China: a rich flora needed of urgent conservation

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Manuscript received in april 2004

Abstract

China is one of the richest countries in plant biodiversity in the world. Besides to a rich flora, which contains about 33 000 vascular plants (being 30 000 of these angiosperms, 250 gymnosperms, and 2 600 pteridophytes), there is a extraordinary ecosystem diversity. In addition, China also contains a large pool of both wild and cultivated germplasm; one of the eight original centers of crop plants in the world was located there. China is also considered one of the main centers of origin and diversification for seed plants on Earth, and it is specially profuse in phylogenetically primitive taxa and/or paleoendemics due to the glaciation refuge role played by this area in the Quaternary. The collision of Indian subcontinent enriched significantly the Chinese flora and produced the formation of many neoendemisms. However, the distribution of the flora is uneven, and some local floristic hotspots can be found across China, such as Yunnan, Sichuan and Taiwan. Unfortunately, threats to this biodiversity are huge and have increased substantially in the last 50 years. The combined effects of habitat destruction and/or fragmentation, environmental contamination, overexploitation of natural resources and, in lower extent, introduction of exotic species, have produced an irremediable damage to plant biodiversity; furthermore, the economic and population growth have contributed to this deterioration. Currently it is considered that up to 5 000 species of flora are endangered in China, and some taxa have already become extinct. Although government authorities have done some efforts in order to preserve biodiversity in recent years, there is still a lot of work to do. China has established a extense network of nature reserves and protected areas, covering more than 16% of the total land area; nevertheless, lack of budget and staff are common trends in their management. *Ex situ* conservation is still also deficient, primarily due to botanical gardens are not representative of the several local floras and they often have not adequate sizes and amount of species. The lack of an efficient environmental legislation and education are also root causes which enhance the loss of Chinese plant biodiversity.

Key words: Conservation, threatened, flora, biodiversity, endemic, mainland China, Taiwan, Hong Kong.

Interest of Chinese flora

Biodiversity is the general term to refer to the total sum of life's variety in a region or in the whole Earth. According to the Convention on Biological Diversity, three levels of biodiversity, strongly intercorrelated, are recognized: ecosystem diversity, species diversity and genetic diversity (Glowka et al., 1994). Even discarding ethical and aesthetic considerations, the loss of plant (and animal) biodiversity involves enormous direct and indirect economic consequences. The overexploitation of plant resources, besides to the increasing habitat destruction and/or fragmentation, pollution and introduction of exotic species, have been leading many plant species to the unavoidable way of extinction. Today is widely recognized that the rate of plant extinction approach one species per day due to human activities, a speed between 1 000 and 10 000 times faster than it would naturally be (Hilton-Taylor, 2000), and a trend which could cause the disappearance of nearly 50 000 plant species during the next 30 years (Raven & Johnson, 2002). The most recent approaches to the size of the world's threatened flora suggest that as many as half of the world's plant species may qualify as threatened with extinction under the IUCN criteria (Pitman & Jørgensen, 2002).

China covers a vast territory of 9.6 million km^2, the third largest country in the world, stretching c. 5 200 km from east to west and 5 500 from north to south. It spans 50 degrees of latitude, and covers five climatic zones: cold-temperate, temperate, warm-temperate, subtropical, and tropical. The geography is very complex, comprising very high mountain ranges (the Himalayas), vaste plateaus such as Qinghai-Xizang (Tibetan) and Pamir (with an average elevation of 4 500m and 5 000m above sea level, respectively), enormous and arid basins such as Tarim, which contains the largest desert in China (Taklamakan), and lower lands, as those in eastern and northern China and the Yangtze River Basin. Main great rivers of Asia, including those with their fluvial streams occurring in China, all originate in Qinghai-Xizang Plateau, such as Mekong (*Lancang*) River, Brahmaputra (*Yarlung Zangbo*) River, Yangtze (*Chang Jiang*) River, and Yellow (*Huang He*) River.

China is one of the richest countries in plant biodiversity, ranking third in the world (after Brazil and Colombia) in number of species (Anonymous, 1996a; Liu et al., 2003), and it is considered as one of the seventeen world 'megadiversity countries' (SEPA, 1998). The estimated number of vascular plant species is nearly 33 000, being 30 000 of these angiosperms, 250 gymnosperms, and 2 600 pteridophytes (Table 1). Furthermore, in China we can find about 2 200 bryophytes. There are more than 3 000 different genera and c. 380 families of angiosperms, about 30 genera and 10 families of gymnosperms, more than 200 genera belonging to 52 families of pteridophytes, and nearly 500 genera and 106 families of bryophytes (Table 2). In addition, China also contains about 2 000 lichens, 8 000 fungi, and probably more than 10 000 algae, totalizing about 55 000 *sensu lato* plant species (Table 1). Nevertheless, these figures do not include data from Taiwan island and Hong Kong (see Table 3), which we have treated separatedly from mainland China due to their own idiosincrasies. Taiwan, with an area of only about 36 000 km^2, harbors more than 4 000 vascular plants (Hsu & Agoramoorthy, 1997;

Table 1. Richness of Chinese flora. Data are only for mainland China.

Taxa	Species in China (SC)	Species in the world (SW)	SC/SW (%)
Lichen	2 000[c]	10 000[f]	20.0
Fungi	8 000[b,d]	77 000[e]	10.4
Algae	8 979[d] – 12 500[a]	27 100[e]	33.2 – 46.1
Bryophyta	2 200[a,b,c,d]	15 000[f]	14.7
Pteridophyta	2 300[a] – 2 600[b,c,d]	13 025[f]	17.6 – 20.0
Gymnospermae	192[a] – 270[d]	980[f]	19.6 – 27.5
Angiospermae	25 000[b] – 30 000[c,d]	258 650[f]	9.7 – 11.6

[a] Li (2003)
[b] NEPA (1994)
[c] Xue (1997)
[d] SEPA (1998)
[e] Raven & Johnson (2002)
[f] IUCN (2004)

TaiBIF, 2004). The island, renowned as the 'Natural Botanic Garden' (Gu, 1998), is dominated by rugged mountainous lands still extensively forested; about 52% of the total area is covered by forests (Gu, 1998; TESRI, 2004). On the other hand, the Hong Kong Special Administrative Region (HKSAR) constitutes an area of only about 1 100 km^2, and despite it is one of the most densely populated areas on the Earth, it still retains a very rich plant biodiversity with more than 2 100 higher plants. Of these, c. 1 900 are angiosperm species (Xing et al., 1999; Yip et al., 2004) and about 200 are pteridophytes (Groombridge, 1994; Xing et al., 1999). Moreover, more than 1 000 algae species, 360 bryophytes, and 260 lichens have been reported in the HKSAR (Dudgeon & Corlett, 2002; Wu, 2002; Zhang & Corlett, 2003).

China exhibits a enormous variation of geographical, climatological and topographical features, in addition to a complex and ancient geological history (with most of its lands formed as early as the end of the Mesozoic). All these features are the responsible of the great diversity of habitats and ecosystems found in China, besides to the huge figures of species diversity described above. This ecosystem richness includes several types of forest (coniferous, broad-leaved, and mixed forests), grasslands, shrubs, meadows, deserts (covering up to 20% of the Chinese landmass), marshes, savannas, tundras, and alpine and snow ecosystems. Moreover, the vegetation of China is the only on the world which maintains an unbroken connection between tropical, subtropical, temperate and boreal forests (Qian, 2002; FOC, 2004a). China is also considered one of the main centers of origin and diversification for seed plants on Earth, and contains inherited elements of Laurasian and Gondwanaland (Indian subcontinent) floras. Furthermore, China has received plenty of species from the surrounding areas, such as tropical areas in the south, Mediterranean Basin through central Asia, and Siberia and Mongolia in the north (Qian & Ricklefs, 1999).

China also contains a large pool of wild germplasm, since the primitive members of many groups of plants are found here (about 1 200 primitive, relict or monotypic genera currently present in China were long extinct in other parts of Northern Hemisphere; Fu, 1992). Moreover, genetic diversity of cultivated plants is equally rich. China is one of the eight original centers of crop plants in the world, with more than 200 originated and differentiated here (Gu, 1998) as a result of 7 000 years of agricultural activities (Xue, 1997). Some of the clearest examples are rice (*Oryza sativa*), of which there are about 50 000 strains and three wild rice species (*O. rufipogon*, *O. officinalis* and *O. meyeriana*), soybean (*Glycine max*), which has about 20 000 strains in China, and wheat (*Triticum* sp.), with c. 30 000 cultivars (SEPA, 1998). At present, there are more than 600 taxa of crops cultivated in China, being 140 of these fruit trees species (MOA, 1995). It has been reported to be at least 400-500 wild species of vegetables, 300 wild species of oil plants, more than 200 wild species of starch plants and sugar plants, and about 200 wild species of aromatic plants (MOA, 1995). Conserving genetic diversity is also a key point for obtaining new varieties of ornamental plants from the wild species. More than 2 200 ornamental species belonging to 30 different genera come from China (SEPA, 1998). On the other hand, up to 11 000 species of medicinal plants have been used in China from Palaeolytic to nowadays (SEPA, 1998; Hamilton, 2004).

Table 2. Endemicity of the Chinese flora. Data are only for mainland China.

Taxa	Endemic species in China (ESC)	Known species in China (KSC)	ESC/KSC (%)	Endemic genera in China (EGC)	Known genera in China (KGC)	EGC/KGC (%)
Bryophyta	225[d]	2 200[a,b,c]	10.2	8[b] – 13[a]	494[b] – 495[a]	1.6[b] – 2.6[a]
Pteridophyta	—	2 300[a] – 2 600[b,c]	—	5[b] – 6[a]	224[a,b]	2.2[b] – 2.6[a]
Gymnospermae	79[f]	232[f] (192[a] – 270[c])	34.0[f]	5[a,f] – 8[b]	34[b] – 35[a,f]	14.3[a,f] – 23.5[b]
Angiospermae	>9 000	27 403[f] (25 000[b] – 30 000[c])	>33.0	232[b] – 246[a]	3116[b] – 3128[a]	7.4[b] – 7.8[a]
Total	10 000[e] – 18 000[c]	33 000	30.3 – 54.5	253[b] – 270[a]	3 868[b] – 3 882[a]	6.5[b] – 6.9[a]

[a] Li (2003)
[b] NEPA (1994)
[c] SEPA (1998)
[d] MFC (2004)
[e] Fu (1992)
[f] Values calculated from data of FOC (2004a)

Table 3. The Chinese 'hotspots'.

Hotspot	Area (in km^2)[1]	Vascular plants[2]	No. of vascular plants per 100 km^2	Angiosperms[2]	Gymnosperms[2]	Pteridophytes[2]	Bryophytes[2]
Yunnan Province	394 000 (4.1%)	16 600[c]/—	4.21	15 000[c]/—	100[c]/21[c]	1 500[c]/—	1 500[c]/—
Sichuan Province	488 000 (5.1%)	9 254[f]/—	1.90	8 453[f]/464[f]	88[f]/14[f]	708[f]/—	—/—
Qinghai-Xizang Plateau	2 000 000 (20.8%)	12 000[g]/3 500[g]	0.60	—/—	—/—	—/100[g]	641[o]/—
'South-Central China' hotspot	500 000 (5.2%)	12 000[b]/3 500[b]	2.40	—/—	—/20[a]	—/100[a]	—/50[a]
NW Yunnan	70 000 (0.73%)	7 000[d]/910[h]	10.00	—/—	—/—	—/—	—/—
Xishuangbanna	19 200 (0.20%)	5 000[e]/—	26.04	—/150[c]	—/—	—/—	—/—
Three Gorges Area	53 200 (0.55%)	2 859[p] – 6 388[q]/—	5.37 – 12.01	2 708[p]/—	41[p]/—	110[p]/—	—/—
Hainan	15 500 (0.16%)	4 200[i]/630[i]	27.10	—/—	—/—	—/—	412[m]/—
Taiwan	36 000 (0.37%)	3 577[j] –4 585[n]/1 075[j]	9.66 – 11.71	—/—	20[j]/—	565[j]/—	900[k] – 1 404[m]/—
Hong Kong	1 100 (0.01%)	2 145[l]/25[j]	195.00	1 929[l]/—	9[r]/—	216[l]/—	360[m]/—

[a] CI (2004)
[b] Kelley (2001)
[c] Yang et al. (2004)
[d] Xu & Wilkes (2004a)
[e] Zhang & Cao (1995)
[f] SUU (1994)
[g] Miller (2003)
[h] Xu & Wilkes (2004b)
[i] Carpenter (2001)
[j] Groombridge (1994)
[k] Hallingbäck & Hodgetts (2000)
[l] Xing et al. (1999)
[m] Zhang & Corlett (2003)
[n] TaiBIF (2004)
[o] Donoghue et al. (1997)
[p] YWRP, 2004
[q] Wu et al. (2003)
[r] Corlett et al. (2000)
[1] In parentheses, percentage of hospots' area with respect total China's land.
[2] First value is the total number of species in the hotspot, second value is the number of endemic species to the hotspot.

