

Hai Ren *Editor*

Conservation and Reintroduction of Rare and Endangered Plants in China



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Preface

In the face of unprecedented biodiversity losses and global change, effective approaches for the conservation of rare and endangered plant species are urgently required. The major approaches to integrative plant conservation include in situ conservation, ex situ conservation, and reintroduction. Reintroduction may be especially effective at protecting and rescuing rare and endangered plants.

China has protected about 65% of the vascular plant communities through in situ conservation in natural reserves and national park systems and has preserved about 60% of the plant species through ex situ conservation in botanical gardens and other ex situ conservation facilities. However, we know less about reintroduction in China. Throughout the book, we and our invited authors explore to what extent information about reintroduction of plants is currently available in China.

This book is composed of two parts. Part I introduces the plant diversity and its conservation in China, and Part II displays some cases of reintroduction of rare and endangered plants in China. The majority of the chapters in the book are devoted to the case studies of reintroduction.

Books such as this one become a reality only with the support and involvement of many people. The editors are indebted to the team of enthusiastic authors, all famous experts in the fields in China, who have made available experience. The editors divide their work as follows: Prof. Hai Ren designed the contents and organized the manuscripts. Prof. Hongfang Lu edited Chaps. 1–4, Dr. Hongxiao Liu edited Chaps. 5–20, Director Ju Zhou co-organized the manuscripts and co-conceived the contents, Prof. Yan Zeng edited tables, photos, and figures. Thanks to Prof. Elizabeth Platt Hamblin for editing English. We thank the anonymous reviewers for their constructive comments. We are very grateful to Dr. Xin Zhu and Beracah John Martyn for their careful fine-tuning of the editorial work at press.

The financial support from Chinese Academy of Sciences and Ministry of ecological environment (No. 8-3-7-20-10) is gratefully acknowledged. We hope

that this small book will be of value in stemming the tide of plant diversity loss and unsustainable development in China and even in the world. This book is dedicated to Convention on Biological Diversity-COP 15, which will be held in 2021 in Kunming, China.

Guangzhou, China
November 12, 2019

Hai Ren

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Part I
Plant Diversity and Its Conservation in
China

An Overview of China's Vegetation and Plant Diversity



Haining Qin, Xiaohua Jin, and Ke Guo

Abstract China's complex climate and geological condition have enriched species and created a diversified spatial distribution pattern of biodiversity, making China one of the countries of the most abundant of species and special types of vegetation in the world. Seven vegetation type groups are recorded by *Vegetation of China* (Editorial Board of Vegetation of China, *Vegetation of China* (Science Press, Beijing, 1980)): forests, shrubs, deserts, grasslands, meadows, alpine vegetation, and swamp or aquatic vegetation. The main characteristics of Chinese vegetation are (1) a complete range of categories, including various types of forests, steppes, deserts, and marshes; (2) vast areas of subtropical evergreen broadleaf forest owing to the influence of the monsoon climate; and (3) unique plateau vegetation on the Qingzang Plateau and the unique altitudinal spectra of numerous mountains. The complexity of China's vegetation types is not only a manifestation of China's complex biodiversity but also is the basis for the evolution of diverse plant species, animals, fungi, and microorganisms. China has 36,152 species of higher plants, 9% of the world flora. Two national floras completed in early of this century *Flora Reipublicae Popularis Sinicae* (1959–2004) and *Flora of China* (1994–2013) are the key breakthroughs in understanding and mastering China plant diversity. *Catalogue of Life China* (CoL-China) (2008–) is designed to update the species information in the above floras with latest taxonomic literatures, to meet timely the needs of biodiversity conservation. These three works are recognized as the primary reference

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book for the study of China plant diversity. Hundreds of new species are described every year and added to the annual checklist of CoL-China. It is essential to complete inventory of Chinese plants, since it's impossible to conserve the undiscovered species.

Keywords Mega-diversity country · Vegetation · Plant species diversity · Conservation

1 An Overview of China's Vegetation

From south to north, the eastern monsoon region of China has tropical forests and seasonal rain forests; subtropical evergreen broadleaf forests; warm temperate deciduous broadleaf forests; temperate coniferous, broadleaf mixed forests; and cold temperate coniferous forests, showing obvious latitudinal gradients. From east to west, north China gradually transitions from forest to grassland and then to desert along longitudinal gradients (Fig. 1).

