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Review

Progress of implementation on the Global Strategy for Plant Conservation in (2011–2020) China

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ABSTRACT

Plants are essential resources for the earth and human survival. Many plant species are threatened by human disturbance and are now in danger of extinction. The Global Strategy for Plant Conservation (GSPC) seeks to halt the continuing loss of plant diversity and species across the globe. China endorsed the GSPC in 2002, and launched a national plant conservation strategy related to the GSPC in 2008. This paper assesses the progress of GSPC implementation in China. The results show that Targets 1, 2, 4, 5, and 7 of the GSPC were achieved in China before 2018, and substantial progress has been made toward meeting Targets 3, 8, 9, 14, and 16 by 2020. Limited progress has been made so far in reaching Targets 6, 10, 11, 12, 13, and 15. Although GSPC implementation has promoted the conservation and restoration of plant diversity in China, China needs to scale up and accelerate its actions related to conserving and/or restoring on both ecological region and vegetation type dimensions in the long run, including integrated *in* and *ex situ* native species recovery programs.

1. Introduction

Plants play a key role in maintaining the planet and supporting human survival. There are at least 383,671 vascular plant species known in the world (Krupnick et al., 2009; Lughadha et al., 2016; Royal

Botanic Gardens Kew, 2017) and approximately 31,150 in China (Yang et al., 2005; Ma and Clemants, 2006; Wu et al., 2013; Wang et al., 2015). Many plant species are threatened with extinction because of the environmental consequences of a growing human population and urbanization, which has resulted in habitat loss and fragmentation, over-

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exploitation, alien species invasion, pollution, and climate change (Miller et al., 2012; Ren et al., 2014). Some plants are also threatened by reproductive obstacles of their own nature (e.g., low pollination success, embryo defects, low germination rates). A total of 94,000–194,000 species are threatened with extinction in the wild (Miller et al., 2012) and 3879 species in China (Qin and Zhao, 2017, some Chinese plant species are not evaluated due to insufficient data). One of the greatest challenges for the world community is to conserve, restore and sustainably use plant diversity. To meet this challenge, the international community has launched various activities and programs to prevent further losses of plant diversity (GSPC, 2002; IUCN, 2008, 2011; Williams et al., 2012; CBD, 2010; Sharrock et al., 2014; Royal Botanic Gardens Kew, 2017; Sharrock and Wyse Jackson, 2017).

The Global Strategy for Plant Conservation (GSPC) is a cross-cutting strategy, developed and adopted by the United Nations' Convention on Biological Diversity (CBD) in 2002. The GSPC has acted as a catalyst for working together at local, national, regional and global levels to understand, conserve and use sustainably the world's immense wealth of plant diversity while promoting awareness and building the necessary capacities for its implementation (Wyse Jackson and Kennedy, 2009; Clubbe et al., 2010). Within the framework of the CBD, the GSPC represented a remarkable new approach to biodiversity conservation, with the incorporation of measurable outcome targets for the first time. The Convention Secretariat had already discussed the need for such targets (Wyse Jackson, 2001), and these subsequently became the norm with the development and adoption of the Aichi Targets in 2010. The GSPC had five broad objectives and 16 outcome-orientated targets designed to halt the current and continuing loss of plant diversity by 2010, and it was adopted by the sixth conference of the Parties to the CBD in April 2002 at The Hague in the Netherlands (GSPC, 2002). An updated strategy with revised targets for 2020 was adopted by the Parties to the CBD in October 2010 (CBD, 2012). The GSPC has been the subject of a formal review of progress by the CBD in 2008 (Secretariat of CBD, 2008) and a mid-term review in 2014 (Sharrock et al., 2014).

China's Strategy for Plant Conservation (CSPC, *The editorial committee of "China's strategy for plant conservation", 2008*) was adopted in 2008 as a joint initiative of the Chinese Academy of Sciences, the State Forestry Administration (now, National Forestry and Grassland Administration) and the State Environmental Protection Agency (now, Ministry of Ecology and Environment). The CSPC targets were established following the updated GSPC at the global level. In late 2011, a review of progress in implementing the CSPC was carried out by Botanic Gardens Conservation International (BGCI, Ma, 2011; Sharrock et al., 2014; Gratzfeld and Wen, 2012). China's fifth national report on the implementation of the CBD also included progress in implementing the GSPC (Ministry of Environmental Protection, 2014).

China is a developing country with about a tenth of the world's known plant species, of which approximately 15–20% of them are threatened with extinction. China is one of the world's mega-diverse countries (Mittermeier et al., 1997; Ren and Duan, 2017); of the 34 listed world hotspots, three are entirely in China and one is partially in China (Mittermeier et al., 2005). For this reason, the progress in the implementation on GSPC in China is of global importance. This paper provides an overall image on the progress of GSPC implementation in China, and it assesses whether or not China is on track to achieve its targets by 2020, and makes recommendations on the further implementation of the GSPC in China.

2. Methods

To assess how existing plant conservation projects are addressing GSPC targets in China, we conducted a desk review of all publically available documents on plant conservation projects both at the national and provincial scales in China during the period 2002–2017. For each project, we reviewed basic information (e.g., project title, goals, size, location, stated threats to biodiversity, planned conservation/

restoration/utilization activities, and monitoring results).