Endemic and/or threatened species: current status and selected examples

Chinese flora is unique and diversified, and contains a high number of endemic species, endemic genera and even endemic families, a fact which can be mainly attributed to a very complicated geological and evolutionary history of the Asian continent. On one hand, in China and generally in eastern Asia there are numerous examples of phylogenetically primitive living taxa. On the other hand, the discovery of some fossil records of primitive angiosperms from the early Cretaceous in Mongolia, Baikal Lake (eastern Russia) but also in Liaoning and Heilongjiang provinces (north-eastern China), as those of *Archaefructus liaoningensis*, illustrates the ancient origin of Chinese flora (Sun et al., 1998; Chapman & Wang, 2002). Furthermore, during the Quaternary glaciation, the limited coverage of the ice in east Asia (significantly milder than in Europe and North America and only limited to northern areas) enabled the Chinese paleocontinent to be a refuge for many ancient species, i.e. paleoendemics (from the Cretaceous and Tertiary periods). Some of these paleoendemic species have remained superficially unchanged for millions of years, thus being named 'living fossils' (Qian, 2001). Some examples of these 'living fossils' such as *Metasequoia glyptostroboides*, *Cathaya argyrophylla*, *Glyptostrobus pensilis*, *Cycas panzhihuaensis* and *Gingko biloba* illustrate such endemics' ancient origin and persistence. Other 'living fossils', although not strictly endemic to China, are *Taiwania cryptomerioides*, *Cunninghamia lanceolata*, *Fokienia hodginsii*, *Platycladus orientalis*, *Amentotaxus yunnanensis*, and *Keteleeria davidiana*.

China is specially rich in several 'primitive' groups of vascular plants, e.g. pteridophytes, gymnosperms, Magnoliidae and Ranunculidae (Qian & Ricklefs, 1999). It is noteworthy the presence of very old lineages of gymnosperms, most of them extinct long time ago in other regions of the Northern Hemisphere. Most of the gymnosperms are monotypic or oligotypic, which denotes antiquity because they are probably relics or remnants of wider groups in the Tertiary or earlier (Qian, 2001). Some examples of antique lineages are the pre-Jurassic Cycads; the Cretaceous families Trochodendraceae, Cercidiphyllaceae, Celastraceae, Magnoliaceae, and Rhamnaceae, and the Cretaceous genera *Picea*, *Torreya*, and *Cephalotaxus*; the Tertiary families Myricaceae, Simaroubaceae, Saururaceae, Nyssaceae, Theaceae, Bretschneideraceae, Calycanthaceae, and Eucommiaceae, and the Tertiary genera *Keteleeria*, *Tsuga*, *Cryptomeria*, *Cunninghamia*, *Podocarpus* and *Ephedra*. China is currently considered the richest country worldwide in gymnosperm diversity.

The south-western part of China is also the cradle of numerous neoendemisms in addition to paleoendemisms. The collision of the Indian subcontinent with the Asian continent has been postulated as the main reason to explain the huge floristic richness of that area, with over 17 000 species of seed plants (Qian, 2002). This collision, which took place during the Eocene, resulted in the formation of the Himalayas and surrounding mountain ranges, in addition to the Qinghai-Xizang Plateau. One of these surrounding montainous systems, the Hengduan Mountains, and large watersheds as those of Mekong (*Lancang*) and Salween (*Nujiang*) rivers became natural barriers preventing species from spreading, and favouring vicariance and intense allopatric speciation processes. The wide array of young habitats created by the uplift of the Himalayas and surrounding mountains along a wide altitudinal range, allowed this region to become a centre of survival of relict species but also of speciation and evolution (Chapman & Wang, 2002; Qian, 2002). Most species generated there further penetrated to the tropical and warm-temperate regions of eastern China and temperate and boreal regions of northern China (Qian, 2002).

Currently it is considered that more than 10 000 higher plant species are endemic to China (Fu 1992; Pitman & Jørgensen, 2002), and some estimations rise this number up to 18 000 (Groombridge, 1994; SEPA, 1998). There are many cases of extremely narrow endemics, such as those of *Abies yuanbaoshanensis*, a species with only about 100 individuals restricted to Yuanbao Mountain (Guangxi Province; IUCN, 2004); *Magnolia zenii*, which has only one population containing 18 individuals in the Baohua Mountain (Jiangsu Province; He, 1998); *Ulmus gaussenii*, with only about 30 individuals growing in Longya Mountain, Anhui Province (IUCN, 2004); *Pinus squamata*, discovered in 1991 in Qiaojiaxian (Yunnan Province) with a total population of only 20 individuals (IUCN, 2004); *Carpinus putoensis*, with a sole plant located in Putuo island (Zhoushan archipelago, Zhejiang Province), discovered in 1930 and not found later in any other place (He, 1998); and *Bhesa sinica*, a recently discovered species with a single tree located in Nankan (Guangxi Province; IUCN, 2004).

Many genera (more than 250) found in China are also endemic to its territory (see Table 2) and even a few families (2). These two endemic families are the relict and monotypic Gingkoaceae and Eucommiaceae. Some families were also considered endemic in the past, such as the monotypic Davidiaceae, which has recently moved to a lower taxonomical rank, i.e. genus *Davidia* belonging to Nyssaceae (FOC, 2004b); the also monotypic Acanthochlamydaceae has also suffered the same process than Davidiaceae, and currently it is regarded as the genus *Acanthochlamys*, belonging to Amaryllidaceae (Wu & Raven, 2000). Bretschneideraceae was considered until recently an endemic family, but it has been found also in northern Laos, Thailand and Vietnam (Wu, 1998). Additional nearly endemic families are the monotypic Rhoipteleaceae, Cercidiphyllaceae, Circaeasteraceae, Eupteleaceae, Tetracentraceae, and Trochodendraceae. Some of the well-known endemic genera of China, most of which being monotypic or oligotypic, are *Pseudotaxus* (1 species), *Cathaya* (1), *Metasequoia* (1), *Glyptostrobus* (1), *Pseudolarix* (1), *Ajaniopsis* (1), *Ombrocharis* (1), *Kingdonia* (1), *Chuanminshen* (1), *Semiliquidambar* (3), *Sinoleontopodium* (2), *Tetraena* (1), *Pteroceltis* (1), *Anemoclema* (1), *Urophysa* (2), *Sinofranchetia* (2), *Salweenia* (1), *Delavaya* (1), *Craigia* (2), *Hainania* (1), *Sinojackia* (5), *Sichuania* (1), *Schnabelia* (2), *Echinocodon* (1), *Phaeostigma* (3), and *Ferrocalamus* (1).

Perhaps the most well-known example of endemism is the family *Ginkgoaceae*, once widely widespread in the Northern Hemisphere according to the fossil records, and currently with only one living species, the dioecious *Ginkgo biloba*. It has commonly been designated as a 'living fossil' due to its old lineage (back to the lower Jurassic, about 190 million years ago) and the high resemblance with the fossil species from the Early Cretaceous *Ginkgo adiantoides* (Del Tredici et al., 1992). Located in a intermediate position between the cycads and conifers, it is currently widespread worldwide due to its horticultural value. Furthermore, in China it is also cultivated for timber and medicinal properties. Until recently, the only population considered as wild, was located in Tianmushan (Zhejiang Province) and contained only 167 individuals in the 1989 census (Del Tredici et al., 2002). Nevertheless, three additional populations have been recently proposed to be wild: Wuchuanshan (Guizhou Province), Dahong (Hubei Province) and Longchou (Guangxi Province; Zheng et al., 2004). The endemic and monotypic genus *Cathaya* also harbors a very ancient origin and it is called as the 'Panda' of the plant kingdom (He, 1998). The sole species, *C. argyrophylla*, was discovered in 1958, confined to four widely separated mountainous areas in four diferent provinces (Guangxi, Hunan, Sichuan and Guizhou), consisting of fewer than 4 000 individuals (Ge et al., 1998). Another example of 'living fossil' is the genus *Pseudolarix*, endemic to eastern and central China. Its unique species, *P. kaempferi*, known as 'golden coin pine', was firstly discovered in Ningbo (Zhejiang Province) and it has its origin in the Oligocene (Hu, 1980).

Although not endemic to China, there are many genera where most of their species have been recorded here. For example, up to 650 *Rhododendron* species of about 1 025 distributed worldwide have been recorded in China, being the largest plant genus there (Ng & Corlett, 2000). Other genera with a high species' richness are *Saussurea* (320 species found in China, 400 worldwide), *Pedicularis* (352 C, 600 W), *Camellia* (98 C, 119 W), *Primula* (300 C, 500 W), *Gentiana* (248 C, 360 W), *Aconitum* (211 C, 400 W), *Ligularia* (100 C, 150 W), *Delphinium* (173 C, 350 W), *Corydalis* (300 C, 440 W), *Euonymus* (125 C, 175 W), and *Acer* (150 C, 200 W) (FOC, 2004a). Moreover, China exhibits the world's highest diversity in the subfamily Bambusoideae (the "bamboos"), being the main centers of diversity located in southern China (Guangxi, Guangdong and Hainan provinces; Bystriakova et al., 2003). Of the nearly 1 500 species of bamboos in the world, almost half of them (626 species) are present in China (Ohrnberger, 1999).

At national level, more than 3 000 species are currently endangered (Fu 1992; Gu 1998) although some estimations rise this value up to 4 000-5 000 (Wang, 1992; Xu, 1997). However, the current rate of habitat destruction could increase significantly these figures in the short-term. Unfortunately, some plant species (up to 200 since the 1950s; Zhang et al., 2000) had gone extinct in the past decades and at present they can be found only in the literature, e.g *Dalbergia sacerdotum*, *Otophora unilocularis*, and *Ormosia howii*, which are EX ('extinct') following the IUCN criteria (IUCN, 2004). Currently it is considered EW ('extinct in the wild') the species of tree *Firmiana major*, which conserves only some remaining individuals planted around temples and villages in Yunnan Province; wild populations probably existed in central and western Yunnan (IUCN, 2004). Nevertheless, many species are in the threshold of extinction, such as *Thymus mandschuricus*, *Sinojackia xylocarpa*, *Camellia omeiensis*, *Neolitsea sericea*, *Acer yangjuechii*, *Abies ziyuanensis*, *Picea neoveitchii*, *Cycas multipinnata*, *Cycas hongheensis* and

Cycas szechuanenis. Are specially threatened the species *Abies beshanzuensis*, with only five living specimens known in the wild in Baishanzu Mountain (Zhejiang Province), a result from a severe decline due to expansive agriculture, fires and poor regeneration (IUCN, 2004); *Nyssa yunnanensis*, a species of tree with a remaining small population in Jinghe county (Xishuangbanna, Yunnan Province) due to its extensive logging (IUCN, 2004); *Magnolia omeiensis*, confined to Emei Mountain (Sichuan Province) with only male individuals (IUCN, 2004); and *Thuja sutchuenensis*, a tree extensively used in the past for home building. Although it was believed to be extinct, recently (1999) it has been rediscovered in a very inaccesible locality in Chengkou (Chongqing Municipality; IUCN, 2004).

