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Special issue on *Ecology, evolution, and conservation of plants in China*: Introduction and some considerations

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Abstract

Special issue on *Ecology, evolution, and conservation of plants in China*: Introduction and some considerations.— China has one of the world's richest floras with around 33,000 vascular plants, of which up to 17,000 are endemic. Besides these astonishing figures, the Chinese flora is very interesting from the point of view of evolution, as it shows a strong relictual character with some truly "living fossils" such as *Ginkgo biloba* or *Metasequoia glyptostroboides*. At the same time, China probably harbours the most important "evolutionary front" of the world's temperate flora, the Hengduan Mountains. Unfortunately, the flora of China also includes a high number of threatened species (with nearly 4000), mostly due to the destruction of natural habitats and the over-exploitation of natural resources. This special issue, which corresponds to volume 34 of *Collectanea Botanica*, is aimed to contribute to the knowledge of Chinese flora through a series of contributions (seven full-length articles and one short note) spanning several topics such as biogeography, conservation, demography, ecology, evolution, and plant-animal interactions.

Key words: China; endemism; hotspots; richness; threatened species.

Resumen

Número especial sobre *Ecología, evolución y conservación en las plantas de China*: introducción y algunas consideraciones.— China tiene una de las floras más ricas del mundo con alrededor 33.000 plantas vasculares, de las cuales hasta 17.000 son endémicas. Además de estas cifras asombrosas, la flora china es muy interesante desde el punto de vista de la evolución, ya que muestra un fuerte carácter relictual con algunos auténticos «fósiles vivientes» como *Ginkgo biloba* o *Metasequoia glyptostroboides*. Al mismo tiempo, China probablemente alberga el «frente evolutivo» más importante de las floras templadas del mundo, las montañas Hengduan. Por desgracia, la flora de China también destaca por el elevado número de especies amenazadas (casi 4000), sobre todo debido a la destrucción de los hábitats y la sobreexplotación de los recursos naturales. Este número especial, que corresponde al volumen 34 de *Collectanea Botanica*, tiene como objetivo contribuir al conocimiento de la flora de China a través de una serie de contribuciones (siete artículos y una nota breve) que abarcan varios temas como la biogeografía, la conservación, la demografía, la ecología, la evolución y las interacciones planta-animal.

Palabras clave: China; endemismo; especies amenazadas; *hotspots*; riqueza.

摘要

中国植物生态，进化与保育专辑：导言与思索。— 中国是世界上植物多样性最丰富的国家之一，有着33, 000种维管植物，其中约17, 000特有植物。除此之外，中国植物区系包含了非常典型的孑遗成分，有着众多野生个体的真正的“活化石”，如银杏、水杉等。中国还有着世界温带植物区系最为重要的“进化热点地”——横断山区。不幸的是，中国植物区系中也存在着极高比例的受威胁物种（约有4, 000种），其濒危原因主要是生境的破坏和自然资源的过度采用。本期专辑，*Collectanea Botanica* 的第34卷，收集了7篇论文、1篇简报，从生物地理学、保育、种群统计学、生态学、进化以及植物-动物相互关系等多个方面对中国植物进行了详细的研究，希望能有助于人们更好地认识中国植物区系。