The vegetation on the Qinghai-Tibet Plateau is a variation on highland integrating the horizontal and vertical gradients, with a distribution pattern as follows: from the southeast to the northwest, with the gradual increase of altitude, there is a sequential distribution of a mountain forest belt (Fig. 2), a belt of alpine shrub land and meadows, an alpine grassland belt, and an alpine desert belt.



Fig. 1 Some vegetation types in China



Fig. 2 Some mountain forests in China

1.1 Forests

Forest is a type of vegetation in which trees dominate and the canopy coverage reaches 30% or more. Its community structure is usually complex; for example, the canopy can be divided into two or more sub-layers, under which there are usually shrub layers, then herb, and moss layers. The forest is mainly distributed in the eastern monsoon humid region and the mountains in semiarid and arid regions.

China's forest ecosystems are distributed from south to north in different types. Different climatic zones have their own representative forest types, including deciduous coniferous forests, evergreen coniferous forests, mixed coniferous and broadleaf forests, deciduous broadleaf forests, evergreen deciduous broadleaf mixed forests, evergreen broadleaf forests, rainforest and monsoon forests, and so on.

Deciduous coniferous forest is a forest type dominated by deciduous conifers, such as *Metasequoia glyptostroboides*, *Glyptostrobus pensilis*, *Pseudolarix kaempferi*, and *Taxodium distichum*. The main feature of this forest type is that the canopy layer defoliates collectively, forming a distinct growing season and a falling season within 1 year. According to the climatic characteristics of the distribution sites, China's deciduous coniferous forest is divided into two vegetation subtypes, namely, the subtype of cold-temperate deciduous coniferous forests featured by

dominant *Larix* species and the subtype of warm-temperate deciduous coniferous forests featured by some species of Pinaceae and Taxodiaceae.

Evergreen coniferous forest is characterized by evergreen conifers as dominant species, in which the main feature is a green or gray-green appearance throughout the year. This type has a wide range of distribution and great variety of types of dominant species and communities. According to the climatic characteristics of community distribution, it is divided into four subtypes, namely, a cold-temperate evergreen coniferous forest subtype, a temperate evergreen coniferous forest subtype, a warm-temperate evergreen coniferous forest subtype, and a tropical evergreen coniferous forest subtype.

Mixed coniferous and broadleaf forest is composed of evergreen conifers and broadleaf trees. Usually, the conifers occupy the upper layer of the arbor layer, and the lower layer consists of more broadleaf trees. According to community characteristics such as community composition and the climate characteristics of the distribution area, it is divided into two subtypes of vegetation, namely, the typical coniferous and deciduous broadleaf mixed forest subtype distributed in the middle temperate zone and the mountainous conifer and broadleaf mixed forest subtype in the subtropics.

Deciduous broadleaf forest is dominated by deciduous broadleaf arboreal species. It is mainly distributed as zonal vegetation in low mountain and hilly areas in the mid-temperate and warm-temperate zone, and also as vertical zonal vegetation in temperate and subtropical mountains. There are many species that make up the arboreal layer, such as *Quercus* spp. (Fagaceae). Due to defoliation in winter, the seasons of the community are very distinct, with sufficient light under the canopy in winter and spring, allowing development of shrub and herb layers. According to the species composition characteristics of the community, the geographical distribution of the dominant species, and the characteristics of the habitat, it is divided into four vegetation subtypes, namely, the cold-temperate deciduous broadleaf forest subtype, the temperate deciduous broadleaf forest subtype, the warm-temperate deciduous broadleaf forest subtype, and desert riverbed deciduous broadleaf forest subtype.