Despite many species are severely threatened in China, it was not until 1984 when the first national list of rare and endangered plant species was published (Fu, 1992), which included 388 species [8 listed as 'first grade' nationally protected (NPC-1), 159 species at 'second grade' and 221 species at 'third grade']. Finally, in 1992 it was published the Volume I of *China Plant Red Data Book*, which included 388 endangered taxa which should be protected; 121 listed as 'endangered', 110 as 'rare' and 157 as 'vulnerable'. Meanwhile, the volume II of the Red Book is currently under compilation and it will contain 640 additional species; further, it will appear the Volume III. On the other hand, China promulgated the first batch of the *List of National Key Wild Flora Under Protection* in 1999, which includes 246 flora species in 8 categories (Zhu, 2001). However, only 369 species of mainland China have been evaluated in the *2003 IUCN Red List of Threatened Species* (IUCN, 2004), falling 185 into one of the threatened IUCN categories (CR, EN or VU), and three already extinct. In Taiwan and Hong Kong, 60 and 4 species are listed as threatened, respectively. Therefore, only 249 species are considered to be threatened in China, a value very far from the estimations noted above (up to 5 000), which clearly show the lack of a conservation scope in the study of Chinese flora in last years.

Is is noteworthy that most areas of co-ocurrence of species with small ranges (centers of endemism) are severely threatened by human activities and have experienced a significant habitat loss; i.e. the 'biodiversity hotspots' (Brooks et al., 2002). Two of the 25 world hotspots are located totally ('South-Central China') or partially ('Indo-Burma') within the Chinese boundaries. The South-Central China hotspot (also named 'Mountains of South-West China') is mainly constituted by the Hengduan Mountains region, which comprises portions of south-eastern Xizang (Tibet), western Sichuan and northern Yunnan. Although represents only 5% of China's land area, it contains almost half the total number (12 000) of all Chinese flowering plants, of which 3 500 are endemic to this area (Kelley, 2001) (Table 3); nevertheless, it conserves only around 8% of the primary vegetation (Myers et al., 2000). This hotspot is likely the botanically richest region —of comparable size— in the world's temperate zone (Kelley, 2001). The rugged mountain ranges (with glaciated peaks exceeding 7 000 m and deep gorges down to 600 m) allow a huge diversity of broad vegetation zones spanning from subtropical to alpine, which may explain the high species diversity and endemisms of this region. These mountain ranges and gorges have provided sufficient isolation for significant and rapid evolution of local flora and diversification into many new genera. Hengduan Mountains are recognized to be an important Tertiary center of species diversification and a refugium for some groups of Laurasian angiosperms such as *Rhododendron*, *Rhodiola*, *Kingdonia* and *Circaeaster* (Donoghue et al., 1997; CI, 2004). Among the well-known endemisms in Hengduan Mountains, there are several species of *Abies* (*Abies forrestii*, *A. ferreana*), but also other gymnosperms (*Larix speciosa*) and angiosperms (*Acanthochlamys bracteata*, *Calanthe dulongense*, *Coelogyne tarongense*, *Cymbidium gongshanense*, *Paphiopedilum markianum*, *Salvia evansiana*, *Bergenia emeiensis*, *Nomocharis pardanthina*, *Paeonia delavayi*, *Anemoclema glaucifolium*, and *Delphinium smithianum*, among others). Some species-groups are specially rich in this area, having probably their diversification centres here, such as *Rhododendron* (224 of c. 1000 species distributed worldwide), *Primula* (113 of 500 worldwide) or *Saussurea* (101 of 400 worldwide), and many species belonging to these groups are endemic to Hengduan Mountains. South-Central China hotspot is also very rich in medicinal plants, harboring more than 2 000 species, mainly used as Tibetan medicine drugs. Most of them are endemic, e.g. *Incarvillea forrestii*, *I. delavayi*, *Lilium lophophorum*, *Corydalis benecincta*, and *Meconopsis speciosa*.

Due to its high diversity of geographical features and climate conditions, Yunnan Province harbors more than half of the vascular plants of China, containing nearly 17 000 species, whereas it only accounts for 4% of the total area of China (see Table 3). Of these, 15 000 are angiosperms, 100 gymnosperms, and 1 500 pteridophytes; moreover there are 1 500 bryophytes (Yang et al., 2004) (Table 3). It is therefore considered the richest Chinese province in plant biodiversity. Moreover, another characteristic of Yunnan flora is its high degree of endemicity. Thirty angiosperm genera occur only in Yunnan (e.g. *Manglietiastrum*, *Cyphoteca*, *Siliquamomum*, *Chaerophylopsis*, *Musella* and *Ferrocalamus*, among others). Yunnan is also rich in bamboo species, with 250 species, 150 of them being endemic to the province (Yang et al., 2004). In addition to the northern section of the province, which belongs to the South-Central China world hotspot, the Xishuangbanna region, located in southern Yunnan and bordering with Laos and Myanmar, possesses a very rich biodiversity and belongs to the 'Indo-Burma' world hotspot. Owing to its unique geographical location, there are floral mixtures and vegetation transitions from the tropics to the subtropics. With an area of only about 19 200 km^2, it harbors about 5 000 species of higher plants (Zhang & Cao, 1995; Liu et al., 2002) and more than 150 are endemic (Table 3), e.g. *Beilschmeidia brachythyrsa*, *Vatica xishuangbannaensis*, *Pterospermum menglunense*, *Myristica yunnanensis*, and *Nyssa yunnanensis*. Xishuangbanna has suffered a strong deforestation (the forest cover has decreased from more than 60% to less than 30%), due to fuelwood collection, shifting cultivation (included repeated slash-and-burn) and massive rubber plantation (Zhang & Cao, 1995). As consequence of this, about 340 plant species have been recognized as threatened in Xishuangbanna (Zhang & Cao, 1995) and about 600 have probably been lost (Liu et al., 2002).

Hainan island, located in the South China Sea, is part of the larger Indo-Burma's biodiversity hotspot, and exhibits a high plant diversity with about 4 200 species, 630 of which considered endemic to the island (Carpenter, 2001) (Table 3). Some examples of these endemics are *Keteleeria hainanensis*, *Hopea hainanensis*, *Dalbergia odorifera*, and *Sonneratia hainanensis*. Nevertheless, Hainan has been subjected to a severe deforestation, and rubber, palm and coffee plantations currently occupy large areas of the island. Up to 45 plant species are considered to be endangered, and about 450 tree species are harvested for timber. Although there is a high diversity of conifers in the interior uplands, most are threatened, such as *Cephalotaxus manii*, *Pinus fenzeliana*, *P. latteri*, *P. massoniana* var. *hainanensis*, *Keteleeria hainanensis*, and *Podocarpus annamiensis*. Moreover, only 1.3% of the island's landscape is protected. Many angiosperms are also menaced, e.g. *Hopea hainanensis*, *Vatica mangachapoi*, and *Dracaena cambodiana*.

Although it is not considered as one of the world-level hospots, the Yangtze Valley is a region with a very rich biodiversity. Nevertheless, the local flora is severely threatened due to rapid economic development of the area, a situation worsened by the Three Gorges Dam (Xie, 2003a). In fact, two of the three primary distribution centers for endemic groups of plants in China are located in the valley (SW Sichuan-N Yunnan and E Sichuan-W Hubei; the other is S Yunnan-SW Guangxi), and 127 of the 388 species listed in the China Plant Red Data Book can be found here (Xie, 2003a). Eight species endemic to the valley are in a very critical situation, since they have only one population: *Abies fanjingshanensis*, *Picea aurantiaca*, *Ulmus gausseni*, *Gletsidia vestita*, *Cystoathyrium chinense*, *Magnolia zenii*, *Sibbaldia omeiensis* and *Tangtsinia nanchuanica*. One of the most interesting areas in the Yangtze Valley is the 'metasequoia area', a region of about 800 km^2 in the juncture oh Hubei, Hunan and Sichuan, where there are still natural populations of *Metasequoia glyptostroboides* (Hu, 1980). In this so small land extension, at least 550 species of vascular plants occur; the most interesting, however, is that we can found there many 'living fossils' in addition to metasequoia, most of them belonging to monotypic or oligotypic genera, e.g. *Cunninghamia lanceolata*, *Keteleeria davidiana*, *Pseudolarix kaempferi*, *Taiwania cryptomeroides*, *Eucommia ulmoides*, *Tetracentron sinense*, and *Tapiscia sinensis*.

Sichuan is considered the second Chinese province in plant biodiversity after Yunnan, and contains about 9 300 species of vascular plants, belonging to over 1 600 genera in 230 families (SUU, 1994). Of these, 8 453 are angiosperms, 88 are gymnosperms and 708 species are pteridophytes (Table 3). Due to the ancient origin of Sichuanese flora, there are plenty of relict and/or endemic species. Among the angiosperms, 464 species are currently considered as true endemics (SUU, 1994). Although glaciers were formed in the high mountain ridges in western Sichuan during the Quaternary, they did not affect the survival of many ancient species due to the plant movement southwards through Hengduan Mountains, and then radiating again after glacial periods (SUU, 1994). The other province with lands within the South-Central China hotspot, Xizang, represents itself another rich area in plant biodiversity, harboring 9 600 species of vascular plants. Nevertheless, the biogeographical area to which belongs, Qinghai-Xizang Plateau (or Tibetan Plateau), contains over 12 000 species distributed in 1 500 genera of vascular plants. Of these, about 3 500 species and at least 29 genera are endemic to the Plateau, including c. 100 pteridophytes (Miller, 2003) (Table 3). Some examples of endemic species to Tibetan Plateau are *Primula latisecta*, *P. tsongpenii*, *Clerodendrum tibetanum*, *Fritillaria delavayi*, *Delphinium ceratophoroides*, *D. kingianum*, *Aconitum alpinonepalense*, *A. qinghaiense*, *Silene davidii*, and *Paeonia ludlowii*. Despite of the geographic isolation and unaccessibility to some areas, human factors, such as logging, expansion of livestock and tourism rise, are increasing substantially the threats to the Tibetan biodiversity. At present, about 40 species are considered to be seriously menaced, such as *Dipentodon sinicus*, *Cupressus gigantea*, *Pinus gerardiana*, *Picea smithiana*, *Sophora moorcroftiana*, and *Mandragora caulescens*.

Taiwan and Hong Kong can be also considered themselves as 'local hotspots'. Taiwan, mainly due to its insularity, possesses a rich flora on endemic taxa (about one-quarter of the total flora, i.e. 1 000-1 100 taxa; Gu, 1998; TESRI, 2004) (Table 3), some of them well-known such as *Chamaecyparis formosensis*, *Amentotaxus formosana*, *Cycas taitungensis*, *Calocedrus formosana*, *Camellia hengchunensis*, *Keteleeria davidiana* var. *formosana*, *Lilium formosanum*, *Pseudotsuga sinensis* var. *wilsoniana*, and *Koelreuteria elegans* subsp. *formosana*. The Red Data Book of Taiwan lists 502 species; from these, three are already extinct, 14 are endangered, 62 are vulnerable, and 423 are listed as rare species (TESRI, 2004). Only during the last twenty years, 11 species of flora have been added to the Taiwanese Red Book.

Hong Kong SAR has been subjected to intense and sustained human impacts during the last centuries, and, by the 19th century, it was nearly to reach the complete deforestation (Yip et al., 2004). Currently, about 360 species of vascular plants are considered rare by the local government (AFCD, 2004), some severely threatened as *Diospyros vaccinioides* (CR; IUCN, 2004) and *Castanopsis concinna* (VU, IUCN, 2004). Hong Kong also holds some examples of endemic flora, as the recently described species *Asarum hongkongensis* and *Balanophora hongkongensis* (HKISD, 2004), and the bryophytes *Macromitrium brevituberculatum* and *Syrrhopodon hongkongensis* (Zhang & Corlett, 2003).

Threats to plant biodiversity

Natural processes, such as demographic, genetic and environmental stochasticity, may threaten or directly cause the extinction of plant species. Natural catastrophes (e.g. floods and storms) are relatively frequent in China and may easily cause local extinction of plant populations. Nevertheless, these processes are often enhanced by the impact of anthropogenic activities, resulting in negative synergic effects on biodiversity. The main direct human threats to the Chinese plant biodiversity may be classified into habitat destruction, environmental contamination, overexploitation of species for human use, introduction of exotic species and lack of efficient legal environmental protection. The spectacular economic growth of China in the last two decades, in addition to the sustained population growth, are indirect factors which also threaten plant biodiversity because of their enhancement over direct threats.