We used key words to collect records of plant conservation initiatives in China after 2002, and searched English databases (Thomson's online Web of Science database and Google Scholar: plant diversity* OR online flora* OR conservation status* OR conservation action* OR assessment* OR ecological region* OR genetic diversity* OR *in situ* conservation* OR *ex situ* conservation* OR reintroduction* OR threatened plant species* OR rare and endangered plants* OR indigenous and local knowledge* OR biological invasions* OR international trade* OR sustainable use/utilization* OR public education* OR public awareness* OR partnerships* OR international cooperation* OR global strategy for plant conservation* OR China's strategy for plant conservation* AND plant AND China). In addition, we carried out similar searches in the Weipu Chinese journals database (in Chinese) and in Baidu (a Chinese general search engine) using the above query. We also verified the gray literature (newspaper articles, government reports, etc.) by calling or emailing people or organizations identified in the reports.

We reviewed these documents, papers, and articles, and extracted statistical data that we classified according to the different targets. We also designed Table 1 and contacted 18 Chinese experts and practitioners (among them, 6 from botanical gardens, 6 from natural reserves, 6 from institutes or universities) working on threatened plant conservation, restoration or utilization and three government officials to assess the progress towards the GSPC targets (including current status, confidence about implementation by 2020, and comments). Finally, all authors reviewed the collected data as part of the effort to write this review paper.

We organized the main assessment results into the GSPC's five main objectives and 16 targets to be achieved by 2020 (CBD, 2012), i.e. 1) plant diversity is well understood, documented and recognized; 2) plant diversity is urgently and effectively conserved; 3) plant diversity is used in a sustainable and equitable manner; education and awareness about plant diversity, 4) its role in sustainable livelihoods and importance to all life on Earth is promoted; and, 5) the capacities and public engagement necessary to implement the strategy have been developed.

3. Results

3.1. Understanding and documenting plant diversity (GSPC targets 1–3)

Target 1 - An online flora of all known plants. China has been progressing very well and is close to achieving this target (Table 1). The Flora of China (FOC, Chinese version, <http://frps.eflora.cn>) was completed in 2004 and the English version (<http://foc.eflora.cn>) was completed in 2013. Both versions (<http://www.onlineflora.cn/>) are online and openly accessible (Ma, 2017a). The Flora of China (English version) has also been included in the World Flora Online (www.worldfloraonline.org), the global project that has been developed in response to Target 1. There are 31,150 vascular plant species in FOC (Yang et al., 2005; Wang et al., 2015). The Catalogue of Chinese Plant Species (CPS) was an updated checklist applied to both versions, and had been compiled and published in twelve volumes by 2018, covering all wild higher plants in China, as well as important and common cultivated plants and naturalized plants. The CPS is also online (<http://www.chinaplantspecies.org>). There are 33,259 vascular plant species in CPS (Qin et al., 2017). Both FOC and CPS were submitted to World Flora Online. The Chinese Virtual Herbarium (CVH, <http://www.cvh.ac.cn/>) has about 7,000,000 digitized plant specimens from about 100 herbaria and can be accessed online too. There are 30,705 vascular plant species in CVH. CVH provides sufficient additional information to support the on-line flora, e.g. specimens, literature, and *in-situ* plant images, etc. Numerous other initiatives to survey and catalogue the Chinese flora or herbal medicine plants have been published or are underway at sub-national, provincial and local scales. All document the tremendous efforts undertaken related to GSPC Target 1. Lu and He

Table 1
Progress towards the GSPC targets.

GSPC targets	Target implementation status ^a	Confidence in implementation by 2020 ^b
Objective I: plant diversity is well understood, documented and recognized		
Target 1: An online flora of all known plants	+++	High
Target 2: An assessment of the conservation status of all known plants as far as possible, to guide conservation action	+++	High
Target 3: Information, research and associated outputs and methods necessary to implement the strategy developed and shared	++	High
Objective II: plant diversity is urgently and effectively conserved		
Target 4: At least 15% of each ecological region or vegetation type secured through effective management and/or restoration	+++	High
Target 5: At least 75% of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity	+++	High
Target 6: At least 75% of production lands in each sector managed sustainably, consistent with the conservation of plant diversity	++	Medium
Target 7: At least 75% of known threatened plant species conserved <i>in situ</i>	+++	High
Target 8: At least 75% of threatened plant species in <i>ex situ</i> collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs	+++	Medium
Target 9: 70% of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge	+++	Medium
Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded	++	Medium
Objective III: plant diversity is used in a sustainable and equitable manner		
Target 11: No species of wild flora endangered by international trade	++	Low
Target 12: All wild harvested plant-based products sourced sustainably	++	Low
Target 13: Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care	++	Medium
Objective IV: education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted		
Target 14: The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programs	+++	High
Objective V: the capacities and public engagement necessary to implement the Strategy have been developed		
Target 15: The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy	++	Medium
Target 16: Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this strategy	+++	Medium

Note:
^a Indicates target implementation status. “+” means “not implemented or < 25%”, “++” means “partially (25–50%) implemented or”, “+++” means “mostly (50–75%) implemented or”, and “++++” means “75–100% implemented”.

^b Indicates confidence in implementation by 2020, divided into three grades: low, medium, and high.

(2017) reported that the number of vascular plant species discovered in China per year fluctuates considerably but, on average, 110 species per year were discovered in China in the first decade of the 21st century. It is essential to complete inventory of Chinese plants, since it is difficult to conserve unknown species. We recommend that more funds to support plant taxonomy research and improve institutional capacity in the foreseeable future.

