

Species Composition and Structure of Chinese Beech Forests

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Abstract Chinese beech forests do not occur in the warm temperate, deciduous forest region but in the subtropical, evergreen broad-leaved forest region as a component of the vertical zonal spectrum of forest vegetation. Chinese beech forests composed mainly of deciduous species are distributed mainly in the western part of China and often contained *Fagus lucida* as the dominant species. Pure stands of *Fagus lucida* are seen in some areas. Forests containing more evergreen species are mainly in the eastern part of China, and contain species such as *Lithocarpus* spp., *Castanopsis* spp. and *Quercus* spp. in addition to *Fagus* spp. (*F. longipetiolata* and *F. engleriana*). As compared with beech forests in Europe, Japan and North America, those in China are unique in that they are mixed with many evergreen species and have a far richer flora. Chinese beech forests are considered to be a remnant of the Tertiary forest community.

Key words: *Fagus*, beech forests, mixed (evergreen and deciduous) forests.

In the classification system of vegetation of China (Zhu and Li, 1980), vegetation including beech (*Fagus*) as its main component species is classified into mixed (evergreen and deciduous) broad-leaved forest. It is treated similarly in the Chinese Great Encyclopedia—Agriculture (Zhou, 1991). The reason for this is that the beech forests in China do not occur in the warm temperate, deciduous broad-leaved forest region, but in the subtropical, evergreen broad-leaved forest region. Even scattered occurrence of beech species is not observed in the former zone. Furthermore, beech forest does not comprise a horizontal vegetation zone, but is only one component of the vertical zonal spectrum of forest vegetation.

Until now, Chinese beech forests have not been studied extensively and no detailed or comprehensive reports are available. However, the beech forest is one of the main deciduous broad-leaved forest types in Europe, North America and Japan. Therefore, data on beech forests in China are of significance for comparative studies of beech forests worldwide.

Distribution

In the classification system of vegetation regions in China, there are eight first-class regions (He and Zhang, 1980). Among them, one of five regions located in the forest area of

China is named “the warm temperate, deciduous forest region”. This region covers the area between the Great Wall–Qinling Mountains and the Huaihe River, and the zonal vegetation type of this area is the deciduous broad-leaved forest. Another region which covers the area from the Huaihe River southward to the Nanling Mountains is named “the subtropical, evergreen broad-leaved forest region” and is further divided into three vegetational zones: (1) the northern subtropical evergreen broad-leaved forest zone, with a zonal vegetation type of mixed (evergreen and deciduous) broad-leaved forest; (2) the middle subtropical evergreen broad-leaved forest zone, containing mainly evergreen broad-leaved forest; (3) the southern subtropical evergreen broad-leaved forest zone, containing mainly monsoon evergreen broad-leaved forest.

Although beech forest is regarded as one of the mixed (evergreen and deciduous) broad-leaved forest types in the classification system of Chinese vegetation, it does not occur in the northern subtropical evergreen broad-leaved forest zone either as its zonal vegetation type, or one component of the vertical zonal spectrum of forest vegetation. Beech forest is one of the typical mixed broad-leaved forest types developing in the mountainous area of the middle subtropical zone with acid yellow-

brown soil.

Chinese beech forests are distributed mainly in Sichuan, Guizhou, Hunan, Jiangxi, Hubei, Zhejiang and Anhui provinces: the border area of the Sichuan Basin (1500–2000 m in altitude); the western part of Hubei Province (1500–1900 m in altitude); the western part of Jiangxi Province (1100–1400 m in altitude); the southwestern and the northwestern parts of Zhejiang Province (1000–1700 m in altitude). As an element of the vertical, zonal spectrum of forest vegetation, it is distributed close to the upper limit of the evergreen broad-leaved forest, or mixed with other evergreen broad-leaved forest types, and sometimes it is the transitional vegetation type extending into the deciduous broad-leaved forest.