1. Destruction and/or fragmentation of natural habitats are the most important causes of species extinction. China has experienced in the past, specially from 1950s, a huge loss and/or fragmentation of its natural habitats. The main human activities causing habitat destruction are the over-logging of forests (for obtaining timber, fuel wood and raw material for the pulp and paper industry), and the conversion of both forests and grasslands into croplands. Forests are one of the most severely affected ecosystems, with an estimated deforestation rate of 0.6% per year in 1990s (Dinerstein & Wikramanayake, 1993) and a coverage of only 16% of the land at the beginning of 2000s, half of the world average (SEPA, 2003; CBD, 2004). In addition, the forest area per capita is only 0.0012 km^2 in China, about 12% of the world average (CBD, 2004). Some areas have experienced a dramatical reduction of the forest coverage; e.g. rainforest on Hainan island covered 25.7% of the total area in early 1950s; thirty years later the coverage decreased to 10.6% (Chen & Chen, 1998), and around 70% of the natural forests of the three largest coniferous areas in China (Da Hinggan Ling, Changbai Mountains and south-western Hengduan Mountains) have been cleared (SEPA, 1998). However, overall China the forest cover has progressively increased in the last 40 years due to afforestation and/or reforestation campaigns. In 1962 the forest cover was around 9.0% of the total land area, while in 1981 it was 12.0% and 16.5% at the end of 2002 (World Bank, 2001; SEPA, 2003). Nevertheless, nearly all of these new plantations which replaced logged natural forest have been monospecific and often consisting of exotic species, diminishing significantly the biodiversity value of the forestlands (World Bank, 2001; Xu & Wilkes, 2004a). The progressing expansion of the desert in the north-eastern Chinese provinces (Xinjiang, Inner Mongolia, Gansu, Tibet and Qinghai) is a direct consequence of the massive conversion of grasslands into crop fields specially during the 1960s and 1970s. Currently, China exhibits the highest ratio of actual to potential desertified land in the world (2 620 000 km^2 are suffering desertification from a total of 3 320 000 km^2 prone to desertification; Gu, 1998; World Bank, 2001). About 67 000 km^2 of grasslands from the 1950s to 1970s were converted into farmlands as part of the national food self-sufficiency policy (World Bank, 2001). At present it is estimated that about 34% of grasslands are moderately to severely degraded and about 90% are degraded to some degree; in Inner Mogolia, c. 60% of the total extension of grasslands is severely degraded (World Bank, 2001). The loss of grasslands has palpable consequences even in the urban areas, e.g. the increasing incidence of dust storms in Beijing. Moreover, the loss of vegetation cover and the subsequent soil and water erosion (the estimated area of erosion is up to 3.67 million km^2, 38% of country land, and increases by 10 000 km^2 anually; Zhang et al., 2000; CBD, 2004) may contribute to the ocurrence of natural disasters such as floods and landslides, which have increased singnificantly in the past 40 years. For instance, the devastating floods in the middle reaches of the Yangtze River and in north-eastern China in 1998 were considered to be caused at least partly by deforestation in the catchments of the rivers in those areas (Zhang et al., 2000; World Bank, 2001). In response to them, the government issued a national ban for logging in the upper reach of Yangtze River and the upper and middle reaches of

Yellow River, in addition to decrete a decrease in timber production in the key national forest areas of Inner Mongolia and north-eastern China (CEPF, 2002; Xu & Wilkes, 2004a).

2. Environmental contamination produces a degradation of habitats which may compromise the species survival. At present, the environmentally most problematic issue is the air pollution derived from the extensive use of coal as the main energy resource in China, representing in 2002 the 70.7% of total energy consumption (World Bank, 2003). Most SO_2 and suspended particulate emissions come from this source. SO_2 emissions increased from 19 Mt in 1989 to 26.2 Mt in 1996. Nevertheless, their levels decreased to 20.8 Mt in 2000, a reduction of about 21% (Streets et al., 2001), due to the combined effects of declining coal consumption and improving the pollution control, and, therefore, probably refuting the pessimistic prospects of reaching up to 44 Mt in 2010 without controlling measures (Gan, 1998). The effects of the acid deposition, mainly associated with SO_2 emissions, are severe in the most industrialized areas (south, central and east China), where the yearly average values of acid rain pH are less than 5.0 (with peaks as low as 2-3); they have caused the disappearance of some species of lichens from cities and forests near the pollution sources (SEPA, 1998). On the other hand, CO_2 emissions, mainly also coming from coal use, may enhance the supposed global climate change due to their greenhouse effect. Although the growth in CO_2 emissions has been significantly lower than the previously projected, it is still important (22% of increase in the period 1990-1996; Streets et al., 2001). A simulation with doubled CO_2 concentration under the perspective of climate change would mean dramatic changes in the current ecosystem distribution and the migration of plenty of species mainly northwards (Chen et al., 2003). Nevertheless, a slight reduction (about 7.3%) has been detected from 1996 to 2000, a trend also exhibited by black carbon (2.2% of reduction from 1997 to 2000) and CH_4 (a decrease of 32% in 1995-2000) emissions (Streets et al., 2001), which gives us some room for optimism.

3. The overexploitation of species with a special interest may represent a serious damage to their survival. It is specially dramatic the case of some plants used in Traditional Chinese Medicine (TCM), often overcollected even being protected by law. It is estimated that more than 5 000 plant species are often used in TCM (Liu, 2001), and in 1990 traditional Chinese doctors prescribed c. 700 000 tons of plant material (Anonymous, 1997). Nevertheless, other kinds of traditional medicine use extensively plants, such as Tibetan medicine (up to 3 600 plant species); it is estimated that more than 11 000 species are used in China by their medicinal properties (Hamilton, 2004). Among the 426 herbal drugs (unprepared or stir-baked) listed in the 1995 edition of the *Pharmacopoeia of the People's Republic of China*, 28 are included in the *China Plant Red Data Book* due to their threatened status and therefore theoretically protected by Chinese laws. However, 49 additional plants listed in the Red Book are also extensively used in TCM (Peng & Xu, 1997). For instance, the epiphytic orchid *Dendrobium candidum*, second-grade nationally protected (NPC-2), will probably become extinct within 10

years by the extensive cutting of the host trees due to the high selling price of the dry drug (1 250 USD/kg; Yang et al., 2004). Other valuable medicinal plants also protected by law, such as *Gastrodia elata* (NPC-3), *Cistanche deserticola* (NPC-3), *Panax ginseng* (NPC-1), *Boschniakia rossica* (NPC-3), and *Oplopanax elatus* (NPC-2) have severely decreased in wild habitats as consequence of overcollecting. Moreover, there are some species that, despite of being widely cultivated in China, their wild populations are severely threatened such, as the case of *Gingko biloba* or *Juglans regia* (wild gene resource can be only found in two extant localities in the valley of Yili River, Xinjiang Province; Peng & Xu, 1997). In addition to medicinal plants, other non-timber forest products are also subjected to over-collection, such as edible mushrooms (e.g. *Tricholoma matsutake*) or some orchids for its horticultural value.

Additional human activities such as fuelwood collection and timber procurement have severely affected some forest species. Of the 8 000 species of trees and shrubs in China, about 2 000 are timber species (World Bank, 2001). Fuelwood is still the main source of heating energy in mountain rural areas, representing up to 70% of their total energy consumption. About 1 300 km^2 of forest in NW Yunnan disappear due to fuelwood collection every year (Xu & Wilkes, 2004b), and only in Diqing Prefecture (NW Yunnan) a total of 600 000 m^3 of fuelwood are collected each year (Xu & Wilkes, 2004a). One of the most threatened species due to its use as fuelwood is *Haloxylon ammodendron*, a species listed in the Red Book; its endargement is also reinforced because it is the host tree of the medicinal parasitic herb *Cistanche deserticola* (Peng & Xu, 1997). *Dalbergia odorifera* is also a protected species subjected to overcollection due to its uses as medicinal plant and timber for furniture and handicrafts (Peng & Xu, 1997). *Tetraena mongolica*, also listed in the Red Book, has been decreasing at an alarming speed as consequence of its massive use as firewood because it is combustible even in fresh state (Ge et al., 2003). In SW China, one of the main causes for the widespread deforestation —in addition to the commercial-scale logging— is the timber demand for construction, because of the traditional house design (i.e. they need a lot of timber) and the household structure (new houses for the newly married) (Xu & Wilkes, 2004a). At the rate of timber extraction until the logging ban of 1998 (around 300 million m^3/year), the resources overall China had less than 10 years of remaining life (World Bank, 2001). Nevertheless, illegal commercial logging still occurs at small scale, and it is estimated that about 80 million m^3 of furtive logging occurs nationwide each year (CEPF, 2002). It is specially awkward the case of Yunnan Province, where the actual cutting volume (including timber and fuel wood) is over 40 million m^3, despite of the reduction in the state's logging limit to 3 million m^3 in 1998 and to 0.83 million m^3 in 2000 (Yang et al., 2004).

4. China has a long history of introduction of non-native species, due to their potential economic value or other type of attributed benefits (medicinal, ornamental, soil improvement, erosion control, landscaping, etc). The first introductions took place more than 2 000 years ago, and consisted of *Tamarindus indica*, *Vitis vinifera*, *Medicago sativa*, *Carthamus tinctorius* and *Punica granatum*, among oth-

ers (Xie et al., 2001). China is a country specially vulnerable to invasive species due to its wide range of suitable habitats and environmental conditions for their establishment and spread (Xie et al., 2001). The first batch of invasive alien species in China has been approved recently (2002) by the government and contains 16 taxa (SEPA, 2003). However, in the preliminary review of alien invasive species made by Xie et al. (2001), they identified about 380 species of vascular plants that have become invasive in China. Some alien species have been introduced for restoring the natural vegetation, without a previous assessment of the potencial damage to local ecosystems. Some nature reserves are planning to make reforestations using alien species, e.g. *Sonneratia apetala* from Bangladesh has been used to reforest mangroves in the Dongzhaigang Nature Reserve in Hainan Province (Xie & Li, 2004). Furthermore, it is also reported the plantation of eucalypts, alien pines and alien larches in wide areas during large-scale reforestations (Xie & Li, 2004). Some of the most hazardous invasive species for the native flora are the plant species *Eichhornia crassipes* ('water hyacinth'), *Alternanthera philoxeroides* ('alligator weed'), *Eupatorium adenophorum* ('crofton weed'), *Spartina anglica* ('common cordgrass'), *Lantana camara* ('common lantana'), and *Mikania micrantha* ('South American climber'). *Alternanthera philoxeroides* is one of the world's worst tropical aquatic weeds, and in China it was spread artificially as a pig fodder from 1950s, although escaped from cultivation since 1980s. At present it occurs in 20 provinces, and forms dense mats floating on the surface in ponds and lakes, shading the indigenous aquatic vegetation from sunlight (Ye et al., 2003). *Eupatorium adenophorum* is a perennial shrub that has invaded large areas in southern China displacing the native flora, and its incidence is specially severe in Yunnan, where it covers an area of 247 000 km^2 (Xie et al., 2001). In addition to plants, mammals, birds, molluscs, insects and microorganisms have also caused damage to native plant biodiversity. Some examples are the nutria (*Myocastor coypus*), sulphur-crested cockatoo (*Cacatua sulphurea*), rainbow lorikeet (*Trichoglossus haematodus*), giant African snail (*Achatina fulica*), pine scale (*Hemiberlesia pitysophila*), fall webworm (*Hyphantria cunea*), vegetable leaf miner (*Liriomyza sativae*), and North American pinewood nematode (*Bursaphelenchus xylophilus*), among others.

5. Government policies have a major responsibility for the past, and still present, huge biodiversity loss. Development policies have historically been focused on the exploitation of natural resources. These include the 'Great Leap Forward' (1959-1960), a period in which communities were encouraged to be self-sufficient in steel. To backyard the steel furnaces, entire forests were cut for obtaining wood. During the Cultural Revolution (1966-1976), the campaigns for local self-sufficience of grain and the lack of logging control allowed most forests to be cleared. Another cause for defforestation are the repeated changes in forestland tenure. After the land nationalization and communization in the 1950s, household responsibility system was introduced in 1978 and it is still continuing today. These tenure changes, together with the ambiguity in the administration of land-tenure policies, have had negative effects on forests (CEPF, 2002). Sometimes it is difficult to

know in which of the main tenure categories (state, collective or household) a forest-land falls, which enhances illegal logging. In fact, sudden changes in tenure policy have historically been related to significant increases in exploitation of forest resources (Xu & Wilkes, 2004a).

