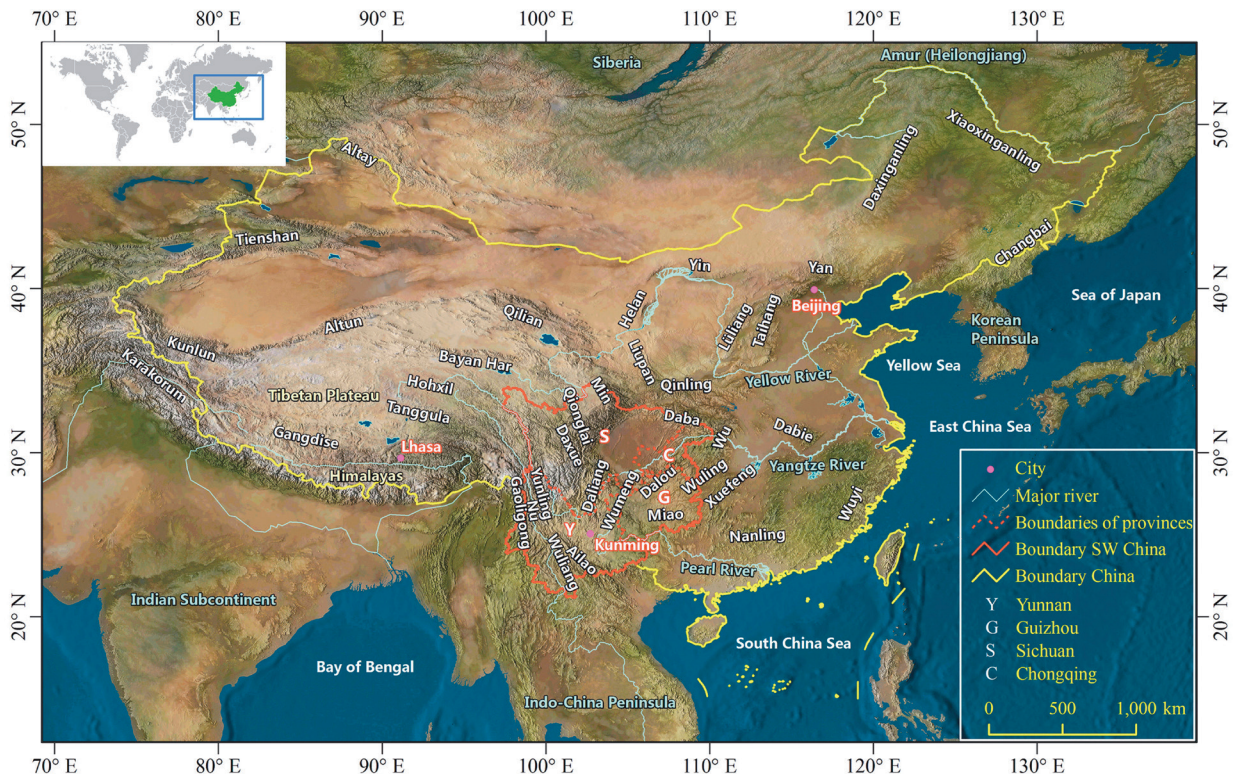


Figure 1. SW China and major mountain ranges of China.

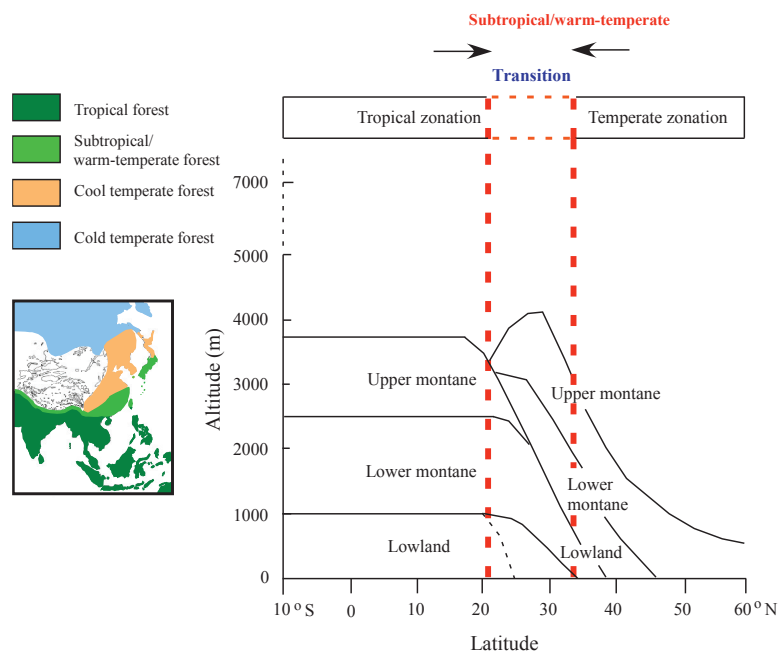


Figure 2. Altitudinal and latitudinal vegetation zonation scheme for East Asia (Ohsawa, 1995). The mountains located between 20° and 30°(33°) N show a transitional zonation pattern; the lower two zones are comparable to the lower two of the tropical zonation (tropical lowland and tropical lower montane), and the upper two zones are comparable to those of the temperate zonation (temperate lower montane and temperate upper montane). The tropical upper montane zone is not found north of 20°–30°(33°) N, while the tropical lower montane zone reaches down to sea level and so becomes also the temperate lowland zone. Thus the zonation between 20° and 30°(33°) N includes tropical lowland, tropical lower montane/temperate lowland, temperate lower montane, and temperate upper montane zones (Ohsawa, 1990, 1995).

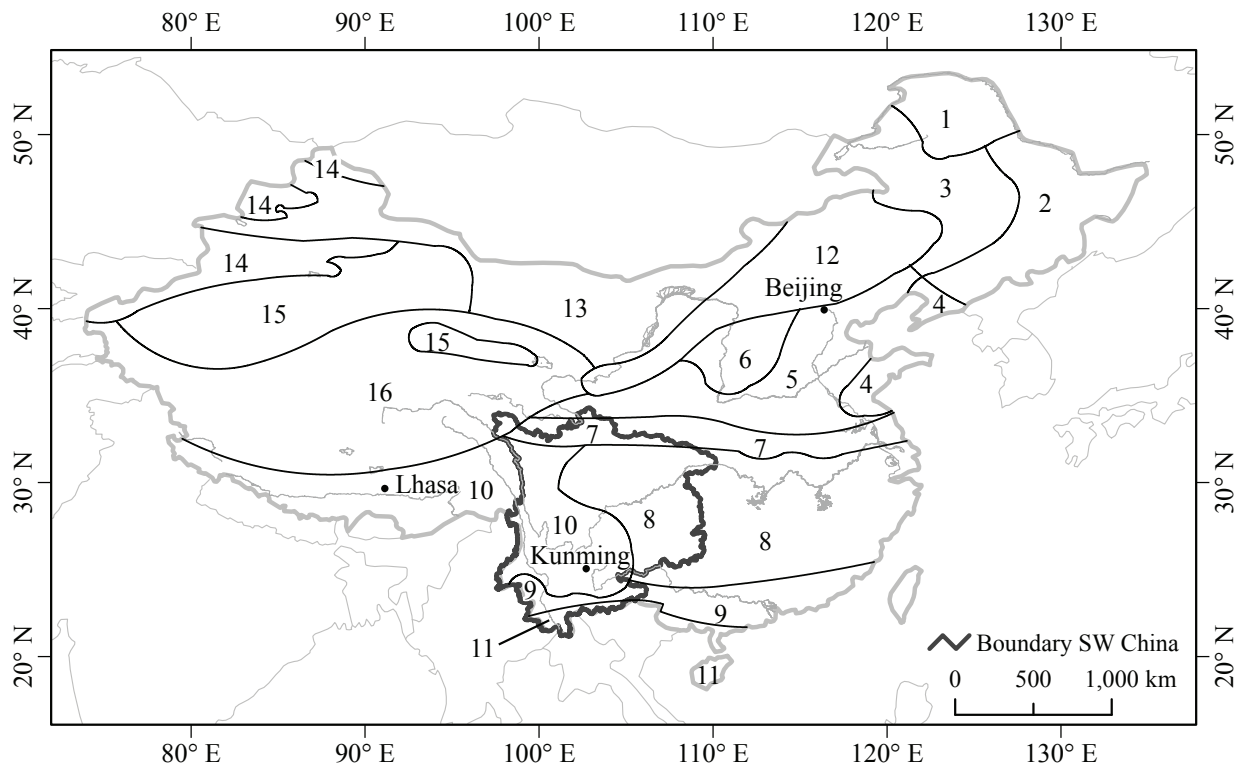


Figure 3. Climate divisions of China. 1: Cold-temperate humid; 2: Middle-temperate humid, 3: Middle-temperate subhumid; 4: South-temperate humid; 5: South-temperate subhumid; 6: South-temperate subdry; 7: North-subtropical humid; 8: Middle subtropical humid; 9: South-subtropical humid; 10: Middle-subtropical subhumid and plateau; 11: Tropical humid; 12: Middle-temperate subdry; 13: Middle-temperate dry; 14: Middle-temperate alpine subdry; 15: South-temperate dry; 16: Plateau (dry and subdry). Modified from NCNWC (1984) and Winkler & Wang (1993).