关键词：中国；特有性；热点地区；丰富度；濒危物种。

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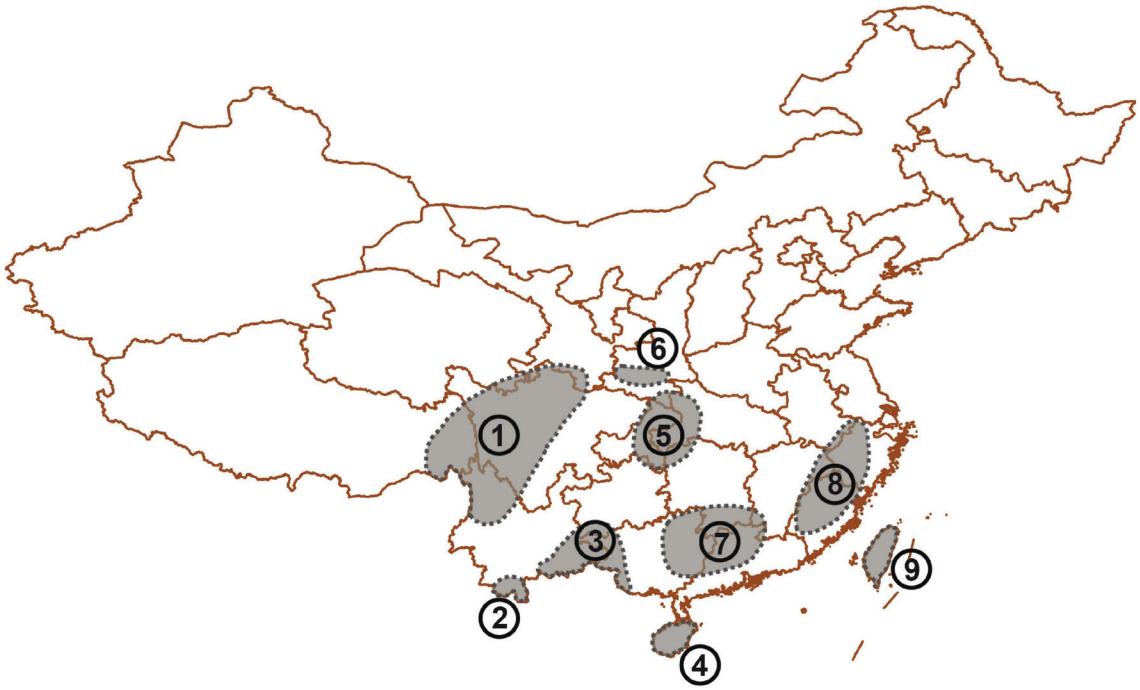
China is one of the world's richest countries in terms of plant diversity, only behind Brazil and Colombia. The estimated number of vascular plant species is about 33,000, with ~30,000 angiosperms, 200–250 gymnosperms, and 2100–2600 pteridophytes. Furthermore, approximately 2200–3000 bryophytes can be found in China (López-Pujol *et al*., 2006; Huang *et al*., 2015*a*; Wang *et al*., 2015*b*). More relevant are, nevertheless, the rates of endemism of Chinese flora: some 17,000 higher plants (i.e. over 50% of the total) are endemic to China (Wang *et al*., 2015*b*). At the generic level, about 250 genera are endemic, and, at the family level, several families are endemic (*Eucommiaceae* and *Ginkgoaceae*) or nearly endemic (e.g. *Cercidiphyllaceae*, *Circaeasteraceae*, *Rhoipteleaceae*, *Tetracentraceae*, and *Trochodendraceae*; Huang *et al*., 2015*a*). This wealth of species diversity and endemism is attributable to a series of physical and biotic factors, including: (1) a large country's area (about 9.6 million km^2); (2) a complex and extended geological history, with many tectonic events (including the collision of the Indian subcontinent at the Eocene); (3) an unbroken connectivity between tropical, subtropical, temperate and boreal forests; (4) a large proportion of tropical and subtropical habitats; (5) the close connection of China to tropical regions of Southeast Asia; (6) a highly rugged and dissected topography (especially in southern China); and (7) reduced extinction rates during the late Cenozoic global cooling (Axelrod *et al*., 1996; Qian & Ricklefs, 1999; Qian, 2002; López-Pujol *et al*., 2011*a*). The main centres of species richness and endemism are highly coincident in China, and are almost exclusively located in the mountainous regions of central, southern and southwestern provinces (Fig. 1; Tang *et al*., 2006; López-Pujol *et al*., 2011*a*; Wang *et al*., 2011; Huang *et al*., 2012; Yang *et al*., 2013).