After the adoption of 'open-door' policies by the country since 1978, the government began to legislate on environmental protection and biodiversity conservation. Despite some laws and regulations have been implemented into the legal system, they do not still assure an effective protection of the biodiversity. On one hand, the scope of the legislation is to manage the use of natural resources and not their conservation, while, on the other hand, there is a growing problem of enforcement (Li, 1998). For instance, the environmental impact assessment, although introduced in the legislation twenty years ago, has still serious problems of implementation, and, if performed, there is only applied to great contruction projects.

6. The imparable economic growth of China in the last two decades, showing the highest growing rates of GDP (gross domestic product) in the world (an average 9.4% in the period 1979-2002; World Bank, 2003) has led to a strongly increasing demand of natural resources. Nevertheless, their exploitation has been ecologically unsustainable, specially in the last five decades. One of the best examples is the construction of Three Gorges Dam, which will flood over 600 km of the Yangtze main channel, totalling an indundation area of 28 000 km^2 after final filling in 2009 (Park et al., 2003). The affected terrestrial flora will be of about 550 species, involving the disappearance of entire plant populations of some interesting species, such as *Distylium chinense*, *Buxus harlandii*, *Hibiscus syriacus*, *Buddleia lindleyana*, *Eriobotrya japonica*, *Litchi chinensis*, *Dimocarpus longan*, and *Trachycarpus fortunei* (Anonymous, 1996b; YWRP, 2004). However, it will be specially damaged *Adiantum reniforme* var. *sinense*, *Chuanminshen violaceum* and *Myricaria laxiflora* (YWRP, 2004), because all of them are endemic to the Three Gorges area. *Adiantum reniforme* var. *sinense* is also listed as 'endangered' in the Chinese Red Book and second-grade nationally protected (NPC-2), and most of its distribution area, along the Yangtze riverside in Wanxian and Shizhu, will be flooded. For these species, a series of conservation measures have been planned, such as the establishment of some species-specific reserves (for the three former taxa) and the maintenance of germplasm banks (YWRP, 2004).

Economic development has involved the installation of plenty of industries and the growth of the road network (about 25.000 km of new motorways have been constructed in the last decade). The unprecedented rise in the incomes per capita and living conditions experienced by Chinese people (e.g. the poverty incidence has declined from 49% in 1981 to 7.8% in 1999; World Bank, 2003) has originated a new industry, the domestic tourism, with the subsequent construction of new hotels and holiday resorts, often located close to areas of natural and scenic interest or even inside nature reserves (J. López-Pujol, pers. obs.). The improving of the communications and accesses to these natural areas —by the construction of new roads and cable cars— has contributed to their habitat degradation, because it has brought an unprecendented increase in the number of visitors. For example, the construction of a new motorway which will link Zhongdian with Kunming (Yunnan) will significantly accelerate the tourists arrival to the Three Parallel Rivers area (J. López-Pujol, pers. obs.), probably one of the world's least disturbed temperate ecological areas. The number of visitors in Huangshan Mountain has rised from 280 000 in 1979 to more than 1 million in 2001 (Eagles et al., 2001). As consequence of tourism impact in those areas, some species are now threatened, such as the lichen *Phizoplaca huashanensis*, an endemic species of Huashan Mountain (Shaanxi Province), or the bryophyte species *Actinothuidium hookeri* and *Hylocomium splendens* in Emei Mountain (Sichuan Province; SEPA, 1998).

7. The population growth, although with a slower rate after implementing the one-child policy, is still significant. At present, the estimated total Chinese population is c. 1 300 million, and it is predicted to raise up to 1 480 million on 2025 (World Bank, 2001). Moreover, under the expected economic growth (China might become the world's largest economy by 2041 in terms of GDP; Wilson & Purushothaman, 2003), the demand of natural resources per capita will increase exponentially. Plenty of species, specially those with economic value (agricultural, medical, timber), will suffer from an increasing overexploitation, putting them into the theshold of extinction. Furthermore, to satisfy the growing demand of consumer goods and services, industrial and tertiary activities should increase significantly, aggravating some of the negative effects explained above.

Past and current conservation measures

China has a long history in nature conservation; the first rules concerning wildlife protection might predate the Zhou period (1122-221 BC; Edmonds, 1994). Historical conservation of the surrounding lands of buddhist and taoist temples —as well as their 'sacred mountains'— by monks has allowed to maintain these intact until nowadays. Moreover, in China there is a clear link between biodiversity conservation and minority cultures, and it is well-known the conservation of Holy Places, Holy Mountains and Holy Trees by several ethnic minorities (Yang et al., 2004). For example, there are 400 'spirit mountains' in Xishuangbanna (Yunnan Province) with a total area of nearly 500 km^2, which have historically been protected by local communities of Dai nationality (Zhu, 2001; Walters & Hu, 2003). Nevertheless, modern nature conservation started late in China, and it can be divided into *in situ* and *ex situ* measures:

1. *In situ* conservation: The development of modern protected areas in China has experienced four main stages: 1956-1965, the initiation; 1966-1974, stagnation and devastation; 1975-1978, restoration; and 1979-present, a period of rapid growth (Lü et al., 2003). China's first nature reserve was founded in 1956 at Dinghu Mountain in Guangdong Province. One year later, in 1957, it was established the Wanmu Nature Reserve in Fujian Province, and, in 1958, the Xishuangbanna Na-

ture Reserve, in Yunnan (Gu, 1998). Seven years later, in 1965, up to 19 nature reserves had been established, covering an area of about 0.7% ot the total Chinese land surface (Gu, 1998). At the end of 2003, there was a total of 1 999 nature reserves, covering a total area of 1 439 800 km^2, e.g. more than 14% of the nation's surface (SEPA, 2003). Most of them have been established in the last 20 years (see Table 4), becoming their set up the main governmental measure to protect the Chinese biodiversity.

All nature reserves in China are placed into three categories according to their functions, i.e. natural ecosystems, wildlife and natural relicts. Besides to nature reserves, there are two figures of protection also contempled by Chinese laws, the natural parks and the scenic spots. A natural park in China differs from a nature reserve in that conservation of ecosystems and biodiversity ranks equally with public enjoyment as the dominant purpose (Gu, 1998). The first natural park in China, Zhangjiajie National Forest Park (Hunan Province) was established in 1982 (Gu, 1998) and, at the end of 2002, there were 1 078 forest (including grassland and

Table 4. Evolution of nature reserves in mainland China.

Year	Number	Area (km^2)	Percentage of Chinese territory	Number of national nature reserves
1956	1	11	—	—
1965	19	6 488	0.07	—
1978	34	12 650	0.13	—
1982	119	40 819	0.43	—
1985	333	193 300	1.99	—
1987	481	237 495	2.47	—
1989	573	270 630	2.83	—
1990	606	400 000	4.00	—
1991	708	560 660	5.85	77
1993	763	661 840	6.80	—
1995	799	718 500	7.19	99
1997	926	769 790	7.64	124
1999	1 146	845 090	8.80	155
2000	1 227	982 100	9.85	155
2001	1 551	1 298 900	12.9	171
2002	1 757	1 329 500	13.2	188
2003	1 999	1 439 800	14.3	226
2010[a]	1 800	1 550 000	16	220
2050[b]	2 500	1 728 000	18	—

Sources: Gu (1998), SEPA (2003)
[a,b] are expected values (SFA, 2004)

wetland) parks, accounting for a total area of more than 98 000 km^2 (Zhu, 2001). The scenic spots, selected for their scenic value, can also protect plant diversity, and in 2002 about 690 scenic areas were set up in China, covering over 96 000 km^2. In addition, there are more than 50 000 small protected areas, covering an area of nearly 14 000 km^2 (Zhu, 2001). Therefore, and taking into account all the described protection figures, the total protected land is c. 1 650 000 km^2, which represents about 16.4% ot the Chinese national territory. Nevertheless, many protected areas include villages, farms, grazing lands and plantations, being the effectively protected surface noticeably lower. Seventeen Ecological Function Protection Areas have been recently proposed, covering 7% of the total land area although overlapping with many of the other protected areas (Xie, 2003b).

Nature reserves, natural parks and scenic spots include four administrative management categories: national, provincial, municipal (or prefectural) and county-level. National nature reserves (226 of the 1 999) are those with a significant international influence and/or special value for scientific research. Some protected areas have received international recognition: 24 have been designated as Biosphere Reserves of the UNESCO's Man and the Biosphere Program, 8 are Natural World Heritage Sites, and 20 have been designated globally significant wetlands under the RAMSAR Convention. One of the 'flagship' Chinese protected areas is Xishuangbanna Nature Reserve, established in 1958 with the main object of protecting local tropical forests and rare plants and animals. It has a total area of 2 070 km^2, covering more than 10% of Xishuangbanna Prefecture (Yunnan Province), and harbors about 3 500 species of higher plants, of which 300 are considered rare. In addition, in such small area there are 200 species of food plants, 100 species of oil plants, 50 species of bamboos, 300 species of medicinal plants, and 30 species of plant 'living fossils' (Nepal, 2000).

The Tianmushan Nature Reserve (Zhejiang Province), established in 1960, is one of the most famous protected areas in China due to its exceptionally amount of large trees. Also known 'kingdom of big trees', and with an area of only 42.84 km^2, the reserve contains the supposed wild population of 167 individuals of *Gingko biloba* (Del Tredici et al., 1992). There are exceptionally large trees of *Torreya grandis*, *Liquidambar formosana*, *Nyssa sinensis*, *Cyclocarya paliurus*, *Litsea auriculata*, *Cryptomeria japonica* var. *sinensis*, *Pseudolarix kaempferi*, and *Emmenopterys henryi*. The reserve is also very rich in plant biodiversity (it contains about 2 160 species of higher plants; Tang & Hegde, 2001), and 29 taxa growing within the reserve are included in the *China Plant Red Data Book* (Del Tredici et al., 1992). The ancient existence of buddhist temples in the area has probably preserved this 'holy mountain' until nowadays.

Taiwan has developed in the last 20 years a complex network of protected areas aimed to conserve its plant and animal biodiversity, which covers 19.5% of the land area. Currently, 6 national parks, 19 nature reserves, 13 wildlife protection areas, 24 nature protected areas, 29 major wildlife habitat areas, and 9 national forest nature protected areas have been established (Yang & Su, 2004). Kenting National Park was the first national park in Taiwan (it was set up in 1984), and it contains a rich subtropical and tropical flora, with about 2 200 plant species

(Hsu & Agoramoorthy, 2004). Of these, more than 1 000 are vascular plants (i.e. constituting 25% of total species in the island), and 41 are classified as rare, including five endemics (Gu, 1998). Are severely endangered the species *Vitex trifolia*, *Zeuxine strateumatica*, *Scaevola hainanensis*, and *Ipomoea littoralis*. The impact of tourism (the park receives about 3 million of tourists anually) and the severe erosion detected in some areas are the main conservation challenges for the park (Hsu & Agoramoorthy, 2004).

About 40% of the land area in Hong Kong is protected, showing the highest percentage in the Asia Pacific region; nevertheless, the protected areas do not adequately cover some habitat types, such as freshwater wetlands and some *feng shui* forests near the urban areas (Yip et al., 2004). Two main kinds of protected areas can be distinguished, country parks (designated for the purposes of nature conservation, countryside recreation and outdoor education) and special areas, with the purpose of nature conservation. At present, 23 country parks and 15 special areas have been established, in addition to 64 sites of special scientific interest ('SSSIs'; Wu, 2002; AFCD, 2004). Most of the SSSIs designations are due to their floristic importance, e.g. Mau Ping was listed as SSSI owing to the occurrence of the largest population of *Camellia crapnelliana* in Hong Kong (Wu, 2002). The most emblematic protected area in HKSAR is the Mai Po Marshes & Inner Deep Bay, which was designated in 1995 as Wetland of International Importance (RAMSAR Convention; WI, 2004).