Evergreen deciduous broadleaf mixed forest is a transitional forest type between deciduous broadleaf forests and evergreen broadleaf forests. In China, it is widely distributed in the northern subtropical regions and subtropical limestone mountains. The composition of the community is diverse. From north to south, the evergreen components are gradually increasing, and the species also have substitution phenomena or more hot and evergreen components. There is usually no obvious dominant species, and the species are mainly in the families of Fagaceae, Betulaceae, and Ulmaceae. The community structure is complicated, and the deciduous tree species usually occupy the upper part of the arboreal layer, which makes the seasonal phase change obviously, while the evergreen tree species have a comparative advantage in the lower part of the arboreal layer. According to the difference of habitats, the evergreen deciduous broadleaf mixed forest is divided into three vegetation subtypes: the (zonal) evergreen deciduous broadleaf mixed forest distributed in the low hills of the northern subtropical zone, the mountain evergreen deciduous mixed broadleaf forest distributed in the subtropical mid-mountain belt,

and the limestone evergreen deciduous broadleaf mixed forest distributed on calcareous soil.

Evergreen broadleaf forest is a vegetation type with evergreen broadleaf tree species as dominant species, widely distributed in subtropical regions with warm and humid climates and abundant precipitation and mountains in the north of the tropics. The species is diverse in the community, whose composition prone to be more complex from north to south. The dominant species are usually not very obvious, mainly including plants from Fagaceae, Lauraceae, and Theaceae families. The arboreal layer can often be further divided into different sub-layers. Plants in the shrub layer mainly include Ericaceae, Symplocaceae, Myrsinaceae, Melastomataceae, and Aquifoliaceae species, being usually sparse, with the height generally below 2 m; the layer also contains a large number of tree seedlings. The herb layer is mainly composed of Liliaceae, Cyperaceae, Zingiberaceae, and Chloranthaceae plants and ferns, distributed sporadically, all hygrophilous. The sporadic patches of moss are distributed on bare rocks, roots, and on base of trunks. Lianas and parasitic plants are also common. The evergreen broadleaf forest has a wide distribution area and various types, so the type division is complicated.

Tropical forests in China mainly include *tropical monsoon forests* and *tropical rain forests*. The former is a type of tropical forest distributed on the edge of the tropics, found in areas with alternating periodic wet and dry conditions. The latter is distributed in areas with abundant rainfall and sufficient heat, but it is located further north compared with the global distribution of rainforests. China's tropical forests are small in area, mainly distributed in southern Guangdong, Hainan Island, south-western Guangxi, southern Yunnan, and southeastern Tibet. They are the most abundant forest ecosystems in China.

1.2 Shrubs

Shrub assemblages are dominated by mesophytic and meso-xerophytic shrub species, with height generally lower than 5 m and coverage more than 30%. The community structure is relatively simple, usually containing shrub layers and herb layers and occasionally a few bryophytes under thick bushes. Natural shrubs are mainly distributed in humid and semi-humid environments where natural conditions, including temperature and moisture, are no longer suitable for the growth of arboreal species, such as forest-to-grass transition areas, wet areas above forest lines, and mountains with relatively sufficient water in arid areas, or secondary vegetation types in places where forest has been destroyed. China's shrubs can be divided into five vegetation types, the main and widely distributed types including deciduous broadleaf shrubs and evergreen broadleaf shrubs.

Deciduous broadleaf shrub is a vegetation type with deciduous shrubs as dominant species in the communities. Deciduous broadleaf shrub has a vast distribution,

quite different habitats, many dominant species, and complicated community types. It has many primitives, while many of them being secondary vegetation formed after forest destruction. The height of the community is mostly between 1 and 2 m, some types reaching 4 m and some less than 1 m. The coverage is generally between 30 and 70%. According to the characteristics of community and habitat, it can be divided into multiple vegetation subtypes.

Evergreen broadleaf shrub is a vegetation type of evergreen broadleaf shrubs as dominant species. It is mainly secondary vegetation formed after the destruction of forests in tropical and subtropical regions, which is a relatively stable stage in the succession process. The community is generally composed of evergreen young trees and shrubs and sometimes mixed with some deciduous species. The shrub layer of most communities is 1–2 m high, and the coverage is above 60%. The herb layer is generally well developed, with a height of less than 1 m, while the coverage is greatly affected by the shrub layer. According to the ecological characteristics and habitat conditions of dominant species, it is also divided into various subtypes.