Target 2 - An assessment of the conservation status of all known plants as far as possible, to guide conservation action. This target aims to assess the conservation status of all known plants, which includes a working list of conservation assessments, and an interim list of threatened species (Bachman et al., 2018). China has established scientific criteria to evaluate plant survival and conservation status according to the International Union for Conservation of Nature and Natural Resources (IUCN) Red List Categories and Criteria (IUCN, 2008) and recently finished the second investigation of national key protected wild plant resources, which was carried out during 2011–2017. The associated report will be issued in early 2019. The first edition of Red List assessment was completed in 1991, and is available online. The Ministry of Ecology and Environment, in co-operation with the Chinese Academy of Sciences, initiated the program “China Biodiversity Red List- Higher Plants” in a comprehensive new edition of the Red List of the Chinese flora during 2008–2013. This project invited > 300 experts to contribute species survival data in the previous 5 years and to review

the assessment results. The working group assessed the threat status of all known higher plant species at the national scale to produce the Red List of China Higher Plants (RLCHP, vascular plant species and bryophytes). The RLCHP was officially released in September 2013 (http://www.mee.gov.cn/gkml/hbb/bgg/201309/t20130912_260061.htm).

The RLCHP covered 35,784 species, including 30,068 species of angiosperms, 251 species of gymnosperms, 2244 species of lycophytes and ferns, and 3221 species of bryophytes (Table 2). In total, 3879 taxa were listed as threatened, including 614 Critically Endangered species (CR), 1313 Endangered species (EN), 1952 Vulnerable species (VU) and 40 extinct species (including 21 extinct species (EX), 9 extinct in the wild species (EW), and 10 regionally extinct species (RE)). The group also revised the 2013 Red List using new literature and data (Qin et al., 2017). However, the above numbers are conservative because of unknown species and species with insufficient data to be assessed. Lu and He (2017) reported that the number of vascular plant species discovered in China per year underwent large fluctuations over time; but on average, 110 species per year were discovered in China in the first decade of the 21st century. They also estimated that there were still > 5000 unknown species in China, while Raven and Qin estimated this number to be fewer than 2000 (private communication). According to CPS, from 1999 to 2015, a total of 2923 new species (including new combinations and new names, belonging to 686 genera and 188 families) were reported, with an average of 172 new species per year.

Table 2

Number and percentage of Chinese higher plants in each of the Chinese red list categories (Qin and Zhao, 2017). Note that the Chinese red list adopts the IUCN red list criteria.

Categories	Bryophytes	Pteridophytes	Gymnosperms	Angiosperms	Total	Percentage (%)
EX	0	0	0	21	21	0.06
EW	0	0	0	9	9	0.03
RE	0	0	0	10	10	0.03
CR	16	43	37	518	614	1.72
EN	58	68	35	1152	1313	3.67
VU	112	71	76	1693	1952	5.45
NT	214	66	0	2538	2818	7.88
LC	1900	1124	87	21,132	24,243	67.75
DD	921	872	16	2995	4804	13.42
Total	3221	2244	251	30,068	35,784	100

Among them, 313 species were moss, 22 species were gymnosperms, and 2512 species were angiosperms (Gao et al., 2018). Taxonomic uncertainty hinders conservation status assessments. Considering the 11% of total known species with Data Deficient status, we estimate that 15–20% of the plant species in China are threatened (Ren and Duan, 2017).

The Ministry of Ecology and Environment and the Chinese Academy of Sciences released the “China Biodiversity Red List- Large Fungi” in May 2018 (http://www.mee.gov.cn/gkml/sthjbgw/sthjbgg/201805/t20180524_441393.htm). Both the plant and fungi red lists provide an important basic reference for plant protection action, for example, the conservation action program for 120 wild plant species with extremely small populations. In addition, the IUCN China Plant Specialist Group (CPSG, <http://www.chinaplantredlist.org/>) has started to re-assess 2000 Chinese endemic species, which will be added to the IUCN global red list by 2020. The assessment results have been broadly applied to protection policies and management programs on rare and endangered plants implemented by the National Forestry and Grassland Administration, Ministry of Ecology and Environment and provincial, municipal, county governments. The next step is to build on this progress and double the efforts to document the conservation status of unassessed plants to better inform conservation decisions and conserve the most threatened species. More funding for field work and assessment activities are needed.

Target 3 - Information, research and associated outputs and methods necessary to implement the strategy are developed and shared: China promotes this target through the compilation and research of its flora, the construction of a nature reserve network, the national specimen resource sharing platform and public education on biodiversity. Since the launch of the Biodiversity Conservation Plan in China in 1994, researchers in China have published a large number of research papers and documents on biodiversity (Liu et al., 2012; Ma, 2016; Wang et al., 2017). China has shown faster growth rate, compared with other countries, in terms of the quantity of biodiversity publications produced, with the annual number of published peer-reviewed papers increasing over 60 times, from 110 in 1997 to 6700 in 2017. Those papers focused on the loss and protection of biodiversity, the assessment of threats and the Red List of species and ecosystems, rate of extinction, analysis of conservation gaps, and progress on assessment of status and protection (Ma, 2016). Plant diversity has become a well-known term with the public in China (Ma and Zhou, 2012). Universities, research institutes, botanical gardens, herbaria, nature reserves and other institutions have also strengthened sharing of information on plant resource protection and utilization, which resulted in the construction of digital network platforms, from which the public can more easily acquire relevant knowledge (Ren and Duan, 2017). There were 10,200,000 items on plant diversity in the Baidu search engine in March 2018. In 2017, the Chinese Academy of Sciences launched its Biological Resources Service Network Initiative to enhance the information and technology sharing. In addition, the CAS-EARTH project, launched by the Chinese Academy of Sciences in 2018, aims to combine