2. *Ex situ* conservation: Although it is widely assumed that the most effective conservation measures are those *in situ*, *ex situ* facilities may support them by providing scientific background and source material for future reinforcements and/or reintroductions. Currently, the most recognized *ex situ* conservation strategies are the preservation of living plants in botanical gardens (and arboreta) and field germplasm nurseries, and the preservation of seeds and plantlets *in vitro* in germplasm and gene banks. In addition, the plant introduction bases and breeding bases may play a key role in the *ex situ* conservation strategies.

Despite the first modern botanical gardens were not established in China until the beginning of twentieth century, we can find their origin c. 2800 BC, when the legendary Shennong established his Medicinal Botanic Garden, currently regarded as the earliest botanical garden in the world (Xu, 1997). Further, Sima Guang (1086-1019 AD) built his 'Enjoying-Myself Garden', with designed plots and name cards in the plants (Gu, 1998). Temple gardens have played a significant role in the *ex situ* conservation of Chinese flora, e.g. more than 100 plant species have been cultivated in the temple gardens of Xishuangbanna (Liu et al., 2002). The first modern botanical garden, Hengchun Tropical Botanical Garden (Taiwan), was established in 1901; Xiongyue Arboretum (Liaoning Province) in 1915, Taipei Botanical Garden (Taiwan) in 1921, and Nanjing Botanical Garden Mem. Sun Yatsen (Jiangsu Province) in 1929 (Xu, 1997). Nevertheless, Hong Kong Zoological and Botanic Garden was established before, in 1861 (Chapman & Wang, 2002). At present, about 140 botanical gardens have been set up in China (He, 2002; Huang et al., 2002), covering an area of c. 2 500 km^2 and cultivating about 23 000 species of vascular plants, of which 18 000 are species found in China (Xu, 1997; Xue, 1997), i.e. 55% of the Chinese flora. Of these, 4 are located in Hong Kong, one in Macao and 4 in Taiwan.

At present, the largest botanical gardens in China are Beijing Botanical Garden (South), Xishuangbanna Tropical Botanical Garden (XTBG), Kunming Botanical Garden, Nanjing Botanical Garden Mem. Sun Yatsen, and South China Botanical Garden (see Table 5). The XTBG, established in 1959 in Menglun

Table 5. Some botanical gardens in China.[a]

Name	Location	Area (km^2)	Number of taxa[b]	Data of establishment
Beijing Botanical Garden (South)	Beijing	0.56	5 000	1955
Beijing Botanical Garden (Northern)	Beijing	4.00	2 700	1956
South China Botanical Garden	Guangzhou (Guangdong)	3.00	5 000	1959
Nanjing Botanical Garden Mem. Sun Yatsen	Nanjing (Jiangsu)	1.87	3 000	1929
Kunming Botanical Garden	Kunming (Yunnan)	0.44	4 000	1938
Shanghai Botanical Garden	Shanghai	0.81	5 000	1974
Xishuangbanna Tropical Botanical Garden	Menglun (Xishuangbanna, Yunnan)	9.00	8 000	1959
Shenzen Fairy Lake Botanical Garden	Shenzen (Guangdong)	5.90	3 000	1982
Wuhan Botanical Garden	Wuhan (Hubei)	0.70	4 000	1956
Xiamen Botanical Garden	Xiamen (Fujian)	2.27	3 000	1960
Qinling Botanical Garden	Zhouzhi County, Xi'an (Shaanxi)	458.00	6 100 (2005) 30 000 (2010)	2005 (first phase); 2010 (second phase)
Hong Kong Zoological and Botanic Garden	Hong Kong SAR	0.054	1 200	1861
Taipei Botanical Garden	Taiwan	0.08	1 500	1921

[a] Data extracted from Xu (1997), Gu (1998), and BGCI (2004)
[b] 'Taxa' include species and varieties

(Xishuangbanna, Yunnan), possesses a collection of about 8 000 taxa (Walters & Hu, 2003). It has several special collections, such as those of palms, orchids, bamboos, tropical fruits, economic trees, shade-plants, medicinal plants, and tropical conifers, among others. It also contains a collection of 30 species endemic to Xishuangbanna (BGCI, 2004) and an *ex situ* conservation area for rare and endangered plants of southern Yunnan, which preserves c. 1 300 species (Xu, 1997). The Kunming Botanical Garden (Kunming, Yunnan) highlights for its special collections, specially those of *Camellia* (there are 40 species of *Camellia* and 100 cultivars of *C. reticulata*), *Rhododendron* (320 species and cultivars) and Magnoliaceae (about 90 species) (He, 2002). It also contains a medicinal plant garden with c. 1000 species of plants used in Traditional Chinese Medicine (KIB, 2003). The Nanning Medicinal Plant Garden contains about 2 500 species of medicinal plants, with 134 endemic to Guangxi Province (He, 2002).

Perennial and vegetatively propagated crops are preserved in field germplasm nurseries, which have been designed in China for preserving alive plants. In the 32 national nurseries (Zhu, 2001), over 20 000 accessions of germplasm for perennial and agamospermic taxa can be found, mainly fruit trees and several crops, such as mulberry, tea, wild grape, hawthorn, sugar cane, rubber, wild cotton, etc (MOA, 1995). On the other hand, about 255 plant introduction bases had been set up at the end of 1990s, which assured the conservation of more than 80% of the nationally protected rare and endangered species; for example, these nurseries have been succesfully propagated *Davidia involucrata*, *Alsophila spinulosa*, *Camellia petelotii*, *Cathaya argyrophylla*, *Ostrya rehderiana*, *Abies beshanzuensis*, *Ormosia hosiei*, and *Carpinus putoensis* (Xu et al., 1999; Zhu, 2001).

The seed storage in germplasm banks started in China in 1980s with the establishment of the No. 1 National Gene Bank in Beijing in 1983, with capacity of 230 000 accessions of seeds. The No. 2 was established later (1988) also in Beijing, with a capacity of more than 450 000 accessions, and which has the responsibility of the global germplasm conservation of *Brassica campestris*, *B. campestris* subsp. *pekinensis*, *Raphanus sativus* and *Triticum aestivum* (MOA, 1995; Gu, 1998); furthermore, a National Duplication Gene Bank was set up in Xining (Qinghai Province) in 1995, which has a total capacity for 400 000 accessions (MOA, 1995; Gu, 1998). Currently, nearly 350 000 accessions have been deposited in these long-term storage facilities, belonging to 28 families, 160 genera and 450 species (MOA, 1995; Gu, 1998). Of these, about 208 000 are accessions of grain crops, 61 000 of rice, more than 1 000 for apple, pear and peach, 25 000 of vegetables, and 3 000 of grass and green manure crops (MOA, 1995). In addition, about 20 000 accessions correspond to wild plants (Gu, 1998). Twenty-seven mid- and short-term seed storage facilities have been also set up by local academies of agricultural sciences of provinces and municipalities (Zhu, 2001). On average, about 3 000 accessions of various kinds of germplasms are collected every year, mainly (c. 85%) native from China (MOA, 1995). China also established in 1994 a seed bank specifically for medicinal plants in Zhejiang Province, with a capacity for 50 000 accessions (Xue, 1997), and the Chinese Academy of Medical Sciences set up a medicinal plant germplasm bank with a collection of 900 species (Xu et al., 1999). Taiwan has also made great efforts to conserve germplasm resources; the genebank of Taiwan Institute of Agriculture can store up to 240 000 accessions (Gu, 1998). On the other hand, the *in vitro* plantlets conservation has only been applied in China to the potato and sweet potato. At the end of 1990s, there were four *in vitro* storage facilities, two for the potato (Beijing and Keshan, Heilongjiang Province) and the other two for the sweet potato (Beijing and Xuzhou, Jiangsu Province) (MOA, 1995; Gu, 1998).

3. In addition to *in situ* and *ex situ* measures, environmental legislation and government planning are also essential to ensure an adequate conservation of biodiversity. Legislation for biodiversity conservation, as stated above, began to be implemented only recently, and it is still relatively limited. China has issued a series of laws (up to 20) concerning biodiversity conservation since early 1980s (see Table 6). The Chinese Constitution of 1982 has two articles (9 and 26) with direct implications on biodiversity (Xu et al., 1999; Wang et al., 2000). Most relevant laws for plant biodiversity are the Environmental Protection Law (issued in 1979, revised in 1989), the Forest Law (issued 1984, revised 1998), the Grassland Law (issued 1985), the Import and Export Animal and Plant Quarantine Law (issued 1991), and the Seeds Law, promulgated recently (2000). China has also issued a significant amount of administrative regulations (Table 6), many accompanying to laws. Are specially significant the Regulation about Nature Reserves (1994), the Regulation on Wild Plants Protection (1996), and the Regulation about Protection and Administration of Wild Medicinal Material Resources (1987) (Xu et al., 1999; Wang et al., 2000).

On the other hand, there are some implemented legal systems which support the biodiversity conservation in China, in addition to laws and regulations. The most relevant is the system of Environmental Impact Assessment (EIA), which was legally implemented in 1981 and amended several times (1986, 1989, 1998 and 2002) to expand its scope, management contents and responsibilities. A second legal system is the licensing system (such as forest logging and land use licenses), aimed to implement the policies for paid use of natural resources and sustainable utilization of those (Xu et al., 1999). A third system are the economic incentives, which are based in the establishment of financial subsidies, tax-deductions, and compensantion fees to enhance a sustainable exploitation of natural resources (Xu et al., 1999; Wang et al., 2000). China implemented in 2001 the Forest Ecological Compensation Fee, aimed to restructure the timber industry in favour of sustainable forestry (CEPF, 2002; CBD, 2004). The fourth legal system are the quarantine controls, established from early 1980s.

Since the 1990s, China has also designed and implemented several strategies focused to the biodiversity conservation and to reach a sustainable development, either at state, interdepartamental and departamental levels. In addition, China has actively joined a number of internationally-scale conventions and programs, such as the UNESCO's Man and Biosphere Program (MAB) in 1978, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1981, the Convention Concerning the Protection of the World Cultural and Nat-

Table 6. Legislation concerning biodiversity conservation issued in China.

Event	Date of issue (and revision)	Lead agency
Laws		
Environmental Protection Law	1979 (1989)	State Environmental Protection Agency (SEPA)
Constitution	1982	National People's Congress
Marine Environmental Protection Law	1982 (1999)	State Marine Administration (SMA)
Forest Law	1984 (1998)	State Forestry Administration (SFA)
Grassland Law	1985	Ministry of Agriculture (MOA)
Water and Soil Conservation Law	1991	State Environmental Protection Agency (SEPA)
Import and Export Animal and Plant Quarantine Law	1991	Ministry of Agriculture (MOA)
Seeds Law	2000	Ministry of Agriculture (MOA)
Law on Desert Prevention and Transformation	2001	State Environmental Protection Agency (SEPA)
Law on the Environmental Impact Assessment	2002	State Environmental Protection Agency (SEPA)
Law on Biosafety	Under redaction	State Environmental Protection Agency (SEPA)
Administrative regulations		
Plant Quarantine Regulation	1983	Ministry of Agriculture (MOA)
Temporary Regulation on Management of Scenic Spots	1985	Ministry of Construction (MOC)
Regulation for the Implementation of the Forest Law	1986	State Forestry Administration (SFA)
Regulation about Protection and Administration of Wild Medicinal Material Resources	1987	State Administration of Traditional Chinese Medicine (SATCM)
Regulation about Control of Forest Fires	1988	State Forestry Administration (SFA)
Regulation about Control of Forest Pests	1989	State Forestry Administration (SFA)
Regulation about Seed Management	1989	Ministry of Agriculture (MOA)
Regulation on Afforestation in Urban Areas	1992	State Forestry Administration (SFA)
Regulation about Nature Reserves	1994	State Environmental Protection Agency (SEPA)
Regulation on Wild Plants Protection	1996	State Forestry Administration (SFA)
Regulation on the Safety Management of Agricultural Biological Genetic Engineering	1996	State Environmental Protection Agency (SEPA)
Regulation on New Plant Varieties Conservation	1997	Ministry of Agriculture (MOA)
Environmental Management Regulation of Construction Projects	1998	State Environmental Protection Agency (SEPA)
Regulation for Implementation of Forest Law	2000	State Forestry Administration (SFA)
Regulation of Biosafety Management in China	2001	State Environmental Protection Agency (SEPA)

ural Heritage (WHC) in 1985, the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (RAMSAR) in 1992, the Convention on Biological Diversity (CBD) in 1993, and the United Nations Convention to Combat Desertification in 1996. In addition, China joined IUCN as a country member in 1996 and became a member of the International Convention on New Plant Variety Conservation in 1999 (Zhu, 2001). China also signed the Kyoto Protocol in 2002, recently (November 2004) ratified.