Because the distributional area of beech forest is located at altitudes of more than 1000 m, the climate of the area is similar to that in a temperate area, viewed from air temperature. The annual mean temperature is 6 to 10°C, the mean temperature in the warmest month 17 to 21.5°C, the mean temperature in the coldest month –2 to –6°C, the maximum temperature in a year 33 to 35°C and the minimum temperature in a year –20 to –24°C. The effective cumulative temperature (higher than 10°C) is 2000 to 3400°C. However, there is plenty of orographic precipitation because of the mountainous topography and the annual precipitation exceeds 1200 mm. The forest vegetation including *Fagus* is located mainly near valleys running through the ridges of mountains, where it is humid and cloudy.

Because beech forest has particular water and heat requirements for establishment, it cannot occur in the warm temperate zone and the north subtropical zone. Although the heat conditions in both zones are similar to that of the distributional area of beech forest, the water conditions are not suitable for the development of Chinese beech forest. The annual mean temperature of the warm temperate zone is 8 to 14°C, the mean temperature in the warmest month 24 to 28°C and the mean temperature in the coldest month –3 to –22°C. On the other hand, precipitation in the warm temperate zone is only 500 to 1000 mm and the air humidity is also low. This is the main

reason why Chinese beech forest does not occur in the warm temperate zone and the north subtropical zone. Another reason may lie in the soil conditions. The soil type of Chinese beech forest is mountainous yellow soil or mountainous yellow-brown soil. On the other hand, the soil in the warm temperate zone is the brown soil or mountainous brown soil.

Floral background

The species composition of Chinese beech forest dates from the Mesozoic. In the Cretaceous period, about 100 million years ago, there were two obvious types of flora in the Northern Hemisphere, one of which was the northern Cretaceous temperate flora. According to spore-pollen analysis and fossil analysis, the northern Cretaceous temperate flora developed in the northern part of Laurasia, i.e. from the northern part of North America to Siberia via northern Europe. The main components of the northern Cretaceous temperate flora were deciduous broad-leaved trees and shrubs, which included *Fagus*. Thus, beech forests were considered to be distributed in the northern China at that time.

From the Cenozoic, the vegetation and climate started to change greatly. The climate of northern China became warm and humid in winter, and hot and rainy in summer. This climate was suitable for the development of deciduous broad-leaved forests including evergreen species. There were deciduous broad-leaved forests including *Fagus* in the Eocene of the Paleogene. Some evergreen species such as *Cinnamomum natoanum*, *Lindera antiqua*, and *Schisandra* spp. grew in the forests. Although the climate of the Northern Hemisphere gradually became colder and drier in the Neogene, *Fagus* was still a component of deciduous broad-leaved forests.

The temperature decreased further, and the glacial epochs and periglacial periods occurred frequently in the Quaternary. The climate became cold in the glacial epochs and became dry and hot in the periglacial periods. This climatic change affected the floristic composition of the forest in northern China. Evergreen broad-leaved species requiring relatively higher temperatures and deciduous broad-

leaved species requiring more water disappeared gradually from the forest.

In view of the above floral history, it is understandable that the beech forest does not occur in the warm temperate, deciduous broad-leaved forest region of China. The beech forest in the subtropical region of China is a remnant of forests which disappeared in the glacial epochs of the Quaternary, and is the direct descendant of the Tertiary vegetation. Because in the Quaternary glaciers did not develop in China, and the Asia Desiccation affected the climate of China only slightly, more plant species remained in beech forests in China than in North America or Europe.

The genus, *Fagus* comprises 11 species worldwide and is distributed in the temperate zone and the mountainous area of the subtropical zone of the Northern Hemisphere. There are six species of *Fagus* in China: *F. longipetiolata*, *F. lucida*, *F. engleriana*, *F. chienii*, *F. hayatae* (in Taiwan and Zhejiang) and *F. pashanica* (in Nanjiang, Sichuan). They are canopy elements of mixed broad-leaved forests and deciduous broad-leaved forests.

The component species of Chinese beech forests are different from those of beech forests in Europe (*F. sylvatica* and *F. taurica*), North America (*F. americana*) and Japan (*F. crenata* and *F. japonica*). *Quercus petraea* and *Q. robur* are the main accompanying species of beech forests in Europe, whereas *Acer saccharum* is found in North America and *Q. crispula* in Japan.

Beech forests in the western mountains of China are established at higher altitudes, where the component species are mainly deciduous. On the other hand, in the eastern part of China (Jiangxi, Anhui and Zhejiang provinces), where it is warmer and there is more precipitation, beech forests are established at lower altitudes (1000–1500 m above sea level) accompanied by many evergreen species.