1.3 Deserts

Desert is a sparse ecosystem type developed in extreme drought habitats with rare precipitation and strong evaporation. It is a sparse vegetation composed mainly of extremely xeric shrubs, semi-shrubs, small semi-shrubs, and small semi-arboreal and succulent plants. China's deserts are concentrated in the inland areas of the north-west and belong to temperate deserts, accounting for about one-fifth of China's land area, including about one million km² of desert and Gobi. The dominant species are mainly from families such as Chenopodiaceae, Zygophyllaceae, Compositae, Caryophyllaceae, Ephedraceae, and Fabaceae. There are many types of communities, and the species composition and community structure are quite different. It is usually divided into several vegetation subtypes based on the dominant species or leaf characteristics of the community.

Since the desert is in an extremely unbalanced state of water and heat, the ecosystem consists of few species of plants, animals, and microorganisms, and the food chain is relatively simple. Among the animals, there are mainly reptiles like lizards, as well as gerbils, wild asses, argali, ibexes, wild camels, and oryxes. As a very fragile ecosystem, once it disappears, it is difficult to recover.

1.4 Grasslands

Grassland is one of the most important types of terrestrial ecosystems in the world. It is mainly composed of perennial xerophytic grasses and a few shrubs. The world's grasslands are distributed from temperate to tropical. They all occupy a special ecological position, both between the moist forest area and the arid desert area. It

is an ecosystem formed under specific semiarid hydrothermal conditions. According to the composition and geographical distribution of grassland, it can be divided into two types, namely, temperate grassland and savanna.

The grasslands in China are mainly temperate grasslands, distributed in the Inner Mongolia Plateau, the western part of the Northeast Plain, the northwestern part of the Loess Plateau, the central part of the Qinghai-Tibet Plateau, and the arid regions in the northwest China. These grasslands are moderate-temperate or cold-temperate grasslands. There are many types of communities, and the species composition and community structure also have certain variations. Grasslands in China are usually divided into several vegetation types. The clumped grassland is the most widely distributed zonal vegetation type, and dominated by moderate-temperate xerophytic cespitose hemicryptophytes, mainly *Stipa* spp., ecologically characterized by adaptations in drought and cold winter climate. According to the difference of ecological and geographical environment, the clumped grassland can also be divided into several vegetation subtypes.

China's savanna area is small, mainly developed in the dry-hot valleys of Yunnan and Sichuan. It is a grassland type with trees and shrubs scattered on the background of mesophytic drought-tolerant grasses.

1.5 Swamp and Aquatic Vegetation

Swamp and aquatic vegetation types are composed mainly of wet plants and aquatic plants that live in conditions with excess moisture in the soil. Three vegetation types are included: woody marsh, herbaceous marsh, and aquatic vegetation (Fig. 3). China's swamps are widely distributed, with the swamp area second only to Canada and the former Soviet Union, with a total area of 14 million hectares, accounting for 1% of China's total land area. They are mainly distributed in the mountainous area of the Northeast, Three River Plain, and Zoige Plateau (including four counties: Zoige, Hongyuan, Aba in Sichuan, and Maqu in Gansu). These three areas are where China's swamps are most concentrated. The source of the Yangtze River in the hinterland of the Qinghai-Tibet Plateau also has a certain area of swamp distribution. Marshes are only sporadically distributed in the subtropical areas. Apart from the middle and lower reaches of the Yangtze River and the major lakes, a small number of swamps are developed in the intermountain basins or in the glacial valleys. In the warm temperate zones, swamps are only found on the edge of rivers and lakes. Chen (2014) believed that mangroves distributed in tropical coastal areas are also woody marshes.

Aquatic vegetation is a type of vegetation that grows in water and consists of aquatic plants. The environment in the water has its own particularity. The variation of water body is on the aspects of depth, fluidity, transparency, light intensity, pH, mineral nutrient content, and oxygen and carbon dioxide comprised. These differences make aquatic plants of different ecological types and have their own adaptation characteristics. For example, submerged plants are born at the bottom of the



Fig. 3 Some swamps and aquatic vegetations in China

water, with the bodies below the water surface, and some of them only expose the flowers out of the surface during the flowering period. Floating plants are those that float on the surface of the water and are further divided into two types: leaf-floating type plants with roots fixed in mud at the bottom of water and full-floating types that have their whole body floating in water. Emergent plants grow upright in water, with the leaves above the water surface, while only the roots, parts of the stems, and petioles inside the water. Usually, aquatic plants are regularly distributed in the water body. Where the water varies from shallow to deep, there are sequenced emergent plant vegetation belts, floating plant vegetation belts, and submerged plant vegetation belts.