The state-level plans related to biodiversity conservation began to be applied since early 1990s. To implement the Article 6 of CBD, it was launched the China Biodiversity Conservation Action Plan in 1994 (see NEPA, 1994). The First National Report on Implementation of CBD was submitted in 1997, and the Second National Report in 2001. China also issued China's Agenda 21 in 1994, aimed to achieve development under the scope of sustainability. A third national plan was launched at the end of 1997, China's Biodiversity: A Country Study, which analyzed Chinese biodiversity and its economic value and benefits (SEPA, 1998). The Tenth Five-year (2001-2005) Plan of National Economic and Social Development and 2015 Plan, emphasize the sustainable development strategy as one of the basic state policies to be implemented, and suggest the enhancement of the environmental legislation (Zhu, 2001).

The most relevant interdepartamental programs related to biodiversity conservation are the China Environmental Protection Action Plan (1996-2000), a program launched to ensure the conservation and sustainable utilization of forests, grasslands, marine environment, wetlands, nature reserves and species (Xue, 1997; Xu et al., 1999); the Development Plan for Nature Reserves in China, which analyzes the situation of nature reserves in China and makes the reserves planning for two phases (1996-2000 and 2001-2010); and the National Tenth Five-year (2001-2005) Plan for Environmental Protection, which establishes some goals to be reached, such as a reduction of 10% in the main pollutants discharge, and a nature reserves' coverage of 13% of the total land area (SEPA, 2002). Among the departamental plans, the State Environmental Protection Agency (SEPA, formerly NEPA) launched the China Trans-Century Green Engineering Plan (issued in 1996), and China's Agenda 21 for Environmental Protection (issued in 1994). The State Forestry Administration (SFA, formerly Ministry of Forestry) launched in 1998 the National Plan for Forest Ecological Construction, with three objectives, short (1996-2000), moderate (2001-2010) and long-term (2011-2050); the China's Forestry Biodiversity Conservation Action Plan (issued in 1992), the Forestry Action Plan for Agenda 21 (issued in 1995), the Action Plan for Implementing the UN Convention to Combat Desertification (launched in 1998), and the Conservation and Sustainable Use of Wetland Biodiversity in China (2000-2004). In addition, all the agencies and ministries have launched their sectorial Tenth Five-year (2001-2005) and 2015 Long-term Plans.

Future of plant biodiversity in China: problems, prospects and recommendations

Habitat destruction

The huge habitat destruction experimented in China, specially since the 1950s, began to receive attention by the government authorities only in recent years, due —at least partly— to the natural disasters occurred and the fall in crop productivity associated with soil erosion and land desertification. To solve these increasing problems, state government recently issued a series of forestation and shrub or grass-planting projects. Although the first plans were implemented in late 1970s, these always consisted of mono-culture forest plantations, often with exotic species, without a scientific basis and taking not into account the local floristic features. For instance, the forestation and grass-planting projects started in the 1970s in Northern Loess Plateau, although did not produced a significant loss of biodiversity, resulted in substantial changes in the floristic features of the local natural vegetation (Jiang et al., 2003). The construction of the shelter forest system since late 1970s, such as those in the Triple-North region and the middle and lower reaches of Yangtze River, had also followed mono-culture policies. The new afforestation projects should therefore take into consideration some basic scientific guidelines, such as avoiding (or at least putting under strict control and monitoring) the introduction of exotic species, in order to prevent massive invasions and severe pest outbreaks, and guaranteeing the availability of habitats and resources for indigenous species. One of the main objectives of the 'Great Western Development Plan', a global program to remove the gap between prosperous coastal areas and underdeveloped interior provinces, and currently under way (endorsed in 2000), is to ensure sustainable natural resources management through forestation and grass planting (CEPF, 2002; Jiang et al., 2003). Two large-scale programs, the Natural Forest Conservation Program (1998-2010) and 'Grain to Green' (or Land Conversion Program, 1999-2010) have been launched to reduce erosion from deforestation and cultivation of slopping lands, and they are focused on the Upper Yangtze and Yellow rivers (Zhang et al., 2000; CEPF, 2002). China has also implemented in 2001 the sand control and abating project to solve the problem of sand storms around Beijing (Zhu, 2001). Despite these programs represent one of the best opportunities for biodiversity conservation, additional efforts should be invested by the authorities to achieve an integrated strategy of sustainable forest exploitation and long-term ecological protection, instead of a merely tree plantation. The National Plan for Forest Ecological Construction between 1996-2050, which projects to increase the forest coverage up to 17.5% of the total land area in 2010 and to 25% in 2050 (Xue, 1997; Xu et al., 1999), should incorporate these scientific described criteria.

Protected Areas

The National Endangered Plant and Wildlife Protection and Nature Reserves Construction Program in China, aimed to protect biodiversity in the next 50 years, stipulates that by 2010 the number of nature reserves must reach 1 800 —with 220 of those being at national level—, occupying about 1 550 000 km^2 and accounting up to 16% of the Chinese territory. The plan also recommends that at the end of the program (2050) the number of nature reserves should reach 2 500, with an area amounting to 1 730 000 km^2, accounting for 18% of the land surface (SFA, 2004). The goal for 2010 has been already reached due to the impressive rate of nature reserves establishment, particularly over the last 20 years (see Table 4). For instance, in Tibet alone, nature reserves cover about 400 000 km^2, i.e. one-third of the total land area (Miller, 2003). However, the provision of staff and financing to manage and protect them has not simultaneously increased. For example, by 1997 only 67% of all nature reserves had staffs and budget, therefore about one-third of them were protected only 'on paper' (Jim & Xu, 2004). Moreover, only 20.8% of the staff was professional (i.e. with higher education) in 1997 (World Bank, 2001). The problem is due —at least partly— to the fact that only a minority of the reserves (about 10.7% at the end of 2002) are financed at state-level, having these in general adequate resources (staff and budget) for their management and protection; the reserves with assigned responsibility to lower levels (province, municipality or county) has much less resources (World Bank, 2001). Consequently, many reserves are forced to be self-sufficient through the promotion of their resources development (tourism and some degree of exploitation of natural resources), a policy inconsistent with their initial purpose. Mass tourism has caused severe habitat degradation in many reserves, as consequence of construction of equipments (resorts, new accesses) and the overexploitation of wildlife resources (e.g. medicinal and edible plants). Tourism should evolve to the sustainability, instead of seeking a short-term benefit —as currently occurs—, and should be planned and managed to combine the protection of biodiversity, the satisfaction of the visitors and the assurance of adequate economical benefits to local people. Involving the local people, even in the management and administration of reserves, is a key-step to reach the nature reserves' sustainability scope (Eagles et al., 2001), because it is the best way to reduce the pressure on the reserves by local residents. On the other hand, guards and other technical staff of nature reserves should have good technical formation and adequate capabilities.

Nevertheless, nature reserves exhibit other serious problems in addition to lack of budget. Overlapping management by several administrations may cause confusion and lack of efficient management and clear boundaries of the reserves. Prior to 1993, only four admninistrations were involved in the nature reserves management (SEPA, SFA, SMA and Chinese Academy of Sciences); at present, this number has expanded up to 7 (World Bank, 2001). Some reserves have multiple designations, e.g. Jiuzhaigou and Gongga Mountain in Sichuan Province, which are simultaneously scenic area, forest park and nature reserve, having each function its own management by different administrations (CEPF, 2002). On the other hand, many reserves are too small to ensure their functions of biodiversity protection, too damaged or not located in biologically significant areas (World Bank, 2001; Jim & Xu, 2004). The design of nature reserves has not been very rational in the past, and criteria of biogeographical and ecosystem representativity have not been followed. Furthermore, lands managed by the army are excluded from the protected areas network, whilst in other countries it is allowed a secondary stewardship (Liu et al., 2003). Establishing a centralized management by a new Nature Reserves Service which should be state-level with adequate funding, is the best measure to solve these problems, as suggested by the World Bank (2001) and Liu et al. (2003).

The evaluation of the efectiveness of nature reserves is generally a neglected issue in China, since they are not routinely monitored (Lü et al., 2003). For instance, of the reserves located in the South-Central China hotspot, 25% have no patrols, 75% have no monitoring programs in place, and 70% lack comprehensive inventories of resources (CEPF, 2002). In a study conducted in Wolong Giant Panda's Reserve (Sichuan Province), and one of the 'flagship' protected areas in China, the reserve resulted to be moderately effective in nature conservation although the overall efectiveness was rather low, because environmental education and social and economic development or local population were not adequate (Lü et al., 2003). Moreover, after the establishment of the reserve (in 1975), the habitat had unexpectedly become more fragmented than before, and the rates of habitat loss inside the reserve were similar or even higher than those outside the reserve (Liu et al., 2001). The nature reserves often do not provide an adequate protection of their flora, even being internationally-level. For example, the narrow endemic species *Ophiopogon xylorrhizus* is confined to an area of 30 × 20 km within the boundaries of Xishuangbanna Biosphere Reserve (Yunnan); however, one of the eight extant populations has recently been extincted, and population sizes have significatly been reduced in the others (Ge et al., 1997). In Changbai Mountain Biosphere Reserve (Jilin Province), the medicinal and nationally protected plants *Panax ginseng*, *Oplopanax elatus*, *Boschniakia rossica*, and *Gastrodia elata* are currently subjected to severe overexploitation (Yang & Xu, 2003).

Traditional cost-benefit focus is not appropriate for managing protected areas and in general the natural environment, because there are many ecological values not considered or underevaluated, such as the ethical and aesthetic values (Yang & Xu, 2003). Nevertheless, managers only look for short-term economic gain, without considering the long-term ecological benefits provided by the environment protection, such as the prevention of soil and water erosion and the reduction of the severity of floods and droughts (Athanas et al., 2001). For example, the economic value of the environmental services provided by Changbai Mountain Biosphere Reserve is estimated to be 16 times higher than the regular timber production there (Athanas et al., 2001).

Ex situ *conservation measures*

Although the number of botanical gardens has significantly increased in the last decades, there are still few according to the huge diversity of ecosystems and species in China. They often have not adequate sizes (about 40% of the botanical gardens are smaller than 0.5 km^2) and amount of species (c. 60% of them has fewer than

1 000 taxa) (NEPA, 1994). Another deficiency is that the pool of botanical gardens is not representative of the several local floras across China. For example, Xu (1997) and He (2002) pointed out that some regions very rich in plant diversity had too few botanical gardens, such as the Himalayas, Qinghai-Xizang Plateau and the dry-hot valleys in south-western China, a trend that it was also observed in the three primary distribution centers of endemic plants in China. Therefore, a desirable policy is that the setting up of new gardens should take place in the above mentioned areas, following scientific guidelines in order to provide the maximum protection of endemic and endangered plants. On the other hand, the conservation of the protected rare and endangered species has still not been reached; currently, about 350 species of the 388 included in the Volume I of *China Plant Red Data Book*, i.e. 90%, are cultivated, but only about 200 species of the 640 listed in the forthcoming Volume II of the Red Book, i.e. 31%, are preserved in the Chinese botanical gardens (Xu, 1997). Xu (1997) also alerts about the risk of cultivating one species in less than 5 different botanical gardens, which is a common feature among the protected rare and endangered species. From the first batch of the Red Book, only 48.5% of the species are preserved in ≥ 5 botanical gardens, a fact which only occurs in 0.5% of the species listed in the second batch (Xu, 1997). Furthermore, sizes of plant populations for each species are generally not enough for maintaining adequate levels of genetic diversity. Only a few cultivated species included in the first or in the second batch of the Red Book (less than 40%) have more than 10-20 individuals in any botanical garden, the threshold for preserving genetic diversity suggested by Xu (1997). These deficiencies may be covered by Qinling Botanical Garden (Xi'an, Shaanxi Province), which, after its finishing in 2010, will be the largest botanical garden in the world, with an extension of 458 km^2. A total of 6 100 rare and endangered species will be specifically cultivated, 3 200 of them belonging to Qinling area, 900 from temperate areas and 2 000 from tropical and subtropical zones (Anonymous, 2002). On the other hand, the Chinese Academy of Sciences drafted a 15-year *ex situ* master plan to conserve the diversity of native Chinese plants in botanical gardens, which is now being implemented. Its main goals are to increase the number of native protected species to 21 000, to enhance the garden collections of rare and endangered plants, and to create 5 new regional gardens (Huang et al., 2002).