Although the dominant species of Chinese beech forests are *Fagus* spp., there are many accompanying evergreen broad-leaved species, such as *Cyclobalanopsis* spp., *Lithocarpus* spp., *Castanopsis* spp. and evergreen species of *Quercus*. Furthermore, there are *Neolitsea*, *Cinnamomum*, *Machilus*, *Schima* and some evergreen species belonging to the Aquifoliaceae and

Symplocaceae, and sometimes the evergreen species of *Daphniphyllum*. This forest also includes many species endemic to China, such as *Liriodendron chinense*, *Davidia involucata*, *Tetracentron sinense*, *Aesculus chinensis*, *A. wilsonii*, *Bretschneidera yinschanensis*, *Nyssa sinensis*, *Taxus mairei* and *Cephalotaxus fortunei*.

With regard to the bioclimate zone, the characteristics of Chinese beech forests are similar to those of deciduous broad-leaved forests composed mainly of deciduous species of *Quercus*. Because of the different environmental factors and the floral history, these two forest types show different species compositions. Although Chinese beech forests occur in the evergreen broad-leaved forest region of China, they are not the zonal vegetation type but components of vertical zonal spectrum. Since water conditions, heat conditions and other environmental factors of the vertical zonal spectrum are different from that in the basal zone, the species composition of beech forests is very different from that of the evergreen broad-leaved forest.

Species composition and structure

There are two types of beech forest in China. One is composed mainly of deciduous broad-leaved species, although some evergreen broad-leaved species may also be present. This type of forest is often regarded as a type of deciduous broad-leaved forest and is distributed mainly in the western part of China. The other type of beech forest contains more evergreen species and is usually regarded as a type of mixed (evergreen and deciduous) broad-leaved forest. This type of forest is the main type of Chinese beech forest and has unique characteristics compared with beech forests in other areas.

Beech forest in which component species are deciduous broad-leaved species is distributed in Guizhou Province. There in Mt. Fanjingshan, *Fagus lucida* is the main component species of the forest and can form pure stands in some areas (Fig. 1).

Three layers are recognized in the vertical structure of the forest: the tree, the shrub and the herb layers. The tree layer can be further divided into two sublayers, the upper and the lower. The height of the upper sublayer is 10–



Fig. 1. *Fagus lucida* forest in Guizhou (1600 m in altitude).

24 m, reaching 35 m at maximum with a coverage of 40–50%. The dominant species is *Fagus lucida* and other deciduous species such as *Acer sinensis*, *Styrax japonica*, *Enkianthus serrulatus* and *Betula austrosinensis*. Evergreen species such as *Castanopsis chunii*, *Cyclobalanopsis stewardiana*, *C. glauca*, *Phoebe newranthoides* and *Quercus engleriana* also become elements of this layer but their height is less than that of *Fagus lucida*. The lower sublayer, 4–8 m in height, is composed mainly of evergreen species. The height of the shrub layer is less than 2 m and its coverage is 45–60%. The dominant species of the shrub layer is *Sinarundinaria chungii*. The herb layer is usually composed of scattered plants on the forest floor and its coverage is 30–70%, although it may be more developed in some areas.

Another deciduous type of Chinese beech forest is the *Fagus longipetiolata* forest (Fig. 2). No large areas of this forest now remain because of human activities. A well-protected forest of this type remains on Mt. Fanjingshan, Guizhou Province. This forest occurs at lower altitudes than the *Fagus lucida* forest, often in the evergreen broad-leaved forest zone.

In the vertical structure of the *Fagus longipetiolata* forest, three layers: the tree, the shrub and the herb layers, are recognized. The tree



Fig. 2. *Fagus longipetiolata* forest in Hupei (1400 m in altitude).

layer can be divided into two sublayers. The height and the coverage of the upper sublayer are 8–16 m and 50% respectively. The dominant species are *Fagus longipetiolata*, other deciduous species such as *Betula* spp. and *Liquidambar formosana*, and evergreen species such as *Castanopsis chunii* and *Tsuga longibracteata*. The height and coverage of the lower sublayer are 3–7 m and 40% respectively, of which the dominant species are *Cyclobalanopsis stewardiana*, *Symplocos stellaria*, *Schima argentea* and some evergreen species of Lauraceae. The height of the shrub layer is less than 2 m, with a coverage of 85%. The dominant species of the shrub layer is *Sinarundinaria chungii*. The herb layer is developed very poorly, its coverage being only 5%.