approaching the Tropic of Cancer. Eastward the subtropics extend to the coastlands and the islands of the East China Sea, the South China Sea and Taiwan; the westward limit is the Chinese national border, extending from the eastern slope of the Tibetan Plateau to southern Yunnan. The subtropical zone thus spans 11–12° from north to south, 28° from east to west (Wu, 1980). China's subtropical region is divided into three different zones: (1) the southern subtropics (transitional tropics), extending from latitude 22° to 24° or 25° N; (2) the middle subtropics, which lie between 24° or 25° N and 31° or 32° N; and (3) the northern subtropics (transitional subtropics) which cover from 31° or 32° N to 34° or 35° N (Hou, 1983). SW China is located at subtropical latitudes often distinguished as north, middle, and south subtropical (Fig. 3). A small part of southernmost Yunnan falls into the tropical zone. According to altitude, climates in SW China include tropical, subtropical, temperate, alpine and frigid. The climate is dominated by the Asian monsoon system, including the southwestern monsoon

(the summer monsoon of India), the East Asian summer monsoon, and the East Asian winter monsoon, with dry continental winds in winter and moist oceanic winds in summer (Fig. 4). In China, generally the oceanic monsoon season begins earlier and ends later in the south than in the north, giving the south a longer rainy season and milder winter winds (Guo & Werger, 2010). In general, Chinese regions east of *ca.* 103° E are strongly influenced by the East Asian monsoon, while the regions to the west are affected by the Indian monsoon.

Song (2013) offers the general information on the climate of the EBLFs. The annual temperature difference between the warmest and coldest months is smaller in the west (10–14°C) than in the east (14–27°C). In Holdridge's life zone system (1947), bio-temperature (the sum of temperatures >0°C, if mean monthly temperature >30°C is calculated as 30°C) ranges from 12 to 24°C for the EBLF. In the subtropical EBLF region of China, the bio-temperature is 15–22°C.

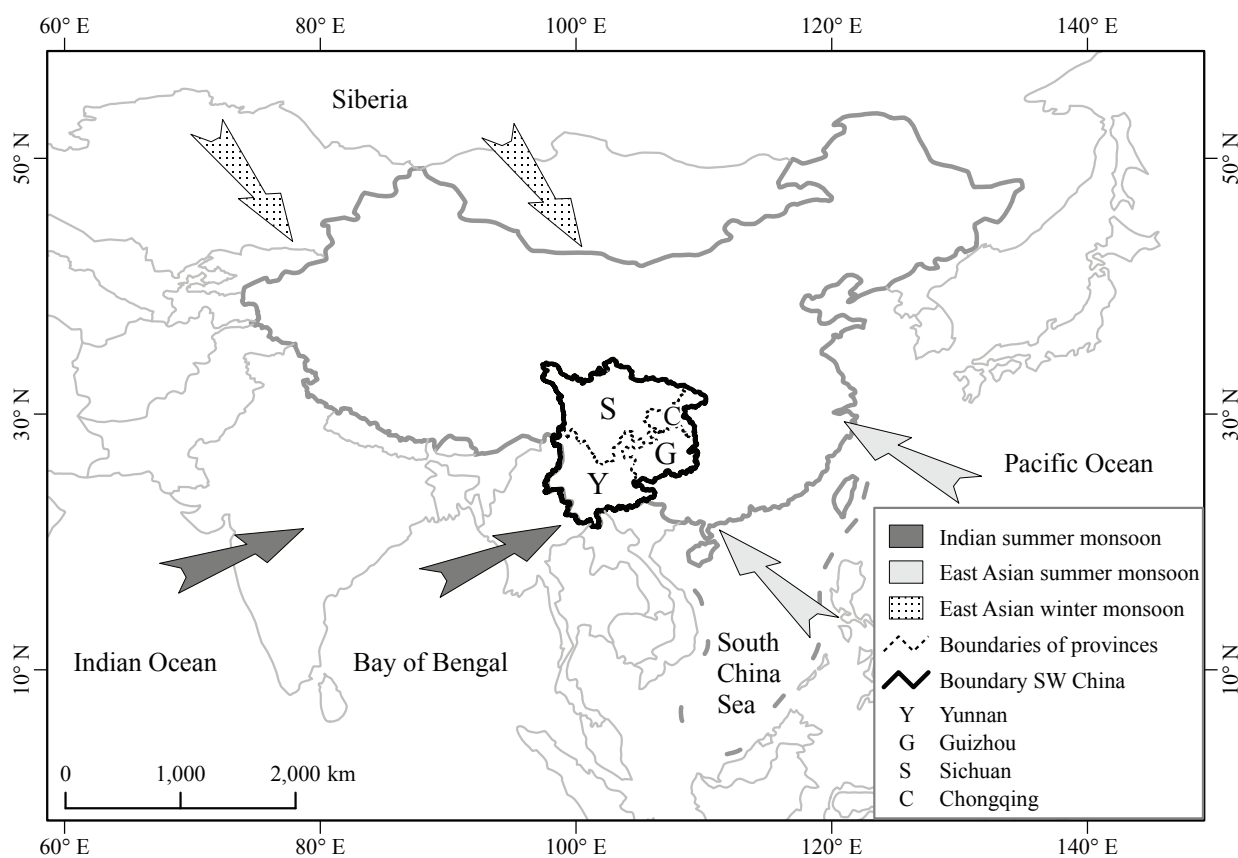


Figure 4. Three monsoon winds in China.

Kira (1945) has proposed a warmth index (WI) and a coldness index (CI) for vegetation zones in East Asia, as follows: $WI (^{\circ}C) = \Sigma(t - 5) \cdot \text{months}$; $CI (^{\circ}C) = \Sigma(5 - t') \cdot \text{months}$; t is the mean monthly temperature $\geq 5^{\circ}C$ and t' is the mean monthly temperature $\leq 5^{\circ}C$. In Japan, a WI of $85\text{--}180^{\circ}C \cdot \text{months}$ and a CI of $-10\text{--}0^{\circ}C \cdot \text{months}$ correspond to the EBLF distribution, and a CI of $-10^{\circ}C$ is a decisive northern limit for the EBLF (Kira, 1945; Hattori & Nakanishi, 1985). In China, a WI of $125^{\circ}C$ and a CI of $-5^{\circ}C$ determine the northern limit of the EBLF distribution; a WI of $135^{\circ}C$, and a CI of $-2^{\circ}C$ correspond to the northern limit of the EBLF zone (Song, 2013).

In China, the annual precipitation for the EBLF in the eastern region ranges from 1100 to 1700 mm, and is between 800–1000 mm in most areas of the western region (such as central and northern Yunnan and northwestern Guizhou). However, due to the complexity of the topography and varying elevations, the annual rainfall is *ca.* 1500–1800 mm in southern Yunnan, though it reaches 1500–2800 mm (but 3673 mm in Bapo, Dulongjiang) in some lo-

calities of western Yunnan, but in deep river valleys and on lee slopes it is just *ca.* 600–800 mm. In the western region, 80–90% of the annual precipitation falls from May to October, and the dry season is much more pronounced from November to April as compared with the east. The mean annual potential evapotranspiration for the subtropical EBLF region is *ca.* 800–1200 mm, and it is greater in the west than in the east. The Sichuan Basin area has the lowest evapotranspiration (Gao *et al.*, 2006).

TYPES OF THE SUBTROPICAL EBLFs

Li (1997) divided the EBLF of East Asia into four regions: the Japanese, eastern Chinese, western Chinese, and western Chinese sclerophyllous distribution regions. The evergreen sclerophyllous forest should be considered apart from the subtropical EBLF, because the morphology, physiognomy, and structure of their leaves are different. The subtropics from 33° to 35° N constitute a transitional zone from EBLFs to deciduous broad-leaved forests.

Zhu (2013) considered a line at *ca.* 22° 30' N to be the northern biogeographic boundary of the tropical zone in southern China. The evergreen broad-leaved forest of southernmost Yunnan is considered to be a tropical montane evergreen broad-leaved forest (Zhu, 2007; Zhu & Yan, 2009). The subtropical EBLFs exclude northern tropical rain forests, which are basically tropical in nature but with some obvious transitional characteristics from tropical to subtropical floras, and are found at low altitudes in southernmost Yunnan (e.g. Xishuangbanna in S Yunnan, Xilongshan and Daweishan in SE Yunnan, Nangunhe in SW Yunnan). But here I do include the tropical montane evergreen broad-leaved forest of S, SE and SW Yunnan so as to take into account the altitudinal transition from the tropical rain forest to the subtropical EBLF. Song (2013) asserted that the subtropical EBLF of China corresponds to the region from 23° to 33° N and from 98° to 123° E. In fact, within Yunnan the forest extends west to *ca.* 97° 32' E (e.g. Dulongjiang), and within Tibet it extends to 95° E (e.g. Chayu and Motuo in Yarlung Zangbo River). The most eastern longitude is 122° E in Taiwan. In sum, 95°–122° E is the longitudinal

range of the EBLF within China. The distribution range of EBLFs in China is proposed in Fig. 5.