all available data on plant diversity research and management practices in China into a comprehensive database, and this will be completed in 2020. Activities relevant to implementing Target 3 where future effort is required, include developing conservation and horticulture protocols for threatened species, dissemination of information on the existing tools and protocols in appropriate formats, and training local counterparts in conservation and horticulture techniques for managing these species (Xu et al., 2016).

3.2. Conserving plant diversity (targets 4–10)

Target 4 - At least 15% of each ecological region or vegetation type secured through effective management and/or restoration. According to the book “Vegetation of China in 1980”, China has six major types of forest, *i.e.* cold temperate coniferous forest, temperate coniferous and broad-leaved mixed forest, warm temperate deciduous broad-leaved forest, subtropical evergreen broad-leaved forest, tropical rainforest and monsoon forest, and Qinghai-Tibet Plateau alpine forest (Hou, 2001; Ren et al., 2012a). According to eight national forest surveys (1950–2014), the coverage of China's forests (including plantations, secondary forests and natural forests) increased from 8.6% in the early 1950s to 21.6% in 2014. The total area of forest in China extended to about 2,080,000 km² in 2014 (Xu, 2014). By the end of 2016, 2740 national, provincial and county nature reserves were established, with a total area of about 1,470,000 km², equivalent to 14.8% of the national land area. Of these, 446 were national nature reserves, accounting for 970,000 km². This nature reserve network has more complete vegetation types, more rational spatial patterns and more functionalities (Xu et al., 2017). Additionally, 225 renowned scenic spots with a total area of roughly 109,000 km², 1486 wetland parks with a total area of 39,720 km² and 3392 forest parks with a total area of 1,188,668 km² have been established. Together these nature reserves, national scenic spots and forest parks have effectively protected 90% of China's vegetation types and terrestrial ecosystems, covering 25% of the original natural forests, 50.3% of natural wetlands and 30% typical desert areas. These areas provide protection for 85% of wild plants *in situ*, and include 65% of the higher plant communities in China. (Xu et al., 2016). In addition, through the implementation of key ecological projects such as the natural forest resources protection project, conversion of farmland to forestry project, wetland protection project, desertification control and so on, some ecosystems have been restored. However, some association level-vegetation types are not protected in the natural reserve network, and the protected areas of some ecological areas or vegetation types are < 15% of their total area. In the future, China needs to strengthen the management of protected areas, and to establish new reserves to cover all ecological areas and vegetation types. China also needs to propose mitigating the impact of climate change on these protected areas (*e.g.* the establishment of wildlife corridors).

Target 5 - At least 75% of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity. According to

international standards and long-term research results, China has identified 34 key areas of biodiversity with global significance and 21 key areas of biodiversity with national significance. These areas add up to a total size of 2,010,500 km², accounting for 20.94% of the country's land area (Liu et al., 2003; Zheng et al., 2013; Ministry of Environmental Protection, 2014). China has established nature reserves in these key areas to conserve plants and their genetic diversity. Collection, growing, and/or grazing in natural reserves is illegal, but in reality, these actions exist to a various degree. At present, China is improving the strategic distribution of nature reserves, strengthening their function, avoiding the destruction of key areas of biodiversity, as well as strengthening the capacity of nature reserves and improving their management. In addition, the “Chinese ecosystem Red List catalogue” project was officially launched by the Ministry of Ecology and Environment in May 2016 and will be completed in 2018 (Ma, 2017b). The next priority is to integrate the conservation of plants into policy, legislative and institutional frameworks in a 10–20-year timeframe to ensure sustained results for this target.

Target 6 - At least 75% of production lands in each sector managed sustainably, consistent with the conservation of plant diversity. There were 134,956,600 ha of arable land in China (including irrigated paddy fields, irrigated land and non-irrigated land) in 2016. China has the largest population of any country in the world, but the arable land *per capita* is lower than the global average, and two thirds of the arable land supports low or medium yield agriculture. China has a tradition of intensive farming, rotation, intercropping and other traditional farming methods, which have benefited biodiversity protection. China started the construction of ecological demonstration areas in 1996. More than 2,000 national-level ecological demonstration areas were established by 2017, while 50% of the country's land area is planned to be covered by ecological demonstration areas by 2050. In addition, China launched the “beautiful village” construction program in 2013. This initiative is expected to greatly improve the environment of rural villages, wildlife habitats and land productivity. China has undertaken some of the largest sustainability programs in human history, implementing 17 major initiatives, including the “Shelterbelt Development Program – Three North (1978–2050); the Soil and Water Conservation Program – National (1983–2017); the Shelterbelt Development Program – Five Regions (1987–2020); the Comprehensive Agricultural Development Program (1988–2020); the Soil and Water Conservation Program – Yangtze (1989–2015); the National Land Consolidation Program (1997–2020); the Natural Forest Conservation Program (1998–2020); the Grain for Green Program (1999–2020); the Fast-growing and High-yielding Timber Program (2001–2015); the Forest Ecosystem Compensation Fund (2001–2016); the Desertification Control Program – Beijing/Tianjin (2001–2022); the Wildlife Conservation and Nature Protection Program (2001–2050); the Partnership to Combat Land Degradation (2003–2023); the Rocky Desertification Treatment Program (2008–2020); the Grassland Ecological Protection Program (2011–2020); the Cultivated Land Quality Program (2015–2030); and the Conservation Program for Wild Plants with Extremely Small Populations in China (2012–2020)”. These sustainability programs invested about \$400 billion, covered 6,240,000 ha of land, and engaged over 500 million people. Current evidence shows that the sustainability of China's rural land systems and biodiversity conservation has been improved substantially by these programs (Ren et al., 2012b; Bryan et al., 2018). However, at some area these large programs (e.g. agri-environment and forestry programs) promoted monoculture plantations which, in many cases, reduced local plant diversity. A better understanding of plant conservation needs by the agriculture and forestry sectors would help achieve this target.