One type of mixed (evergreen and deciduous) broad-leaved forest including *Fagus* is the *Fagus longipetiolata*–*Lithocarpus cleistocarpus* forest. This forest occurs in the transition zone from the middle subtropical zone to the northern subtropical zone, such as the middle slopes (1500–2000 m in altitude) of mountains near the northern border of Sichuan Province. Three layers: the tree, the shrub and the herb layers, are recognized in the vertical structure of the forest. The evergreen broad-leaved trees grow under the canopy of deciduous trees, because evergreen trees prefer shade and humid environment. The dominant, evergreen broad-leaved species is *Lithocarpus cleistocarpus*. The deciduous broad-leaved trees range in height from 10–25 m, and include many species, such as *Fagus longipetiolata*, *F. engleriana*, *Quercus*

serrata, *Q. serrata* var. *brevipetiolata*, *Q. aliena*, *Q. aliena* var. *acutiserrata*, *Q. acutissima*, *Q. variabilis*, *Acer davidii*, *A. tetramerum*, *A. caudatum* var. *pratii*, *A. buergerianum*, *Carpinus cordata*, *C. tangiana*, *C. turczaninowii*, *C. tschonoskii*, *C. cordata* var. *chinensis*, *Betula albo-sinensis*, *B. luminifera* and *Tilia chinensis*. In some areas, there are *Tetracentron sinensis*, *Liriodendron chinense*, *Euptelea pleiospermum*, *Cercidiphyllum japonica* var. *sinense* and *Davidia involucata*. The height of evergreen trees is 6–12 m, and these include species such as *Symplocos setchuensis*, *S. anomala*, *Eurya nitida* var. *aurescense*, *Machilus* sp., *Neolitsea aurata* and *Ilex fargesii*. Other deciduous species are *Sorbus pohuashanensis*, *S. folgeri*, *Crataegus pinnatifida*, *Prunus pilosiuscula*, *Lindera obtusiloba*, *L. glauca*, *Dendrobenthamia kuosa* var. *chinensis*, *Bothrocaryum controversum*, *Swida macrophylla*, *Alalia chinensis*, *Styrax japonica* and *Corylus ferox* var. *tibetica*. The coverage of the shrub layer is 20–85%. This layer is floristically rich and dominated by *Sinarundinaria wilsonii* and *Indocalamus* spp. There are also many species in the herb layer. Some species of liana grow in the forest.

There are other types of beech forest in China, such as the *Fagus lucida*–*Cyclobalanopsis glauca* forest, the *Fagus longipetiolata*–*Rhododendron ovata* forest, the *Fagus longipetiolata*–*Eurya loquiana* forest and the *Fagus longipetiolata*–*Eurya hebeclados* forest. There are also other types of mixed (evergreen and deciduous) broad-leaved forest including *Fagus*, but whose dominant species are evergreen trees, such as the *Fagus engleriana*–*Cyclobalanopsis glauca*–*Daphniphyllum macropodum* forest, the *Fagus longipetiolata*–*Cyclobalanopsis oxyodon*–*Distylium myricoides* forest, and the *Fagus lucida*–*Cyclobalanopsis nubium*–*Castanopsis lamontii* forest.

Regeneration

According to an analysis of the *Fagus longipetiolata* forest in Jiangxi Province (Lai, 1986), *Fagus longipetiolata* showed a coverage of more than 85% of the total area and occurred in every age class. Thus, we can say that *Fagus longipetiolata* had regenerated well in the forest and that its population was at the mature stage. On the other hand, *Machilus thunbergii*

occurred in the younger age class but was absent from the oldest class. Thus, the population appeared to be at the exuberant stage. In contrast, *Magnolia denudata* and *Nyssa sinensis* lacked seedlings and saplings, indicating that their population was at the senescent stage.