Besides the high taxonomic richness and exceptional rates of endemism, one of the main features of Chinese vascular flora is its ancient origin. China has a disproportionately large number of species belonging to the early diverged groups with ancient fossils; for example, the number of the pteridophytes and the gymnosperms are three times and almost two times larger in China than in the United States, respectively (Qian & Ricklefs, 1999), a country with a similar land area and a comparable floristic richness and composition until the Middle Miocene *ca*. 14–15 Ma (Axelrod *et al*., 1996). Likewise, there is also an overrepresentation of the basal groups of angiosperms, such as the magnolids and ranunculids within the Chinese flora (Qian & Ricklefs, 1999; Qian, 2001). Other empirical data supporting the antiquity of Chinese flora are the Tertiary origin of most of the *ca*. 1400 Asian endemic genera present in China (Qian *et al*., 2006), most of the *ca*. 250 Chinese endemic genera (Ying *et al*., 1993; Wu *et al*., 2007), and *ca*. 40% of the species belonging to the Chinese endemic genera (López-Pujol *et al*., 2011*a*). Many lineages that were widely distributed along the Northern Hemisphere at the Miocene are still persisting in China, thanks to much lower extinction rates (Manchester *et al*., 2009). Conspicuous examples include *Cathaya argyrophylla*, *Eucommia ulmoides*, *Ginkgo biloba*, *Glyptostrobus pensilis*, *Metasequoia glyptostroboides* (Fig. 2), and *Taiwania cryptomerioides*. Notably, most of these palaeoendemic taxa tend to occur in central, south-central, and southeastern China (Fig. 1), regions that have generally enjoyed relative tectonic stability since the late Tertiary or earlier (Hsü, 1983). At the same time, China harbours what is perhaps the largest "evolutionary front" of the world's temperate flora, the Qinghai-Tibet Plateau (QTP), especially its eastern fringe (the Hengduan Mountains; Fig. 1). The continuous uplifts of the QTP, in particular the recent uplifts since the late Pliocene, may have created a vast array of new habitats across wide elevational ranges (up to 5000 m), therefore stimulating rapid plant diversification and speciation (Fig. 2), including allopatric speciation, hybrid speciation and explosive radiations (Liu *et al*., 2014; Wen *et al*., 2014; Favre *et al*., 2015; Hugues & Atchison, 2015). Hengduan mountains have been internationally identified as one of the world's biodiversity hotspots, with around 12,000 plant species, of which ~3500 are endemic (Myers *et al*., 2000).



Hotspot	Species richness	Endemism	Threatened plants
Hengduan Mountains (1)	+++	+++ (+/+++)	++
Xishuangbanna (2)	+++	++ (+/++)	+++
SE Yunnan-SW Guizhou-SW Guangxi (3)	+++	++ (++/+)	++
Hainan Island (4)	++	++ (++/++)	++
Central China Mountains (5)	+++	+++ (+++/+)	++
Qinling Mountains (6)	+	++ (++/+)	+
Nanling Mountains (7)	++	+ (+/+)	++
East China Mountains (8)	+	+ (+/+)	++
Taiwan Island (9)	+	++ (++/+)	+

Figure 1. Approximate location of Chinese plant diversity hotspots. The code numbers for the hotspots correspond to those in the table below the map. Relative occurrences for each type of plant species (+++, high occurrence; ++, intermediate occurrence; +, low occurrence) for each hotspot have been inferred after taking into account relevant literature (e.g. Ying *et al*., 1993; Wang & Zhang, 1994; Ying, 2001; Tang *et al*., 2006; Zhang & Ma, 2008; Li *et al*., 2009; López-Pujol *et al*., 2011*a*; Wang *et al*., 2011; Huang *et al*., 2012; Yang *et al*., 2013).

Some alpine genera have their centres of distribution here, a result of the abovementioned rapid radiations; examples include *Rhododendron* (276 out of ~1000 species of this genus around the world are present in the Hengduan Mountains), *Pedicularis* (233 out of ~600), *Primula* (143 out of ~500), *Gentiana* (154 out of ~360), *Saussurea* (119 out of ~415), or *Aconitum* (108 out of ~400) (Zhang *et al*., 2009).

Regrettably, the flora of China also stands out for the high number of threatened species, due to a series of combined factors mainly related with the country's overpopulation, the economic growth [China has shown the fastest rate of GDP (gross domestic product) growth among the world's major economies, with an average of almost 10% since 1980; http://data.worldbank.org/], the large-scale destruction of natural habitats, the over-exploitation of natural resources, and, on a lesser scale, the introduction of exotic species (although the lists of invasive and naturalized plant species have increased several-fold in just two decades; Fig. 3). At the beginning of the 2000s, it was estimated that at least 200 plant