A detrended correspondence analysis (DCA) (Fig. 6) for the plots of natural mature EBLFs of SW China, including Yunnan, Guizhou and the Sichuan Basin, that have been free of major disturbance during the past 60 years, indicates that along Axis 2 from the low to the upper side with increasing moisture, four forest types are roughly distinguished: the semi-humid EBLF (SH), the monsoon EBLF (MS), the humid EBLF (HE) and the mid-montane moist EBLF (MM). Axis 1 may indicate a gradient of topography or soil properties.

In SW China, most significantly, four forest types are representative of the major subtropical EBLFs:

(1) the semi-humid EBLF in Yunnan, western Sichuan, and western Guizhou.

(2) the monsoon EBLF in Yunnan.

(3) the mid-montane moist EBLF in Yunnan, which I combine with the montane mossy EBLF as classified by former researchers (e.g. Wu, 1980; Wu *et al.*, 1987) since their physiognomy and ecological characteristics, including various epiphytes and lianas on tree trunks and branches, are similar.

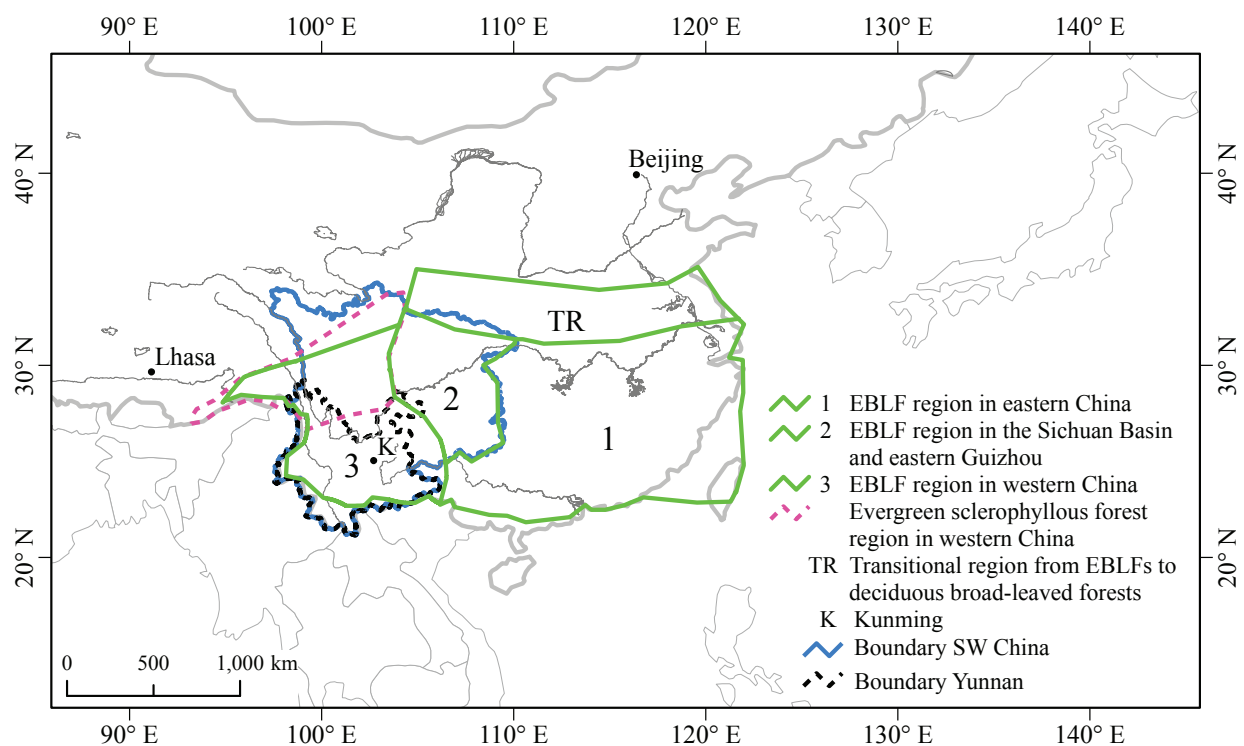


Figure 5. Distribution of subtropical evergreen broad-leaved forests in China. Note: Chayu and Motuo in Yarlung Zangbo River, southern Tibet, are included in the subtropical evergreen broad-leaved forest, though in deep gorges at 100–600 m a.s.l., very limited patches of the tropical rain forest are found, dominated by *Dipterocarpus* C. F. Gaertn.

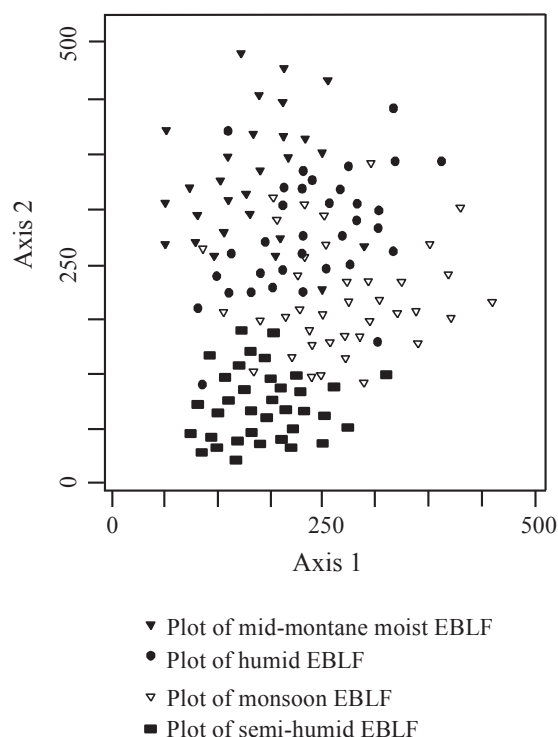


Figure 6. Ordination of plots along the first two detrended correspondence analysis (DCA) axes for SW China. EBLF: evergreen broad-leaved forest. All plots have been free of major disturbance during the past 60 years. The analysis reveals a sequence of 4 EBLF types along Axis 2. Axis 1 may indicate a gradient of topography or soil properties. Partial data sources: Zhou (1992), Zuo (1995), Tang & Ohsawa (1997), Li *et al.* (2000), Liu & Zhong (2000), Bao & Liu (2002), Peng *et al.* (2006a), Tang *et al.* (2007a), Tang & Ohsawa (2009), Shi *et al.* (2011), Tang *et al.* (2013), Wang *et al.* (2013).

(4) the humid EBLF in the Sichuan Basin (also including Chongqing) and eastern Guizhou, having no distinctive dry season throughout the year. The humid EBLF differs from the mid-montane moist EBLF in lacking rich epiphytes and lianas on tree trunks and branches. The humid EBLF in the Sichuan Basin and eastern Guizhou is considered as the same type as the typical humid EBLF of eastern China.

The montane mossy dwarf forest as classified by former researchers (e.g. Wu, 1980; Wu *et al.*, 1987; Shi & Zhu, 2009), dominated by species of *Rhododendron* L. along with some dwarf trees of the Fagaceae, Vacciniaceae, Rosaceae, Aceraceae, grows in special topo-habitats such as near mountaintops. This is not considered a type of the subtropical EBLF in this paper.

SPATIAL DISTRIBUTION PATTERNS OF THE SUBTROPICAL EBLFs

Southwestern China

Yunnan

The spatial patterns of distribution of dominant evergreen broad-leaved communities along latitudes, longitudes, and altitudes in Yunnan, as represented by 22 mountains, are depicted in Fig. 7. In Yunnan, secondary forests such as coppice woods and fast-growing *Pinus* L. (e.g. *Pinus yunnanensis* Franch. and *Pinus armandii* Franch.) and *Eucalyptus* (e.g. *Eucalyptus smithii* R. T. Baker and *Eucalyptus globulus* Labill.) plantations, as well as agricultural fields are common at low altitudes, while remnants of the natural subtropical EBLF are only found in isolated mountains, on steep slopes, and temple grounds. The semi-humid EBLFs (SH) dominated by *Castanopsis orthacantha* Franch., *Cyclobalanopsis glaucoides* Schottky, *Cyclobalanopsis delavayi* (Franch.) Schottky, or *Lithocarpus dealbatus* (Hook. f. & Thomson ex Miq.) Rehder are found at (1500)1900–2400 m in central, south-central, and eastern Yunnan, including Jizhushan, Huaofushan, Shizishan, Qiongzhusi, Wuliangshan, eastern Ailaoshan, Zhujiangyuan, Laojunshan of Wenshan, Wumengshan, and Yaoshan (*shan* means “mountain”).