Fagus species are arboreal and can grow very quickly. The height of a 50 year-old beech tree may reach 30 m, and its diameter 80 cm. Younger plants less than 5 years old show a low growth rate, but this increases later, reaching 1.0 m/year in height and 1.1 cm/year in diameter between 5 and 10 years old. The growth rate begins to decrease again at 25–35 years old, and becomes very small at 35–50 years old, although trees of this age are exuberant and fruitful. Thus, beech forest at 50 years old is most suitable for exploitation.

Necessity of future studies

In the classification system of vegetation in China (1980), mixed (evergreen and deciduous) broad-leaved forest was treated as single independent vegetation type. It was further divided into three sub-types, one of which is the mountainous mixed broad-leaved forest, in which Chinese beech forest was included.

Because of the complex topography and various climatic conditions in China, there are many types of forest including *Fagus* species as their elements. Beech forest composed solely of deciduous species is distributed mainly in the mountainous areas of western China, and beech forest including many evergreen broad-leaved species is distributed in eastern China. From this viewpoint, the pure forest of *Fagus lucida* which was discovered recently in the eastern part of Anhui Province is of great significance.

The Chinese beech forest is a vegetation type transitional from deciduous broad-leaved forest to evergreen broad-leaved forest. An important problem to be solved is whether the forest should be treated as one type of deciduous broad-leaved forest or as an evergreen one, or as a single independent type occurring in both deciduous and evergreen broad-leaved forest.

Chinese beech forests are not distributed within the deciduous broad-leaved forest

region, but horizontally within the evergreen broad-leaved forest region. It occurs commonly as one element of vertical vegetation zones in the evergreen broad-leaved forest region. The northern limit of the horizontal distribution of Chinese beech forest runs along the line of 30° N, although it reaches 32°N in some areas. This limit is located far more south than those in Japan, Europe and North America. This may be attributable to the lower humidity of northern China, which is not suitable for the establishment of beech forest. The environmental conditions in areas where Chinese beech forests are located needs to be analyzed in detail in future.

Although beech forests occur widely in Eurasia, Japan and North America, their component species vary. The different history of floral development among areas is important in bringing about these differences. Continental North America became separated from Continental Eurasia in the primary Tertiary, about 65 million years ago. The Japanese Archipelago became separated from Continental Eurasia in the Pleiocene of the Cenozoic period, about 65 million years ago. A comparison of beech forests among China, Japan and North America is a very interesting and important area of study because of the close floral relationships that exist among these areas. In particular, Chinese beech forest warrants further study because of its uniqueness in that it is mixed with many evergreen broad-leaved species and has the richest flora.

We think that the Chinese beech forest is a remnant of the Tertiary forest community. However, other opinions maintain that the Chinese beech forest is one of several secondary forests which were established after evergreen broad-leaved forests were damaged by human activities. This opinion is based on the fact that beech forest hardly regenerates successfully because seedlings on the forest floor cannot grow well, and that other types of mixed or evergreen broad-leaved forest can easily replace beech forest when it is destroyed. Therefore, further study of the origin and history of the Chinese beech forest is needed.

Although the Chinese beech forest has un-

doubtedly has particular importance for study, it has not received attention because there are many forest types in China and their inter-relationships are complicated. We welcome all foreign botanists who would like to come to China to study the Chinese beech forest.

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中国のブナ林の種組成と構造

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中国のブナ林は、暖温帯落葉樹林域ではなく、亜熱帯常緑樹林域において、垂直的な森林配分図上での一要素として生じる。中国のブナ林のうち、おもに落葉種からなるものは、主として中国西部に分布し、テリハブナ *Fagus lucida* を優占種とすることが多い。テリハブナの純林がみられる場所もある。常緑種を多数含むブナ林は、おもに中国東部にみられ、ブナ属（ナガエブナ *F. longipetiolata* とエングラブナ *F. engleriana*）の他に、マテバシイ属や、シイ属、コナラ属の種が生育する。中国のブナ林は、ヨーロッパや日本、北米のブナ林と比べて、多数の常緑種が混交することや、フロラの多様性がきわめて高い点で独特であり、第三紀の森林群落の遺存であると考えられる。