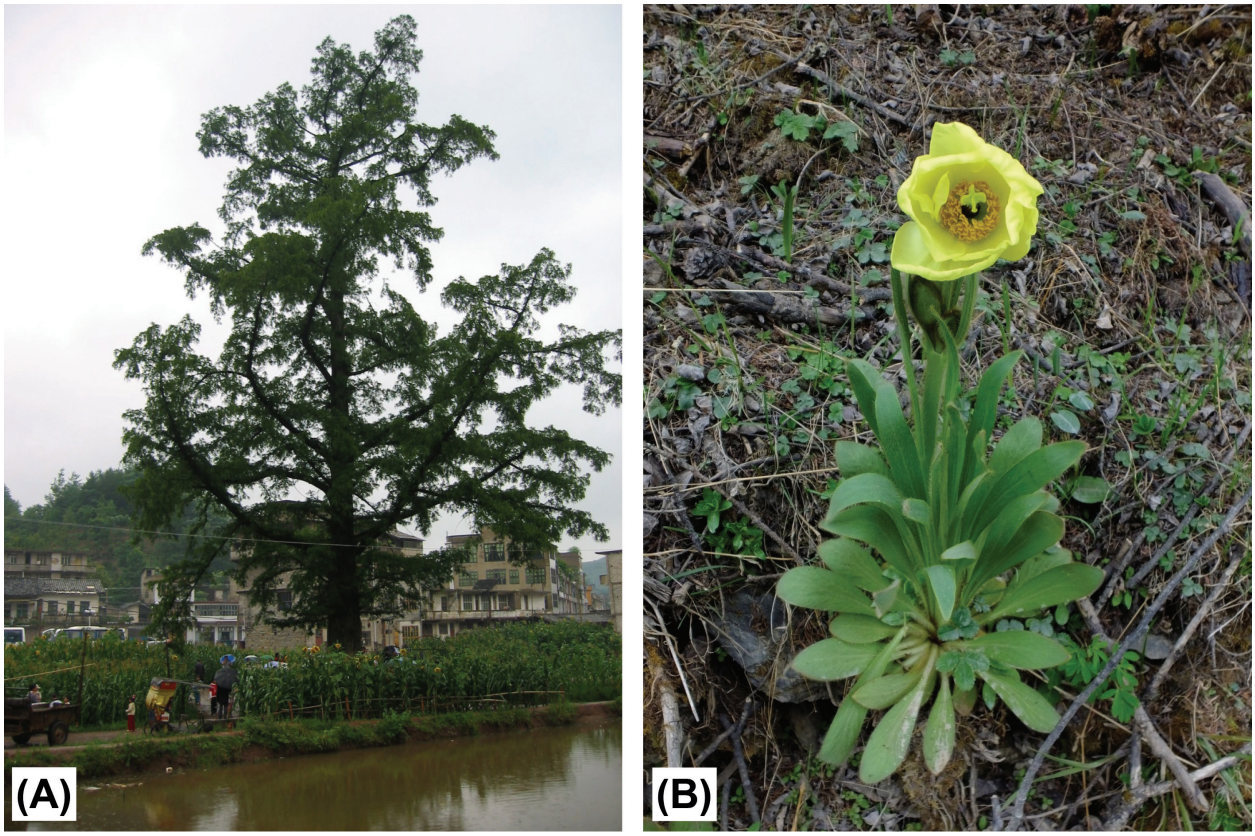


Figure 2. (A), type tree of *Metasequoia glyptostroboides* at Moudao Town (Hubei Province). This truly "living fossil" is a remnant of the Tertiary termophilous flora that once spanned most of the Northern Hemisphere (the "boreotropical flora"; Kubitzki & Krutzsch, 1996). Photograph: Q. Leng; (B), individual of *Meconopsis integrifolia* at Diqing Tibetan Autonomous Prefecture, NW Yunnan; this is one of the flagship species of the Qinghai-Tibetan Plateau, and its speciation probably occurred during the rapid uplift of the plateau at Pliocene–early Quaternary (Yang *et al*., 2012). Photograph: J. López-Pujol.