The monsoon EBLFs (MS) are mainly distributed at (800)1000–1800 m in southern Yunnan (e.g. Tongbiguan, Nangunhe, Beihualin, Yongde Daxueshan, Wuliangshan, Ailaoshan, Xilongshan, Daweishan, and Xishuangbanna) and in the province’s north-west (e.g. Dulongjiang, and Fugong). Most of them are dominated by species of *Castanopsis* and *Lithocarpus* with some *Trigonobalanus* Forman and *Cyclobalanopsis*, as well as Lauraceae and Theaceae, such as *Castanopsis hystrix* Hook. f. & Thomson ex A. DC., *Castanopsis fleuryi* Hickel & A. Camus, *Castanopsis calathiformis* Rehder & E. H. Wilson, *Lithocarpus truncatus* (King ex Hook. f.) Rehder & E. H. Wilson, *Lithocarpus polystachyus* (Wall. ex A. DC.) Rehder, *Lithocarpus fenestratus* (Roxb.) Rehder, *Trigonobalanus doichangensis* (A. Camus) Forman, *Cyclobalanopsis augustinii* (Skan) Schottky, *Cyclobalanopsis kerrii* (Craib) Hu, *Cryptocarya calcicola* H. W. Li, *Cryptocarya densiflora* Blume, *Beilschmiedia yunnanensis* Hu, *Schima wallichii* (DC.) Korth., and *Anneslea fragrans* Wall.

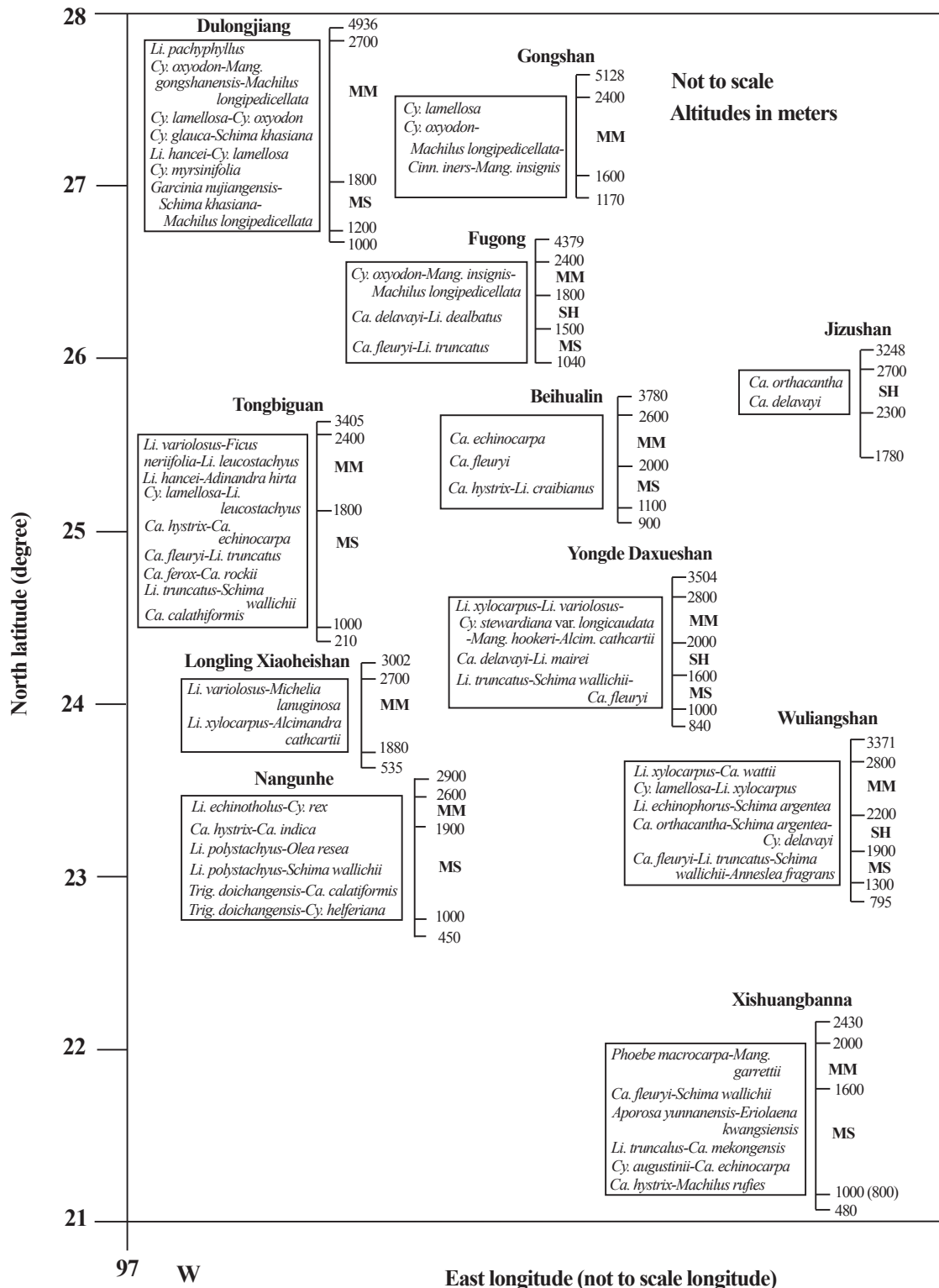
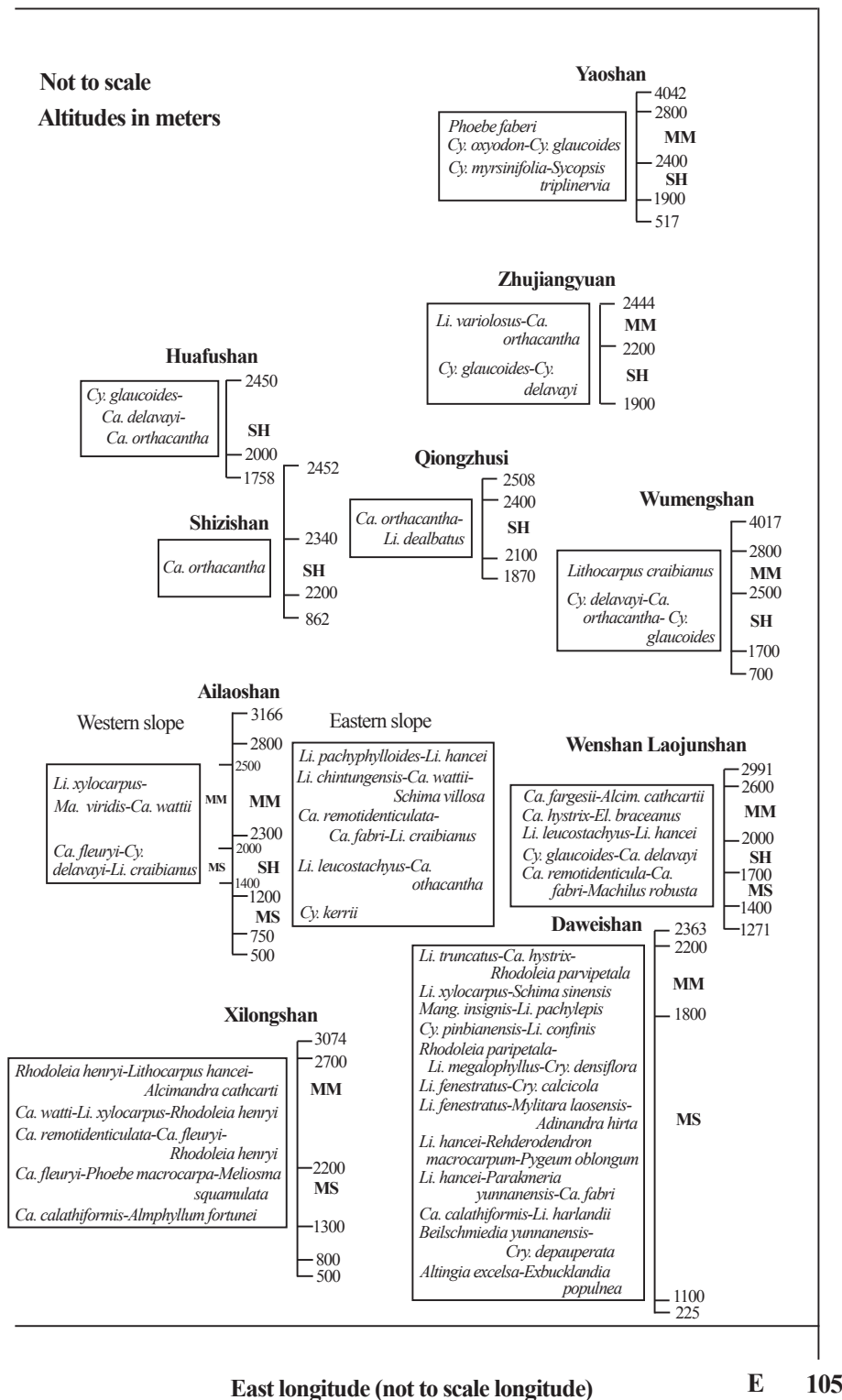