2 An Overview of China's Plant Diversity

The native plants of China represent an important part of our global biological heritage. The rich plant species diversity, the high rate of endemism, the presence of many relictual species from the Mesozoic era and Tertiary period, and the representation in the flora of numerous floristic regions, together with a long history of human culture on the land, have resulted China in a botanical richness paralleled in few other parts of the world (Huang et al. 2013).

2.1 Terrestrial Plant Diversity

China is one of the world's mega-diverse countries (Mittermeier et al. 1997), with 36,152 species (18,213 endemic) of terrestrial plant, or higher plant, including 3021 species of mosses, 2147 ferns and fern allies, 262 gymnosperms, and 30,722 angiosperms (Qin et al. 2017), which are, respectively, 23%, 16%, 24%, and 9% of the world's total (Table 1).

China is the home to the world's second richest flora, next to Brazil (Li and Miao 2016). The diversity of extant vascular plants in China is extraordinary, particularly in the northern hemisphere. China, the United States, and Europe have similar areas, but China has more biodiversity than the other two regions: there are more about 33,000 vascular plants (including ferns and seed plants) in China, in contrast to 19,000 in the United States and 11,500 in Europe (Raven 2011), making the ratio of numbers of species in the three areas approximately 3 to 2 to 1. There are a number of factors to account for these differences in diversity, but the most important must be that China includes a significant area of moist tropical and subtropical regions, almost absent in the United States and totally absent in Europe (Zhang and Gilbert 2015).

The abundance of plant species can also be expressed in terms of the size of the family and genus, that is, the number of species they contain. The world's five largest families, which contain more than 10,000 species, are Asteraceae, Fabaceae, Orchidaceae, Poaceae, and Rubiaceae. The first four families are also the top four families of Chinese seed plants, each containing 2577, 2166, 1514, and 2148 species, respectively. The fifth family in China's flora is Rosaceae, with 1461 species, and the other families having more than 1000 species are Ranunculaceae (1229 species), Lamiaceae (1189 species), and Ericaceae (1021 species) (Qin et al. 2017).

The top ten large genera in the angiosperm are *Rhododendron* (650 species), *Carex* (620 species), *Astragalus* (450 species), *Pedicularis* (372 species), *Corydalis* (360 species), *Saussurea* (340 species), *Primula* (300 species), *Elatostema* (300 species), *Salix* (275 species), and *Gentiana* (265).

About one-third of more than 33,000 vascular plants in China, or 11,000 plant species, are woody plants, including more than 3200 species of trees (Fang et al. 2009). For example, China has almost all genera of temperate woody plants, including *Acer* (99 species), *Betula* (40 species), *Carpinus* (36 species), *Fraxinus* (27 species), *Salix* (275 species), *Sorbus* (101 species), etc. Especially central China, it is the area with most abundant deciduous woody plants in the world.

2.2 Endemism

Endemism is a phenomenon in which a biota (such as a species, genus, or family) is confined within a geographic region without exceeding that region. It is one of the

Table 1 A comparison of global and Chinese plant diversity^{a, 1}

| Group | Family number | | Genus number | | Species number | |
|-----------------------|---------------|-------|--------------|---------|----------------|------------------------|
| | China | World | China% | World | China% | World |
| Mosses | 150 | 215 | 70 | 1254 | 47 | 12,800 ² |
| Ferns and fern allies | 40 | 71 | 56 | 381 | 46 | 13,300 ³ |
| Gymnosperms | 10 | 15 | 67 | 79 | 57 | 1090 ⁴ |
| Angiosperms | 264 | ~400 | 66 | ~10,000 | 32 | 369,000 ⁵ ~ |
| Total | 464 | | | 4001 | | 396,190 |

^aData sources: (1) Qin et al. 2017 and Catalogue of Life China (CoL-China, <http://sp2000.org.cn/>); (2) Crosby et al. 2000; (3) Hassler 2016; (4) WCSP 2016; (5) Kew 2016