Target 7 - At least 75% of known threatened plant species conserved *in situ*. Based on the China Biodiversity Red List - Higher Plants, Zhang et al. (2015) developed a fine resolution distribution database for 3244 threatened plants, explored richness patterns and evaluated the *in situ* conservation status of the threatened plants by overlapping the species

distribution with terrestrial national and provincial nature reserves in China. Both categories of nature reserve cover 88% of the threatened plants, while around 12% of threatened species (397 species) are still outside nature reserves. Only some of those 3244 threatened species are being monitored or managed in their remaining natural populations. We analyzed the latest data on known threatened species and protected areas (including nature reserves, national scenic spots and forest parks) in China by the same method and found that these protected areas had effectively protected 90% of threatened plants *in situ*. The unprotected species are distributed mostly in South China and Northwest China. Considering the current rates of human encroachment and the possibility of future land use changes, the existing nature reserves in China are not adequate to represent all threatened plant diversity (Nori et al., 2015). Plant protection planning and assessment in China has used county-level presence/absence records and assumed that a species is protected if there is a historical record of at least one plant in a county which contains a protected area. In some cases, this does not mean the species is adequately conserved. We therefore propose prioritizing designated provincial reserves at the national level in these areas specifically designed for threatened plant species, and setting up natural reserves especially in Yunnan, Hainan, Guangdong, Fujian, Guangxi, and Xinjiang provinces.

Target 8 - At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs. As a complementary approach to nature reserves, botanical gardens play a key role in *ex-situ* conservation, and plant resources collection and storage. In 2016, there were 1285 living collection sections in the 195 botanical gardens in China (Fig. 1). In these, roughly 288 families, 2911 genera and 22,104 species of native Chinese plants are cultivated *ex situ*. This is equivalent to 91%, 86%, and 60% of all Chinese native plant families, genera, and species respectively (Huang, 2018). In addition, the Chinese Germplasm Bank of Wild Species had preserved about 10,000 wild plant species as seed collections by the end of 2017. By 2015, the botanical gardens and arboreta in China had successfully cultivated around 270 species from the China National Key Protected Wild Plants List (about 85% of the species on the list) and about 40% of the species on the China plant Red List. The problem of *ex-situ* conservation in botanical gardens is that the number of plants planted is small and many, if not most, collections lack sufficient genetic diversity. Besides, 37% of plants are cultivated only in one botanical garden, 40% in two botanical gardens, and 23% in three or more botanical gardens (Ren and Duan, 2017; Huang, 2018). A total of 180 plant species had been successfully reintroduced to the wild by 2017, accounting for about 5% of all threatened plant species in China (Liu et al., 2015; Ren and Duan, 2017). The Chinese Union of Botanical Gardens initiated the program “Full coverage conservation plans for native plants in China” in 2013, which also aims to safeguard national plant diversity. Ensuring the adequate genetic representation of *ex situ* collections will be dependent on better characterization of existing collections and long-term monitoring. Building and managing appropriate genetic diversity should be a top priority for *ex situ* collections and reintroduction programs in future.

Target 9–70% of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge. There are 9631 species or varieties of grain and agricultural plants in China, among which 3269 species and their wild relatives are cultivated. The main crop varieties in China have been renewed 4 to 6 times, and the coverage rate of improved varieties has increased by > 85% since 1949 (Zhang et al., 2011). Simultaneously, China is also increasingly paying attention to conserving the genetic diversity of crops. After 50 years of effort, China has identified the characteristics and the geographical distribution of the germplasm resources of the main crops (Duan et al., 2007; Zhang et al., 2011). By the end of 2016, China had safely preserved > 340 crop germplasm resources, such as grain, fiber, oil, vegetables, fruit trees,