Figure 7. The spatial patterns of distribution of dominant evergreen broad-leaved communities along latitudes, longitudes, and altitudes in Yunnan. SH: Semi-humid EBLF; MS: Monsoon EBLF; MM: Mid-montane moist EBLF; *Cy*: *Cyclobalanopsis*; *Ca*: *Castanopsis*; *Li*: *Lithocarpus*; *Ma*: *Machilus*; *Trig*: *Trigonobalanus*; *Mang*: *Manglietia*; *Alcim*: *Alcimandra* Dandy; *Cry*: *Cryptocarya* R. Br.; *El*: *Elaeocarpus* L. Data sources: Peng & Dang (1998), Hu (1999), Yang & Li (1999), Li *et al.* (2000, 2006), Peng & Wu (2001), Yang & Du (2004, 2006), Wang *et al.* (2005, 2013), Peng *et al.* (2006a), Yang *et al.* (2006), Liu & Peng (2007), Tang & Zhu (2007), Tang *et al.* (2007a, b, 2010a, b, 2013), Tang & Ohsawa (2009), Tang & He (2013).



At low altitudes below the EBLF zones on these mountains, secondary forests or shrublands or plantations of conifers (such as *Pinus yunnanensis* and *Pinus armandii*) or eucalyptus, or agricultural fields are all common, while some localities along rivers support hot-dry valley vegetation; also in southern Yunnan there are some patches of tropical seasonal rain forest or tropical rain forest. At higher altitudes above the EBLFs, there are various vegetation types, such as montane mossy dwarf communities, evergreen sclerophyllous *Quercus* L. forests, or temperate coniferous [e.g. *Tsuga dumosa* (D. Don) Eichler] and broad-leaved mixed forests, or cold temperate forests, alpine scrubland, grassland, meadows.

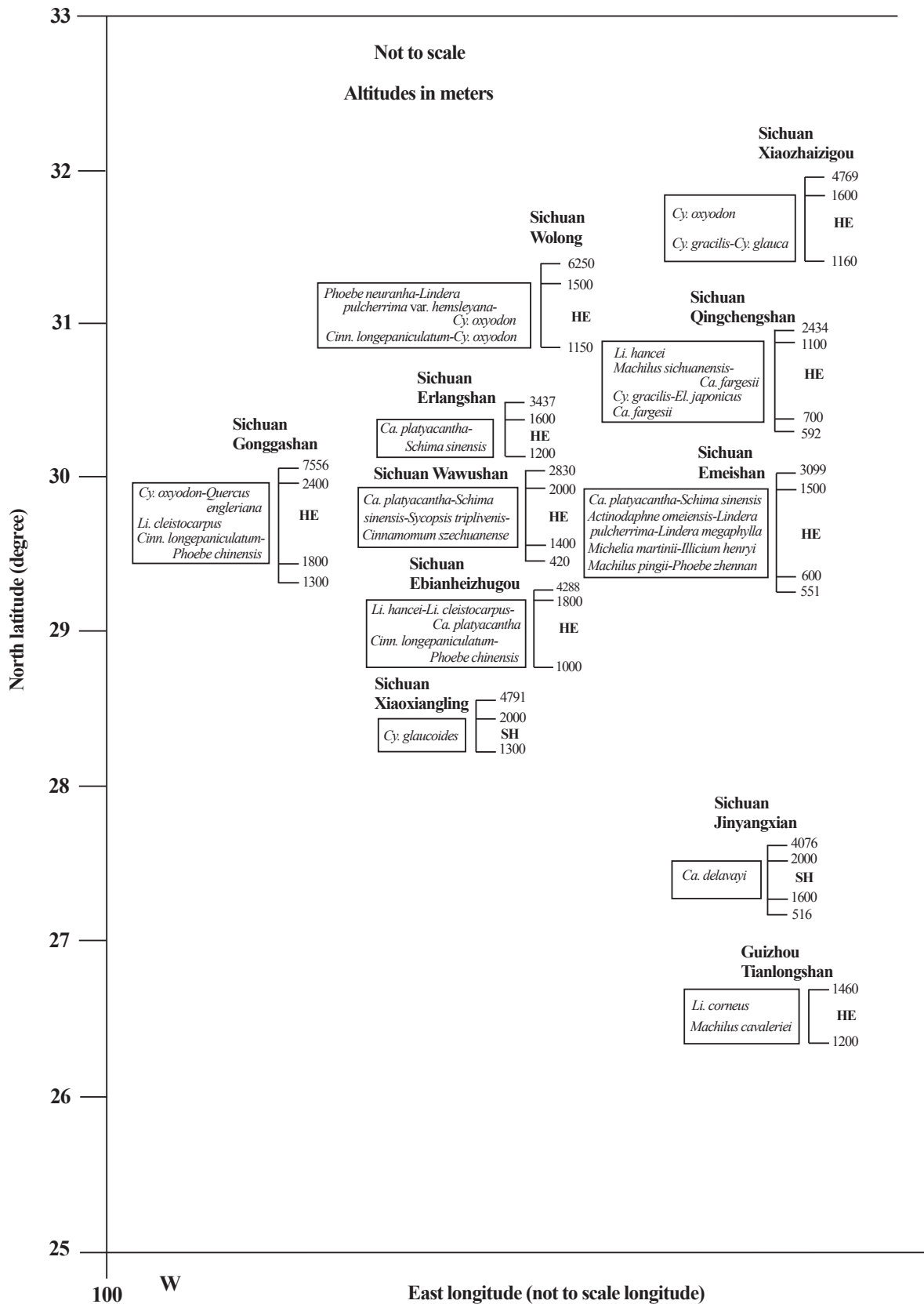
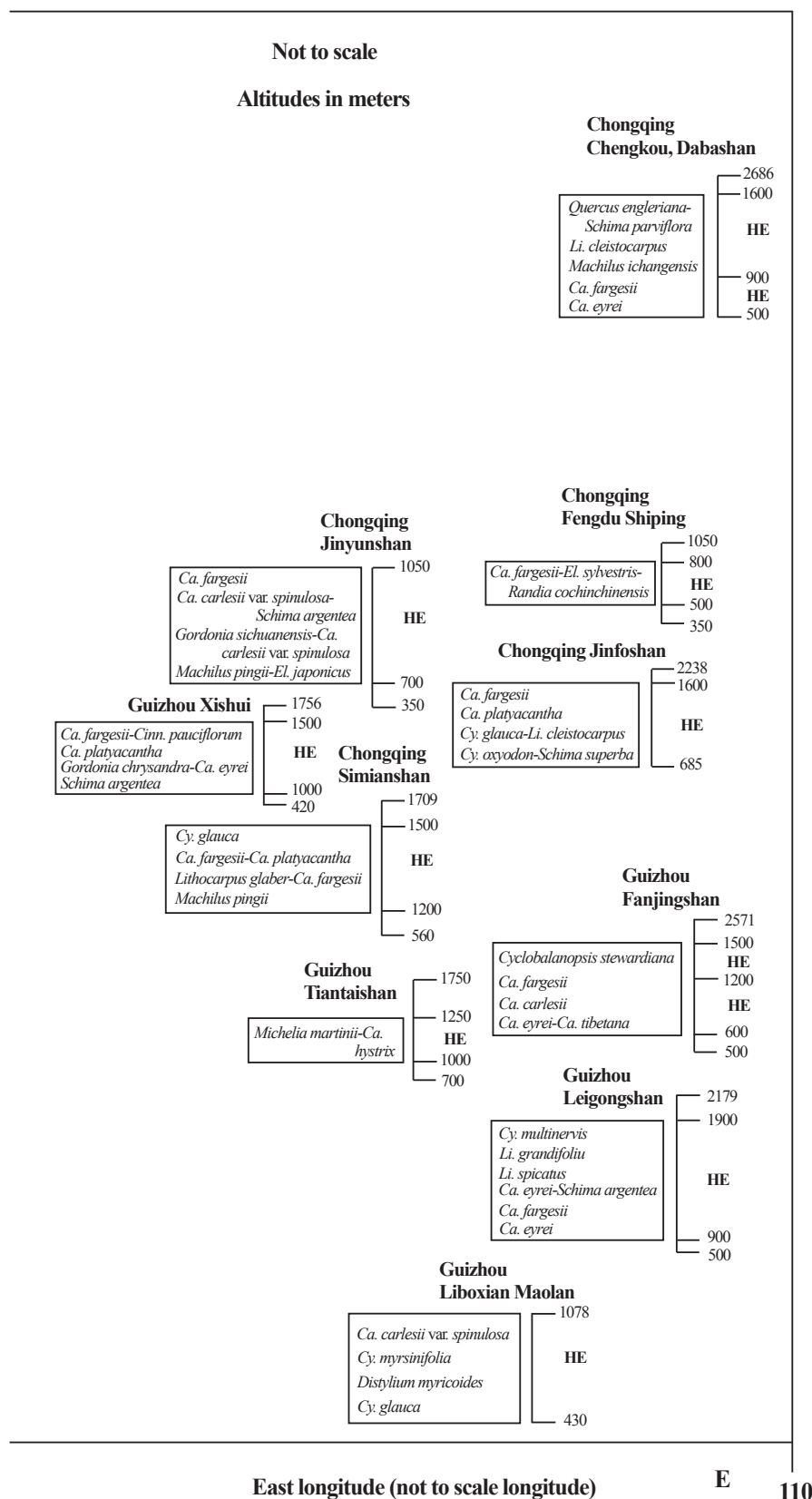