China has achieved significant advances in germplasm storage in the recently years; nevertheless, there are some regions where the germplasm collection has been not enough. Priorities should be given to those areas subjected to severe human pressions, such as mass tourism in some scenic areas. Fortunately, China has recently performed the survey and collection of germplasm resources in the Three Gorges Dam area and in mountainous development zones in south Jiangxi and north Guangdong (Zhu, 2001). Furthermore, the establishment of a new germplasm bank in Kunming (Yunnan) has been planned to guarantee the preservation of germplasm resources of SW China. The ambitious goal of collecting seeds of 24 000 plant species native to Yunnan, Guizhou, Sichuan, Guangxi and Tibet should be reached in 2010 (Cyranoski, 2003). The *in situ* and *ex situ* conservation approaches have been succesfully combined in the conservation plan of the endangered species *Vatica guangxiensis* performed by Xishuangbanna Tropical Botanical Garden. The only three remaining populations of this species (located in Yunnan and Guangxi) have been included in the Nature Reserves network, and about 90 individuals have been successfully transplanted to the garden (Li et al., 2002).

Environmental legislation

The legislation with direct or indirect implications on biodiversity conservation has significantly expanded in the last two decades; nevertheless, there are still two major problems which make legislation not to be an adequate tool for the preservation of Chinese biodiversity: an insufficient and inefficient legal environmental system and a lack of its enforcement (Li, 1998; Xu et al., 1999). On one hand, the main purpose of laws and regulations is to manage the use of natural resources and not their conservation, since they were promulgated from the stand of natural resources' economic value. Another deficiency is that legislation is often oriented to only one type of natural resource, lacking coordination with legislation concerning to the other resources, and there are no specific regulations to preserve entire ecosystems (Li, 1998). Furthermore, there is not a comprehensive law on nature conservation, since Environmental Protection Law is mainly focused on pollution control (Xu et al., 1999). Other inconsistences of environmental Chinese legislation are ambiguous responsibility and unreasonable penalisation of violators; civil and criminal responsibilities are poorly included in the legislation, and punishment consists on compensation of damages instead of their removal and rehabilitation (Xu et al., 1999).

Historically, law enforcement is one of the major problems for the establishment of a sound legal system in China. Violations of environmental legislation are so common in China, and even tolerated. For example, there is a generalised lack of effective *in situ* protection of the nationally protected rare and endangered plant species; e.g. about 1/3 of the nationally listed rare and endangered species in the Yangtze Valley are not protected —although with a theoretically legal coverage—, and deserve effective conservation measures (Xie, 2003a). According to Li (1998), there are three main causes to explain this poor enforcement. Firstly, there is a lack of capacity of the administration, since the extant staff is not enough to assure legislation enforcement (e.g. the enforcement staff of SEPA was only about 250 people at the end of 1990s). Secondly, there is a lack of coordination among the different administrations, and several agencies are sometimes responsible for the same protected area. Thirdly, plenty of corruption cases among the goverment officials have been reported, such as exemptions to industrial plant sitting restrictions in environmentally sensitive areas and falsification of monitoring records (Li, 1998).

The implementation of the environmental impact assessment (EIA) has been showing enormous troubles since its introduction 20 years ago. One one hand, according to the Chinese environmental legislation prior to the implementation of the Law on the Environmental Impact Assessment in September 2003, the EIA was only applied to construction projects which might produce pollution on the environment, instead to be performed in all the activities consisting or affecting natural resources utilization or those which might cause loss of biodiversity. Moreover, EIA only targeted individual construction projects, whilst it was not binding on government-proposed projects, and the rate of implementation was only about 90% at the end of 1990s (Xu et al., 1999; Zhu, 2001). The recent implementation of EIA Law is a great move, because it expands the scope to cover the government planning activities for land use and regional construction and development, which always have been creating larger environmental problems than the individual construction projects.

Scientific research

Scientific research provides critical knowledge about the biodiversity richness of a country but also essential information for conservation biodiversity. Large-scale national surveys of vegetation, natural ecosystems, flora and fauna began in late 1950s in China, resulting in the publication of *Vegetation of China* (1980), *Cryptogams of China* (4 volumes), *Flora of China* (*Flora Reipublicae Popularis Sinicae*) (60 volumes of the 80 prospected from 1950), and *Economic Flora of China*, among others (Xu et al., 1999). Currently, the Missouri Botanical Garden (MBG) and the Chinese Academy of Sciences (CAS) are working in the 'Flora of China' project, an international effort to produce a 25 volume English-language revision of the *Flora Reipublicae Popularis Sinicae*. At present, 10 volumes have already been published and they can also be browsed online (see FOC, 2004a). These same institutions (MBG and CAS) have also promoted the 'Moss Flora of China' project, aimed to provide an online version of the 8 printed volumes of the Moss Flora of China, including Hong Kong and Taiwan (MFC, 2004).

About conservation biology, some surveys and studies have been published from early 1990s, such as *Chinese Biodiversity – Status and Conservation Strategy* (Chen et al., 1993), *A Biodiversity Review of China* (McKinnon et al., 1996), *Conserving China's Biodiversity* (Schei & Wang, 1997), *China's Biodiversity: A country Study* (SEPA, 1998), and *The Plant Life of China* (Chapman & Wang, 2002). The first volume of *China Plant Red Data Book* was finally published in 1992 after ten years of work (Fu, 1992), and the second volume is currently under compilation. Furthermore, some provinces, such as Guizhou, Henan and Shaanxi, have published their own plant red books.

Other biodiversity surveys include the national survey on traditional Chinese medicinal resources conducted among 1984 and 1994, identifying 12 807 species (11 146 plants and 1 581 animals; Xu et al., 1999). SFA has performed from 1973 five-year surveys (including censuses) of forest resources, recently finishing the 6th forest survey. To study the ecosystems and species dymanics, up to 64 ecological field stations had been established by 2001, organised into the Chinese Ecosystem Research Network. On the other hand, establishment of biodiversity databases has significanty rised in the last years. Currently, China has more than 150 biodiversity databases (Xu et al., 1999; SEPA, 2004). Taiwan has also made considerable efforts to study the island's biodiversity, with the publication of *Flora of Taiwan* (6 volumes, with 2 volumes already browsable online; FOT, 2004) and the *Red Data Book of Taiwan Region: Criteria and Measure for Rare and Threatened Plant Species* (Lai, 1991). In Hong Kong SAR, the first surveys on flora were made as early as 1861, with the *Flora Hongkongensis* of G. Bentham. The most recent works on the biodiversity richness are the *Hong Kong Vascular Plants: Distribution and Status* (Corlett et al., 2000), and the *Check List of Hong Kong Plants* 2001 version (Wu, 2002).

Despite of these significant efforts performed by the administrations, universities and research institutes, there are still important gaps on the knowledge of biological diversity. It is specially significant the lack of information on Chinese threatened plant species; of the probably up to 5 000 threatened taxa, only 367 species of mainland China have been evaluated in the *2003 IUCN Red List of Threatened Species* (IUCN, 2004), although the IUCN China Plant Specialist Group is currently working in the evaluation of nearly 1 400 additional taxa (Anonymous, 2003). The survey on the Chinese threatened species should be strengthened, because of their biological sensibility; additional research therefore should be carried out immediately to cover all the presumed menaced species. It is desirable to publish early the two additional volumes of the Plant Red Book, since the first volume appeared long time ago, in 1992. Furthermore, the evaluation criteria of the threatened species in the Chinese Red Book (e.g. a plant species must have a number of populations ≤ 10 as one of the conditions to be considered threatened) and the threat cathegories (i.e. 'endangered', 'rare' and 'vulnerable'), which are strongly influenced by the academic significance of species (Xie, 2003a), should be replaced by the standard international criteria, i.e. IUCN criteria.

Economic policies, financial resources and environmental education

Government policies have promoted a rapid development growth since the end of 1970s, when the 'open-door' policy was adopted. These policies, encouraging a short-term economic benefit, have often been focused on the overexploitation of natural resources instead of pursuing a sustainable profit and long-term but continued economic benefits. These policies have also been implemented even in the protected areas, such as nature reserves and natural parks. Some reserves are currently exploitating natural resources and tourism in an unsustainable way. Natural parks, due to its dual role of preserving nature and public enjoyment, have usually policies to develop tourism and economy. Both tourism and exploitation activities in protected areas, but also in all the fields concerning biodiversity, should be planned and managed to ensure their sustainability along time.

One of the main reasons for the overexploitation of natural resources and the lack of biodiversity protection is that the importance of biodiversity is not fully understood, and its economic value underestimated, because its long-term benefits are not contempled. For example, the 1998 floodings in the Yangtze, as consequence of the decrease of natural vegetation cover, caused a total loss of 167 billion yuan (about 20 billion USD according to the exchange rates in April 2004;

Zhang et al., 2000). The annual economic loss caused by environmental pollution and damage to the biodiversity in the 1990s might be more than 600 billion yuan (about 72 billion USD; SEPA, 1998). In contrast, overall China the total value of ecosystem services is about 8 000 billion yuan per year (about 960 billion USD), according to the calculations made by Chen & Zhang (2000), a figure very close to the Chinese GDP in 1999.

Another of the root causes for the current biodiversity loss is the lack of financial resources. Current investment by Chinese government, although it has increased significantly in recent years, is not enough to assure an adequate environmental protection and biodiversity conservation. Total environmental investment for the Ninth Five-Year Plan (1996-2000) was less than 1% of GDP, (i.e. 450 billion yuan) and about 1.3% of GDP (i.e. 700 billion yuan) in the Tenth Five-Year Plan (2001-2005) (World Bank, 2001). Expenditure should increase at least up to 3.5% GDP per anuum, because this is the estimated environmental cost according to the predictions for China of the World Bank (2001). Furthermore, of the 700 billion yuan spent for environmental protection during the Tenth FYP, only about 50 billion (i.e. 7%) are destined to the ecological conservation *sensu stricto*, while the remaining 650 billion are being spent in the traditional 'brown' areas of water and air pollution, and solid waste protection (World Bank, 2001). In addition to increase the funds, the government should incentivate the participation of all the Chinese society sectors, specially the private one —such as foundations of private companies through fiscal exemptions—, and the non-governmental organizations (NGOs). The current participation of the NGOs in China is still too limited and basically performed by international entities (WWF, Nature Conservancy, Conservation International, etc). The creation of Chinese NGOs is desirable since the active participation of national NGOs has demonstrated to be essential for protecting the environment and natural resources in both developed and developing countries.

The lack of available information both on ecological and biodiversity data and environmental governmental policies, in addition to the lack of environmental education, makes civil society to be insensitive towards the current loss of biodiversity. Environmental education should be strenghtened, through both public media and education systems (including high schools and universities). Environmental education should be specially focused to the indigenous and local communities, because they have usually a direct contact with the natural resources both in the protected and non-protected areas. On the other hand, government efforts should be also conducted to offer high-level conservation education programs, probably, as suggested by Wu et al. (2004), through the establishment of a national centre for ecological and evolutionary studies but also enhancing the first-line research in the already extant institutes and universities.

Acknowledgements

The stay in the Institute of Botany (CAS) of Jordi López-Pujol has been subsidized by a grant of MECD (Spain). The authors thank Fumin Zhang, Song Ge, Jinghua Shi, Ming Lai and Zhiyun Zhang from the Institute of Botany (CAS) of Beijing. Thanks also to Ting Gu (Chengdu, Sichuan) and Zhixiong Wang (Guangzhou, Guangdong).

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