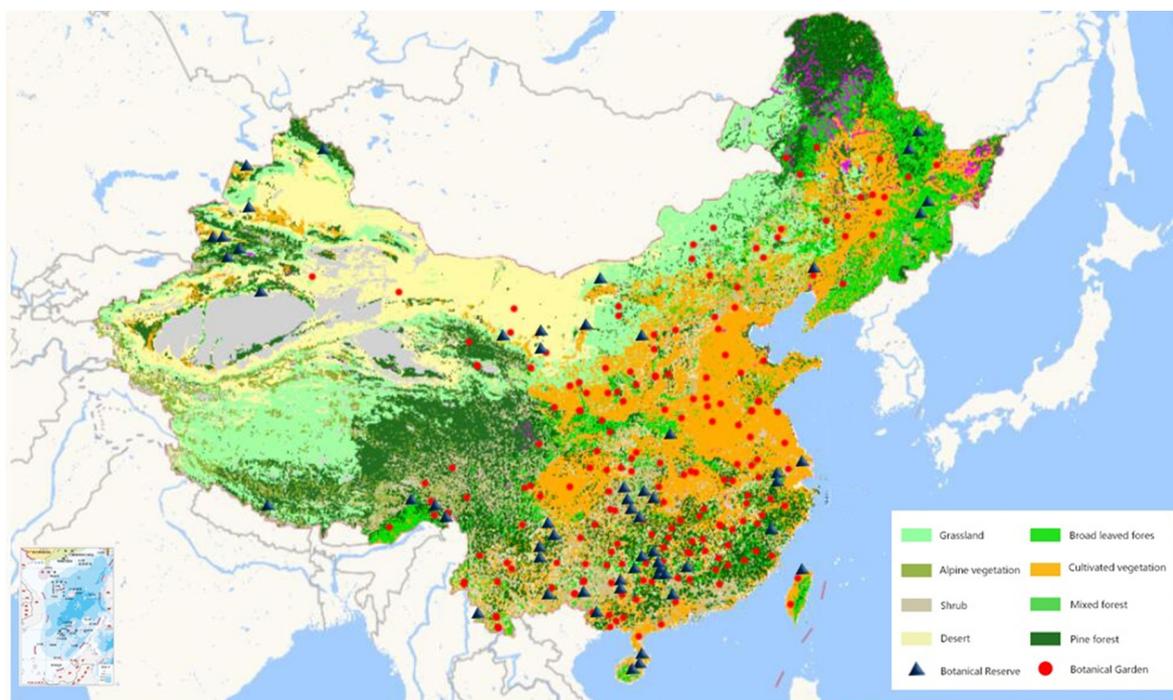


Fig. 1. Botanical reserves, botanical gardens and vegetation distribution in China.

sugar, tobacco, tea, mulberry, grass, green manure, tropical crops and so on, totaling 481,617 collections. Among them, the National Germplasm Bank stored 415,232 collections, and the other 43 germplasm nurseries stored 66,385 collections, including 9631 species or varieties of grain and agricultural plant genetic resources currently used in China. The total amount of germplasm preserved was the second highest in the world. In the germplasm bank, > 50,000 wild plant germplasm collections, > 50,000 tree germplasm collections, and over 6000 wild soybean collections (accounting for > 90% of wild soybean diversity in the world) have been preserved (Ren and Duan, 2017). In 2015, China issued the “National long-term development plan for the protection and utilization of crop genetic resources (2015–2030)”. The Ministry of Agriculture and Rural Affairs organized the third national survey and collection of crop genetic resources in 2015. China completed a resources investigation and *ex situ* conservation of medicinal plants in 2011 (Huang et al., 2011). China also launched the “National forest genetic resources investigation, collection and conservation plan (2014–2025)” in 2014. All these plans promote the conservation of genetic diversity of crops and help with implementing Target 9. China is also carrying out a farm program on genetic diversity protection and related native knowledge. However, preservation of indigenous and local knowledge is not well addressed and should be a future priority.

Target 10 - Effective management plans in place to prevent new biological invasions and to manage important areas that have been invaded for plant diversity. Most invasive plants invaded China before the 1990s, but systematic data analysis started only in the past twenty years (Liu et al., 2006). According to “the Research Report on Invasive Plants in China”, there were 72 families, 285 genera and 515 species of invasive plants in China by the end of 2014 (Wang et al., 2016). Of the 100 most invasive alien species assessed by IUCN, 50 species were found in China. Wang et al. (2016) revealed that all provinces, including municipalities with provincial status and autonomous regions, from cities to countryside, from the coastal areas to the mainland, recorded alien invasive plants, including many national nature reserves. Southwest and southeast coastal areas were the “worst hit areas” by alien plant invasions; 108 species were found in the southeast coastal area. According to field investigations, there are 334 species of invasive plants in Yunnan province and 43 species of invasive plants in the

Ningxia Hui Autonomous Region. The largest proportion of invasive plants in China are exotic taxa native to South America, followed by North America, accounting for more than half of all invasive plants. The plant families Compositae, Leguminosae and Gramineae, totaling 222 species, constitute the majority of alien invasive plants in China (Ma, 2013; Wang et al., 2016). China has established a sound inspection and quarantine management mechanism to prevent new biological invasions from international trade since 2010. However, more than half the experts and officials believe that, because laws and regulations are not strictly enforced, this mechanism does not effectively prevent new invasive species entering through international trade. The direct economic losses caused by invasive alien species to China amounts to 18 billion US\$ per year, and it is difficult to estimate the investment needed for effective control. Although China has invested a great deal of labor, material and financial resources (about 1.1 billion US\$/yr) in eliminating invasive alien species, the areas with invasive species are still expanding. To limit new plant invasions, in 2011 China established a licensing system to control the introduction of exotic plants. Furthermore, the Ministry of Science and Technology has started to compile “Alien invasive plant chronicles in China” for controlling alien invasive plants. Finally, a DNA barcoding data set of invasive plants in China has been established for identification of invasive plants already in China and those that may be introduced in the future (Xu et al., 2018).