Figure 8. The spatial patterns of distribution of dominant evergreen broad-leaved communities along latitudes, longitudes and altitudes in Sichuan, Chongqing and Guizhou. HE: Humid EBLF; SH: Semi-humid EBLF; *Cy*: *Cyclobalanopsis*; *Ca*: *Castanopsis*; *Li*: *Lithocarpus*; *Cinn*: *Cinnamomum*; *El*: *Elaeocarpus*. Data sources: SVEG (1980), Yang (1983), Liu (1985),



Liu & Qiu (1986), Zhou (1992), Zuo (1995), He *et al.* (1996), Tang & Ohsawa (1997), Xie & Chen (1998), Liu & Zhong (2000), Tang & Ohsawa (2000), Bao & Liu (2002), Xu *et al.* (2004), Xu (2005), Tang *et al.* (2007a), Yang *et al.* (2008), Bai *et al.* (2012), Yang & Xie (2012), Yang *et al.* (2012), Zhang *et al.* (2013).

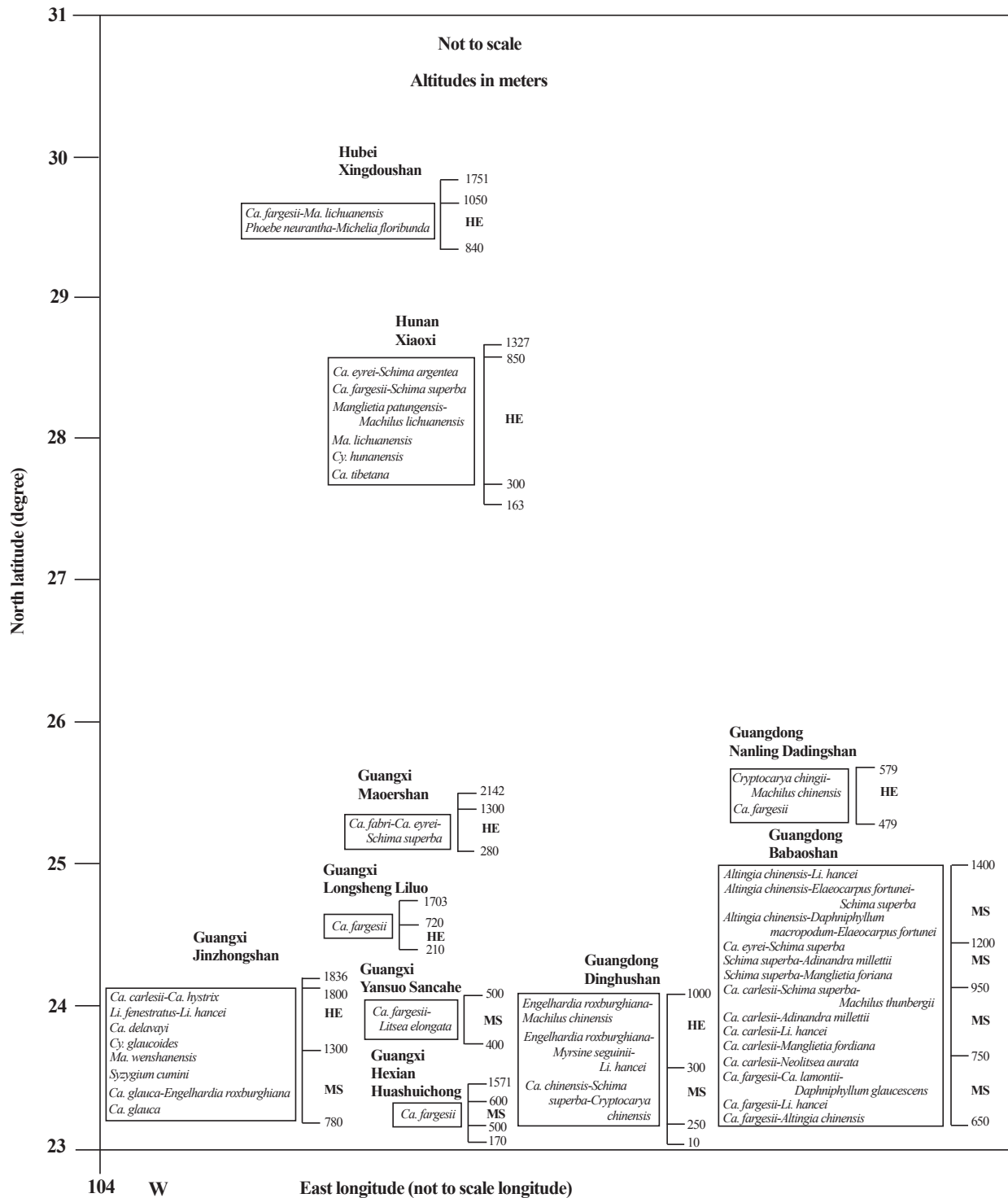
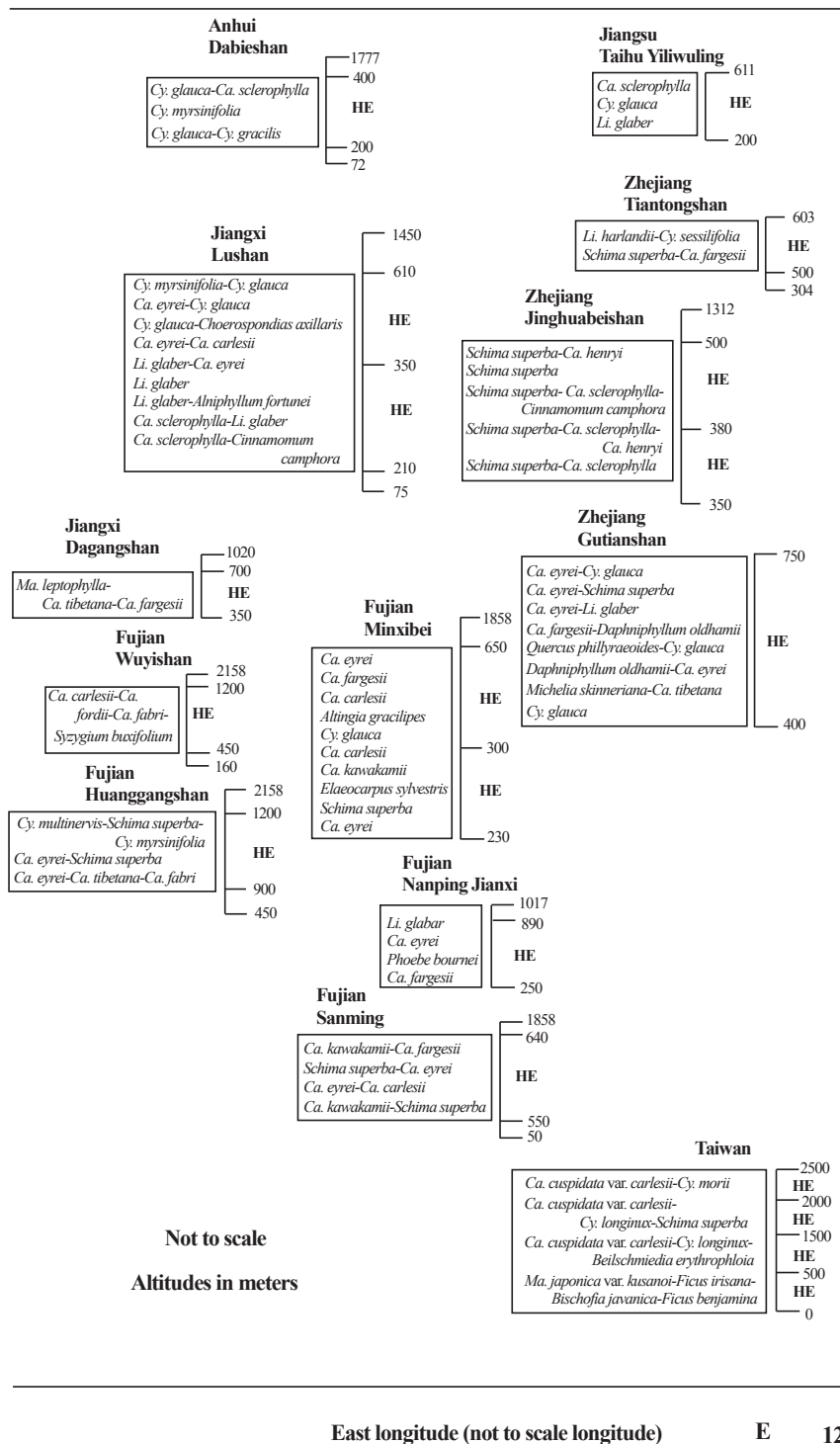