species had become extinct since the 1950s (Zhang *et al*., 2000), and new species have been added to this "black" list since then (see MEP–CAS, 2013). Many more species are in an extreme situation of risk, with population sizes of fewer that one hundred individuals and occurring in just one or very few populations (e.g. López-Pujol & Zhang, 2009; López-Pujol, 2010; Ren *et al*, 2012; Ma *et al*., 2013); examples of these species in the brink of extinction [called sometimes as "Extremely Narrow Endemics" (ENE) or "Plant Species with Extremely Small Populations" (PSESP); *cf*. López-Pujol *et al*., 2013; Ma *et al*., 2013] include *Abies beshanzuensis* var. *beshanzuensis* (from which only three individuals are remaining in the wild), *Acer yangbiense* (four individuals), and *Carpinus putoensis* (only one individual). According to the *China Red List of Higher Plants* (中国生物多样性红色名录–高等植物卷), published in late 2013, 3650 vascular plant taxa were regarded as threatened (CR, EN, or VU) following the 2001 IUCN criteria among the ~33,000 evaluated taxa (MEP–CAS, 2013). The number of threatened plant species in China is, thus, slightly lower than the "classical" estimations of 4000–5000 (Wang, 1992; López-Pujol *et al*., 2006; Huang & Oldfield, 2015), although it should be taken into account that more than 4000 taxa were listed as "Data Deficient" (DD) in the 2013 Red List: an important fraction of these 4000 taxa, once a better knowledge is achieved, could be transferred to any of the threatened categories. Endangered species tend to be concentrated in the southern part of the country (Zhang & Ma, 2008), thus showing high congruence with both centres of species richness and endemism (Fig. 1).

Despite the unquestionable interest, the study of the Chinese flora has been systematically neglected by south European botanists, and particularly by the Spanish ones. These latter have traditionally been more concerned with the flora of the New World. The discovery and further colonization of most of

Figure 3. Construction of the Chengdu–Lanzhou high-speed railway. May 2015, Aba Prefecture, Sichuan. The first line of high-speed railway was completed in 2007, and the network reached 16,000 km at the end of 2014 (Xinhua, 2015). Construction of transportation corridors such as railways do not only cause habitat fragmentation (and the associated edge-effects) but also the spread and establishment of non-native species (Andrews, 1990; Hansen & Clevenger, 2005). Photograph: J. López-Pujol.

the Americas by the Spaniards was followed by the study of their flora (e.g. Álvarez, 1993; De Vos, 2007), which has continued to the present. A variation of this sort of "colonial botany" (*cf*. Schiebinger & Swan, 2005) was behind bringing many Chinese plants to the West (including many ornamental plants such as azaleas, lilies, and magnolias) by European missionaries following the Opium Wars (mid-19th century). Today, many plants are named for some of these "priests-botanists" (the most illustrious are probably J. M. Delavay, A. David, and P. G. Farges; see Kilpatrick, 2014). During late 19th–early 20th century, the European missionaries were gradually replaced mainly by British/Irish (such as G. Forrest, A. Henry, F. Kingdon-Ward, and E. H. Wilson), Austrian (H. von Handel-Mazzetti and J. Rock), and Russian plant explorers (E. Bretschneider and G. N. Potanin), as well as the "first generation" of Chinese botanists (e.g. W.-C. Cheng, R.-C. Ching, W.-P. Fang, and T.-T. Yü) (Hi & Watson, 2015). After the advent of the "open door" policy in China since late 1970s, collaboration between Chinese and foreign botanists (especially with the American ones) is increasing steadily. The recent completion of the *Flora of China* project (partly funded by the U.S. National Science Foundation) is probably the best example.

This special issue of *Collectanea Botanica*, which corresponds to volume 34, has been launched not only for contributing to the knowledge of Chinese flora but also as an effort to increase the collaboration between Spanish and Chinese botanists, which remains, in spite of the pioneering efforts of the authors of the present note, virtually nil. This is not an isolated case, unfortunately, and certainly reflects the narrow-mindedness of the Spanish science system. The last official report on the Spanish scientific activity (FECYT, 2014) placed China, which is already the second-largest producer of research papers in the world (after the United States), "only" the 24th in the rank of scientific collaborations between Spain and a third country (for example, behind Greece, Poland, and Chile).

This special issue is composed by eight articles (seven full-length articles and one short note) addressing several topics such as biogeography, conservation, demography, ecology, evolution, and plant-animal relations. Three of the contributions, those of Liao & Ren (2015), Ren (2015), and Hu *et al*. (2015) are centred on some of the main hotspots of Chinese flora (Fig. 1). Liao & Ren (2015) explored the distribution patterns of long-lived individuals (≥100 years old) of several relict species (*Cyclocarya paliurus*, *Ginkgo biloba*, *Liriodendron chinense*, *Pinus massoniana*, *Podocarpus macrophyllus*, and *Taxus chinensis*) in the areas surrounding Fanjinshan Nature Reserve, located in the central China Mountains hotspot (probably the most important in China in terms of relict species; López-Pujol & Ren, 2010; López-Pujol *et al*., 2011*b*). The authors conclude that, as reported in other studies (e.g. Hu *et al*., 2011; Gao *et al*., 2013), local protection due to traditional beliefs would