Despite the substantial advances and achievements made in all the targets related to conserving plant diversity, further and more ambitious measures should be considered to enhance the management and ensure the sustainability of objectives related to conserving and/or restoring ecological regions and vegetation types in the long run, including integrated *in* and *ex situ* native species recovery initiatives (Targets 4, 5, 7 and 8).

3.3. Sustainable use of plant diversity (targets 11–13)

Target 11 - No species of wild flora endangered by international trade. This target is linked to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and it is consistent with the recently adopted CITES Strategic Vision 2008–2020. China

joined CITES in 1981 and has implemented the Convention in earnest since then. Among the 28,421 globally endangered species recorded in the appendices of CITES, 1316 of these are Chinese species. A total of 1516 species of wild plants are traded in China, representing 26 families and 256 genera. Among these, a total of 1374 species are listed in the CITES appendices (Zhou and Jiang, 2004; Ren and Duan, 2017). Among exported living plants, wild orchids are the largest in number, followed by cacti. As regards imported wild plants, orchids, cacti and CITES-listed timber species account for the largest proportion (Wang et al., 2012; Qin et al., 2017). Among exported plant species, 11 are subject to national key protection status, 47 are subject to national second-class protection status and 67 species are considered to be of important value. Wild plant management in China has benefited from the launch of Wild Plant Protection Regulations in 1996, and the new “Custom Harmonized System Code (HS code)”, which was adopted in 1998. The Wild Plant Protection Regulations and HS code benefited wild plant management in China, especially by improving the control of the wild plant trade. However, it is important to recognize the limitations of the national regulations and the HS code (Chan et al., 2015) and both need updates to cater to the current plant use and trade situations. Countries trading with China have increased from about 10 to > 50 since the regulations were implemented, and a significant number of permits have been issued for commercial purposes, indicating that international trade in wild fauna and flora is very active. Many specimens in illegal international trade are harvested from the wild, which poses threats to the wild populations of the species concerned. China has shifted from an exporting country to an importing country of wild fauna and flora (Wang, 2004). The quantity of species under legislative control in international trade has increased from fewer than 100 to > 500 (Meng et al., 2017). In addition, the illegal trading of wild plants in physical markets persists (Williams et al., 2018) and is increasing in online markets (Chan et al., 2015; Hinsley et al., 2016a, b). All these point to the need to strengthen measures to ensure sustainable use of wild plant resources within China as well as in countries that trade with China. One of these measures is to update the 1996 Wild Plant Protection Regulations and strengthen their enforcement. More than 300 valuable medicinal plants have been planted in accordance with “Good Agricultural Practice in China”, which has reduced the dependence of international trade on wild plant resources and effectively promoted the habitat protection and restoration of rare and endangered plants. However, not all commercial cultivations has been good for conservation of wild populations (Liu et al., 2018). More research is needed into the impact of international trade on local wild plant species, as well as on tropical hardwood timber species imported from various parts of the world, and a broader range of strict management responses needs to be developed in the future.

Target 12 - All wild harvested plant-based products sourced sustainably. At present, the proportion of products from solely wild-sourced plant materials in China is about 40%. In this study we found 188,000 news items or articles on wild plant products and sales information, about 5% of them involving rare and endangered plants. Some of these cases were related to the unsustainable use of medicinal plants, aromatic plants and precious timber. China has popularized non-destructive collection methods for > 90% of its national key protected plants, and strictly implemented the administrative licensing system for collection and trade. Due to the discrepancy between existing regulations and implementation, the effect of these measures is limited. While partially controlling the harvesting intensity of wild plant resources, China has also vigorously developed artificial cultivation of wild plants such as ginseng, the orchid *Gastrodia elata* and honeysuckle. However, Liu et al. (2018) reported that there is no evidence to support the contention that cultivation of over-harvested plants would necessarily generate conservation benefits. They also revealed that the majority of endangered species that had undergone cultivation did not experience any such benefit, only a minority did. Farming of non-medicinal plants was most problematic for species

conservation because of laundering of wild plants. The input of multiple stakeholders with different expertise and tools is needed to ensure cultivation operations benefit conservation. As for development of new plant resources, Chinese botanical gardens have developed a total of 1514 new varieties. Also, the gardens have developed 751 economic plants and varieties and 284 functional plants since the 1980s. Chinese botanical gardens also created a model known as the 3R model (Resource, Research, Resolution) for the use of economic plants (Huang, 2011, 2018). For example, South China Botanical Garden systematically collected, protected and utilized Chinese *Cymbidium* and *Cypripedium* using this model. Nuanced policy to guide cultivation operations based on the target species' biological characteristics, cultural significance, market demand and conservation status is urgently needed. The exchange of experiences and identification of lessons learnt to provide a framework for development of good practices, tools and evaluation procedures would be extremely beneficial. Further efforts should also be made to ensure that plant material imported from other parts of the world are also sustainably sourced from the countries of origin.