Figure 9. The spatial distribution patterns of dominant evergreen broad-leaved communities along latitudes, longitudes and altitudes in eastern China. MS: Monsoon EBLF; HE: Humid EBLF; *Cy*: *Cyclobalanopsis*; *Ca*: *Castanopsis*; *Li*: *Lithocarpus*; *Ma*: *Machilus*. Data sources: Chen & Su (1995), Huang *et al.* (1998), Hu *et al.* (2003), Da *et al.* (2004), Xia & Nie (2004),



Zheng *et al.* (2004), Zhu *et al.* (2004), Huang *et al.* (2006), Peng *et al.* (2006b), Wan (2007), Deng *et al.* (2008), Wang *et al.* (2009), Qiu *et al.* (2010), Chang *et al.* (2013), Tang *et al.* (2013), Yang *et al.* (2013).

The mid-montane moist EBLFs (MM) are distributed at (1600)1800–2500(2800) m from the east to the west of Yunnan, and from southern to south-central, and northern Yunnan, but not in central Yunnan, as on Jizushan, Huafushan, Shizishan, and Qiongzhusi, where no such moist EBLFs grow. Compared with the former two forest types, in the mid-montane moist EBLFs are to be found, besides dominant species of Fagaceae [e.g. *Cyclobalanopsis lamellosa* (Sm.) Oerst., *Cyclobalanopsis oxyodon* (Miq.) Oerst., *Cyclobalanopsis myrsinifolia* (Blume) Oerst., *Lithocarpus variolosus* (Franch.) Chun, *Lithocarpus hancei* (Benth.) Rehder, *Lithocarpus pachyphyllus* (Kurz) Rehder, *Lithocarpus xylocarpus* (Kurz) Markgr., *Lithocarpus echinotolus* (Hu) Chun & C. C. Huang ex Y. C. Hsu & H. W. Jen, *Castanopsis echidnocarpa* A. DC., *Castanopsis wattii* (King ex Hook. f.) A. Camus, and *Castanopsis remotidenticulata* Hu], Lauraceae [*Machilus longipedicellata* Lecomte, *Machilus viridis* Hand.-Mazz., *Cinnamomum iners* Reinw. ex Blume, *Phoebe faberi* (Hemsl.) Chun], Theaceae [*Schima khasiana* Dyer, *Schima argentea* E. Pritz., and *Schima villosa* Hu] and Magnoliaceae [*Manglietia kungshanensis* Law, *Manglietia insignis* (Wall.) Blume, and *Alcimandra cathcartii* (Hook. f. & Thomson) Dandy] also appear as co-dominants. The mid-montane moist EBLF is characterized by abundant lianas, ferns and mosses on tree trunks and branches.

Sichuan, Guizhou, and Chongqing Municipality

Figure 8 shows the spatial patterns of distribution of dominant evergreen broad-leaved communities along latitudes, longitudes, and altitudes in Sichuan, Guizhou, and Chongqing Municipality, as represented by 21 mountains. In these areas, natural EBLFs at low altitudes have been even more severely reduced by human activities than in Yunnan. Here secondary forests, shrublands, and plantations of pines (*Pinus yunnanensis* in the west of Sichuan and Guizhou, *Pinus massoniana* Lamb. in the east of Sichuan and Guizhou as well as Chongqing) or *Cunninghamia lanceolata* (Lamb.) Hook. or *Cryptomeria japonica* (Thunb. ex L. f.) D. Don var. *sinensis* Miq. (formerly *Cryptomeria fortunei* Hooibr.) prevail. Some semi-humid EBLFs dominated by *Castanopsis delavayi* Franch. or *Cyclobalanopsis glaucoides* are found

in western Sichuan (e.g. Jinyangxian, Xiaoxiangling). In these areas, the typical humid EBLFs (HE) prevail. The dominants are *Castanopsis*, *Lithocarpus*, and *Cyclobalanopsis* [e.g. *Castanopsis carlesii* (Hemsl.) Hayata var. *carlesii*, *Castanopsis fargesii* Franch., *Castanopsis eyrei* (Champ. ex Benth.) Tutch., *Castanopsis carlesii* (Hemsl.) Hayata var. *spinulosa* W. C. Cheng & C. S. Chao, *Castanopsis platyacantha* Rehder & E. H. Wilson, *Lithocarpus corneus* (Lour.) Rehder, *Lithocarpus cleistocarpus* (Seemen) Rehder & E. H. Wilson, *Cyclobalanopsis oxyodon*, and *Cyclobalanopsis multinervis* W. C. Cheng & T. Hong], and many species of Lauraceae [e.g. *Phoebe neurantha* (Hemsl.) Gamble, *Phoebe zhennan* S. K. Lee & F. N. Wei, *Lindera pulcherrima* (Nees) Hook. f. var. *hemsleyana* (Diels) H. P. Tsui, *Lindera megaphylla* Hemsl., *Lindera pulcherrima* (Nees) Hook. f. var. *pulcherrima*, *Cinnamomum longepaniculatum* (Gamble) N. Chao ex H. W. Li, *Machilus pingii* W. C. Cheng ex Yen C. Yang, *Machilus ichangensis* Rehder & E. H. Wilson, and *Actinodaphne omeiensis* (H. Liu) C. K. Allen], and Theaceae [*Schima superba* Gardner & Champ., *Schima argentea*, *Gordonia sichuanensis* H. T. Chang, and *Gordonia chrysandra* Cowan], and Magnoliaceae [e.g. *Michelia martini* (H. Lév.) Finet & Gagnep. ex H. Lév. and *Manglietia fordiana* Oliv.] as well as Elaeocarpaceae [e.g. *Elaeocarpus japonicus* Siebold & Zucc. and *Elaeocarpus sylvestris* (Lour.) Poir.].

To summarize: in SW China, the EBLFs are mainly distributed at higher altitudes [1000–(2400)2800 m] in the western areas of Yunnan and Sichuan, while occurring at lower altitudes [600–1500(2000) m] toward the southern and the eastern areas (Figs. 7 and 8). Communities dominated by *Castanopsis* are widely distributed over the region of SW China. In Yunnan, many plant communities dominated by *Lithocarpus* and/or *Cyclobalanopsis* are conspicuous compared with those in the Sichuan Basin and eastern Guizhou.

Eastern China

In Figure 9, representing 23 mountains of eastern China, we find that the Sichuan Basin, eastern Guizhou, and eastern China share some dominant canopy tree species of Fagaceae [e.g. *Castanopsis carlesii*, *Castanopsis fargesii*, *Castanopsis eyrei*,