have also played a role in addition to the existence of long-term stable habitats (see also Huang *et al*., 2015*b*). Ren (2015) focused in another biodiversity hotspot, SE Yunnan–SW Guizhou–SW Guangxi (Fig. 1). He used distributional data of *ca*. 30 species belonging to the genus *Hiptage* to find that this region is a major diversification centre of this Asian endemic genus. Since other studies reported similar results for other tropical families including *Gesneriaceae* and *Begoniaceae* (Li & Wang, 2004; Wei *et al*., 2004; Hou *et al*., 2010), it does not seem unreasonable to define this area (which is dominated by highly-fragmented limestone landscapes) as the "evolutionary front of the tropical plants in China" (Ren, 2015: 9). Hainan is also one of the main hotspots of plant diversity in China (Fig. 1), and it is the subject of the studied carried out by Hu *et al*. (2015). The authors analysed the diversity and the patterns of distribution of the Orchidaceae [the fourth largest family in China in number of species, but the first regarding the number of endangered species (*ca*. 670 are included in any of the threatened categories; MEP–CAS, 2013)] in Hainan Island, identifying over 300 species (with ~10% of them endemic) that mainly occur on the southern part of the island. Hu *et al*. (2015) also revised the threats and the current conservation status of Hainan's orchids, and proposed future directions for research and management.

Although not strictly focused on the Chinese biodiversity hotspots, two additional papers within this special issue deal with biogeographical and ecological aspects within the topographically-complex, floristically-rich subtropical China. Tang (2015) presented an exhaustive analysis of the geographic distribution patterns of subtropical evergreen broad-leaved forests (EBLFs) in southwestern China (Guizhou, Sichuan, and Yunnan provinces plus Chongqing Municipality). In addition to comprehensively review the EBLFs in terms of forest types, species composition, and their distributions along latitudinal, longitudinal, and altitudinal gradients (which are magnificently illustrated), the author compared them with those of eastern China (with a special emphasis on Taiwan Island). Wang *et al*. (2015*a*) focused, instead, on aquatic habitats, and used traditional vegetation surveying methods to assess the richness of plant species and communities in Poyang Lake. This lake, the largest one in China, has gained notoriety for the dam that has been planned to stabilize its water level (due to a series of droughts in recent years), causing serious concerns among biologists and conservationists (Li, 2009). Wang *et al*. (2015*a*) identified over 500 plant species (as a catalogue in a separate appendix) as well as eight dominant plant communities, confirming the lake's wetland as a regional hotspot.

Liu *et al*. (2015) presented the state-of-the-art in the interactions between leaf miners (those insects whose larvae live in and eat the leaf tissue of plants) and their host plants. The authors first reviewed the leaf-mining patterns on plant leaves (i.e. the diversity of leaf mine shapes and depths). Next, they addressed impacts in leaf morphology (e.g. asymmetry, presence of holes and cracks), leaf chemistry (e.g. production of secondary metabolites, formation of callus tissue), plant physiology (typically, a reduction of the photosynthetic capability of the leaf), and plant growth and production (e.g. earlier fall of the leaves, lower plant height, smaller leave size, lower number of leaves, reduction in fruit set). The authors further summarized the studies of leaf miners carried out in China. A further paper in this special issue is a mini-review of the main results of almost one-decade research carried by H. F. Wang and his collaborators on urban vegetation and plant diversity in Beijing, the capital of China. In their mini-review, Wang & López-Pujol (2015) first presented the main results of a study that employed urban structural units (USUs, that were defined based on urban land use and land cover) to explore urban ecological patterns and their relation with socio-economic factors. At the species level instead of landscape level, the authors reported the results of a systematic investigation on the plant species richness and density and the main socio-economic factors affecting them. They also summarized the naturalized and invasive flora in the whole municipality. This special issue was closed by a short note dealing with a growing menace for plant diversity in China: the plant invasions. Wang *et al*. (2015*c*) reported the first occurrence of *Crassula ovata*, the jade plant, in China, and warned about the potential for naturalization of this plant, as it is widely cultivated (at least in Sichuan, the province where it has been observed).

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