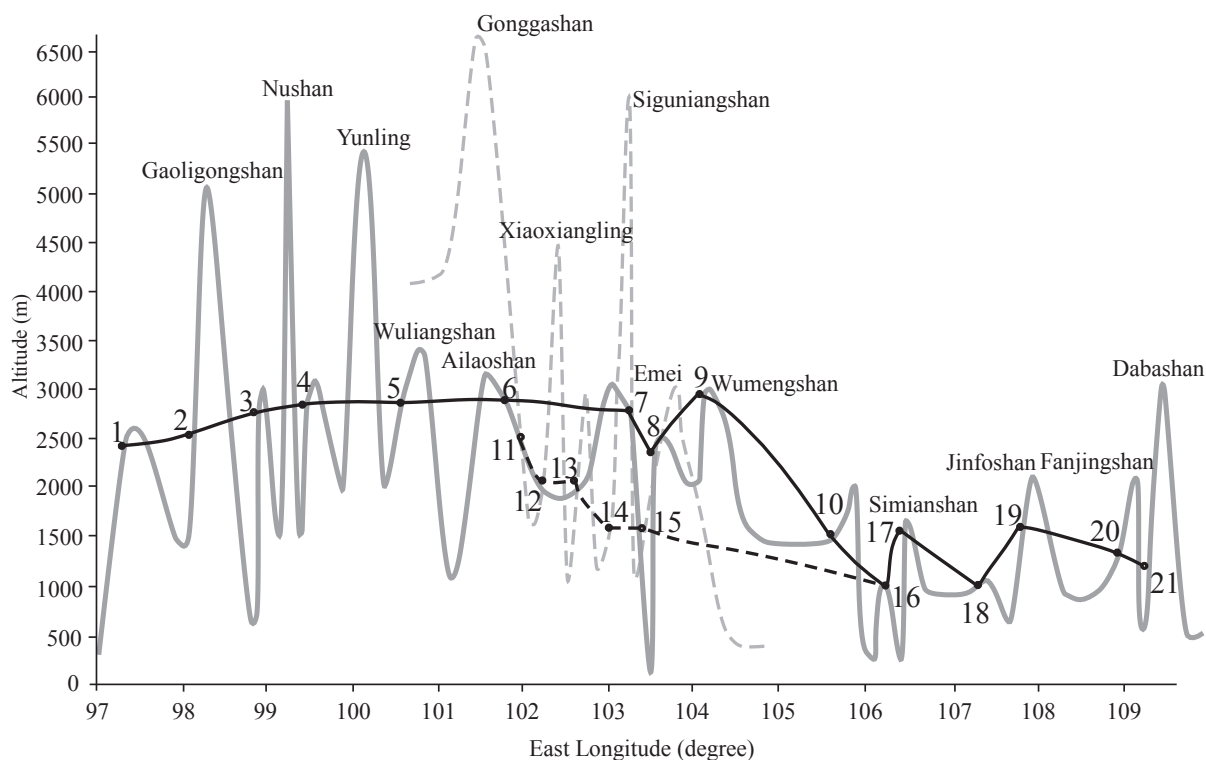


Figure 10. The upper limits of EBLFs in SW China. A dot indicates the upper limit of the EBLF on its respective mountain. 1: Tongbiguan; 2: Dulongjiang; 3: Xiaoheshan in Longling; 4: Yongdedaxueshan; 5: Wuliangshan; 6: Ailaoshan; 7: Xilongshan; 8: Daweishan; 9: Wumengshan; 10: Tianlongshan in Guizhou; 11: Gonggashan; 12: Xiaoxiangling in Sichuan; 14: Siguliangshan; 15: Emeishan; 16: Jingyunshan; 17: Simianshan; 18: Maolan in Guizhou; 19: Jinfoshan; 20: Fanjingshan; 21: Kanghe on Dabashan.

Castanopsis tibetana Hance, *Lithocarpus glaber* (Thunb.) Nakai, *Cyclobalanopsis glauca* (Thunb.) Oerst., *Cyclobalanopsis myrsinifolia*], Lauraceae (e.g. *Phoebe neurantha*), Theaceae (e.g. *Schima superba*) and Elaeocarpaceae (e.g. *Elaeocarpus sylvestris*). In the understory, they often share some genera including *Ilex* L. (Aquifoliaceae), *Lindera* Thunb., *Litsea* Lam. (Lauraceae), *Camellia* L., *Eurya* Thunb. (Theaceae), *Symplocos* Jacq. (Symplocaceae), and *Vaccinium* L. (Ericaceae). However, these forests lack the flourishing epiphytes and lianas on tree trunks and branches, as compared to the mid-montane moist EBLF of Yunnan. Additionally, in the Yunnan area there are more types of plant communities dominated by *Lithocarpus* or *Cyclobalanopsis* or *Castanopsis* than in eastern China, where the chief dominant genus is *Castanopsis*. The upper limits of the EBLFs are mainly 600–1500 m in eastern China (but 2500 m in Taiwan), much lower than in western Yunnan and western Sichuan (2400–2800 m) (Fig. 10).

EFFECTS OF ENVIRONMENTAL FACTORS ON PLANT DIVERSITY PATTERNS IN THE SUBTROPICAL EBLFs

As an evidence of environmental effects on species diversity of the EBLF ecosystems, Tang *et al.* (2013) provided species diversity models comparing the EBLF ecosystems of Yunnan and Taiwan (Fig. 11A, B). In Yunnan, the monsoon EBLF in the mesic-humid sites tends to have higher species richness and diversity (Fig. 11A). Along the altitudinal gradients in Taiwan, higher diversity is found in the *Machilus–Castanopsis* zone at the middle altitudes (500–1500 m) and in the lower *Cyclobalanopsis* zone at the mid-high altitude (1500–2000 m) (Fig. 11B) (see Fig. 9 for the altitudinal distribution of dominant evergreen broad-leaved tree communities in Taiwan). Species diversity, as influenced by temperature and precipitation, varies with altitude. Thus, altitude in the EBLFs of Taiwan may be a proxy for temperature, because

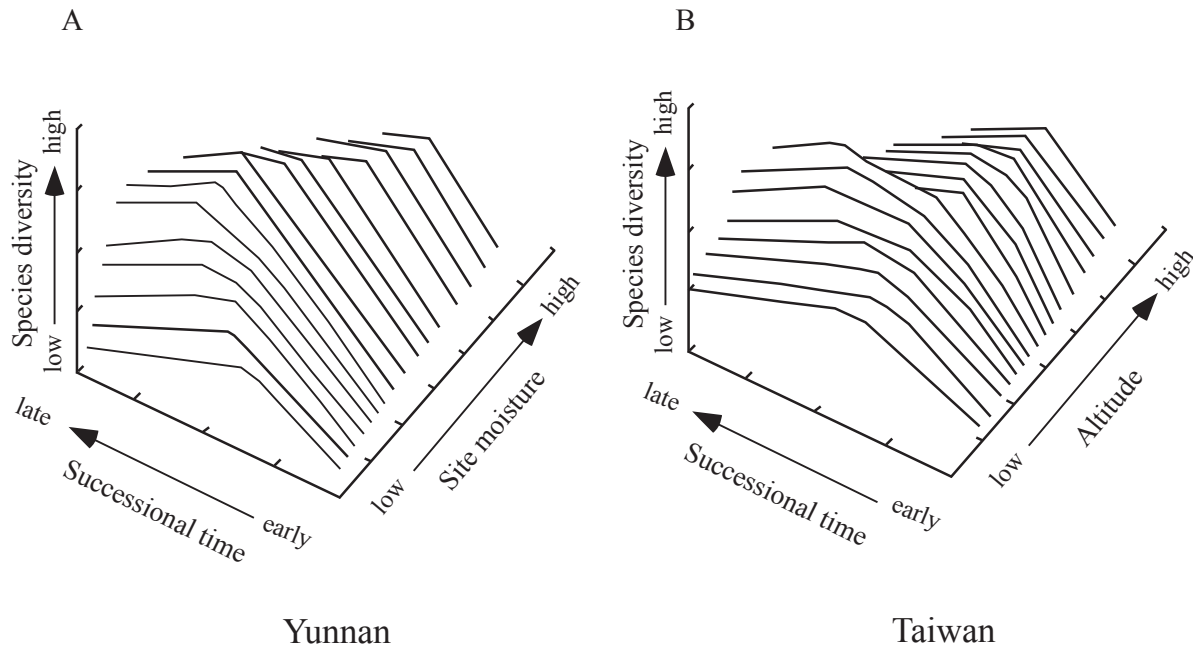


Figure 11. (A), changes in species diversity with site moisture and successional time in the EBLFs of Yunnan; (B), changes in species diversity with altitude and successional time in the EBLFs of Taiwan. Data source: Tang *et al.* (2013).

the annual rainfall is abundant (1800–3000 mm) throughout the EBLF zone. In short, site moisture is the best predictor of species composition and diversity in the EBLFs of Yunnan, while temperature along altitudes plays a decisive role in Taiwan. For forest ecosystems, various temporal trends in diversity have been observed during succession, including increases, decreases, and one or more peaks with passing time (e.g. Auclair & Goff, 1971; Peet, 1978; Halpern & Spies, 1995; Turner *et al.*, 1997). Relationships between diversity and succession are complex and should be seen as system-specific. Secondary forests under varying degrees of human disturbance, such as coppice woods or those growing on abandoned farmland, exhibit a range of stages of plant succession in the EBLF zones of both the Yunnan and Taiwan areas. The peak in diversity in the stands at the middle successional stage of each study site in Yunnan and Taiwan (Fig. 11A, B) reflects the persistence of species with varying attributes, including fast growth, slow growth, light demands, limited or greater shade-tolerance, contributing to significantly higher species diversities

as compared with the early successional stage. In general, as a forest develops, diversity in the late stage tends to decrease with the disappearance of short-lived light-demanding pioneer species (e.g. *Pinus*, *Alnus* Mill., *Populus* L., *Carpinus* L., *Acacia* Mill., *Mallotus* Lour., and *Diospyros* L.); however, in both Yunnan and Taiwan the differences in species diversity between the middle and late successional stages are not significant, which reflects the recruitment of shade-tolerant evergreen trees (e.g. *Cyclobalanopsis*, *Castanopsis*, *Machilus*, *Ficus* L., *Manglietia*, and *Michelia*) into the overstory.

This brief comparison clearly shows the effects of moisture, altitude, and disturbance/succession on plant species diversity patterns in the two EBLF ecosystems of Yunnan and Taiwan.

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