Target 13 - Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care. Questionnaire results showed that traditional knowledge of plants continues to decline in China posing a major problem for plant conservation. China is a multi-ethnic country. Many minorities have traditional methods for the sustainable use of native plants (Pei, 2008; Xue, 2014). Those methods are less destructive to the environment, and play an active role in the conservation of biodiversity in the region. Traditional usage of endemic plants, native plants, medicinal plants, and knowledge on plant conservation are being systematically investigated and recorded. Local well known plant products are being developed rapidly. Benefit-sharing mechanisms for traditional knowledge have been established by national programs targeting intangible cultural heritage since 2006. In addition to documenting traditional knowledge, further efforts need to be made to ensure that traditional knowledge being maintained and shared within local communities and minorities, and being successfully passed down between generations. Inspired by Dunn (2017)'s study, Chinese botanical gardens are planning to incorporate cultural diversity into their plant conservation programs and strategies.

3.4. Promoting education and awareness about plant diversity (target 14)

Target 14 - The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programs. In China, both government agencies and scientific research units have put increasing emphases on training and education about the importance of plant diversity (Ren and Duan, 2017). More and more people understand the value of plant diversity (Ma and Zhou, 2012). The Chinese media reported on > 9,700,000 news items on plant diversity conservation from 1994 to 2017 according to incomplete statistics.

Biodiversity Day has been held by the Ministry of Ecology and Environment every year since 2000 and a National Symposium on Biodiversity Science and Conservation has been organized by the Chinese Academy of Sciences every two years since 1994 (Gratzfeld and Wen, 2012). More than 1,000,000 participants had taken part in the above two activities. The Chinese government had also carried out 200,000 plant conservation activities with 180,000,000 participants during 2010–2017. Compared with natural reserves which are mostly located in rural areas, the location of botanical gardens are much better correlated with population centers. Consequently, besides their *ex-situ* conservation and plant resource collection and storage functions, botanical gardens also play an essential role in public education (Fig. 1). Chinese botanical gardens have held about 1000 public education activities and the number of visitors reached 150,000,000 during

2015–2017. Since 2014, the World Wildlife Day (March 3) had been celebrated nationally each year by the National Forestry and Grassland Administration and provincial forestry bureaus, to convey knowledge and importance on wildlife conservation and CITES implementation to the public. Leaflets, posters, pictures and videos are widely disseminated through all kinds of media. Plant conservation is an important component of these activities.

There are > 1000,000 users of the flower partner app in China (<http://www.aiplants.net/>). The app is based on the thorough learning technology of artificial intelligence, and the mega taxonomy image library of the Institute of Botany, together with a co-built user image library. Users only need to take photos of flowers, fruits, leaves and other characteristic parts of plants by mobile phone, so that plants can be identified quickly and accurately. The app can identify most wild and cultivated plants in China, and effectively promotes the public's understanding of plants. Strengthening public outreach and environmental education will remain of major significance in China to develop a new generation of nature-lovers and amateur naturalists and botanists.

3.5. Building capacity for the conservation of plant diversity (targets 15, 16)

Target 15 - The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy. China is further improving relevant laws and regulations on plant protection, and increasing the investment to strengthen personnel training (Xu et al., 2016). The National Forestry and Grassland Administration has organized training courses on wild plant monitoring, conservation and management techniques for the forest sector and botanical garden community each year since 2012. To date, about 1600 conservation practitioners have been trained. Another example of an institution promoting capacity building in plant conservation in China is BGCI, which has funded an average of 10 practical conservation projects in China each year since 2010 (Gratzfeld and Wen, 2012). Stakeholder workshop and plant conservation techniques training for local villagers and practitioners have been provided for each project every year. This has resulted in some 400 people trained each year and about 3200 people trained overall during 2010–2018. Each year since 2013, the Chinese Union of Botanical Gardens (CUBG) has organized three important training courses in the areas of plant taxonomy, environmental education, and horticulture. However, poor linkages between plant conservation practitioners and policy makers still exist in China. In the future, China needs to train more people with expertise in plant conservation and sustainable utilization, through universities and botanic gardens.

Target 16 - Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this strategy. After years of efforts, China has established relatively comprehensive plant protection agencies at the national, provincial, county levels and a wide range of international cooperation programs (Xu et al., 2016). China has also set up multiple coordination groups and mechanisms on the implementation of the Convention on Biological Diversity, which include the Inter-Ministerial Meeting system for the conservation of biological species resources and The National Committee for Biodiversity Conservation in China. National Inter-agency CITES Enforcement Coordination Group (NICECG). Similar co-ordination mechanisms at province level had also been established since 2012. The Inter-Ministry Joint Meeting for Combating Illegal Wildlife Trade was initiated in 2017. The Ministry of Agriculture and Rural Affairs and the National Forestry and Grassland Administration oversee the protection of wild plants in agricultural area and natural ecosystems, e.g. forest, wetland and desert. Most provinces (autonomous regions and municipalities) have also set up inter-departmental mechanisms to coordinate regional biodiversity conservation and management. China has established cooperation with > 50

international and regional organizations involved in the protection of plant diversity with the participation of international multilateral agencies, bilateral agencies, and international non-governmental organizations. For example, the CUBG was established and sponsored by the Chinese Academy of Sciences, National Forestry and Grassland Administration, and Ministry of Housing and Urban-Rural Development in 2013. CUBG's tasks include preventing the loss of threatened Chinese plants, construction of a national system of botanical garden standards, and capacity building for plant conservation, taxonomy, and public education in botanical gardens. The *Ex-situ* Conservation Committee of Chinese Wild Plant Conservation Association was established in 2015 and has carried out a large number of activities. At the international level, China had been part of important plant conservation networks including BGCI-China, with an office located in the South China Botanical Garden. Moving forward, there is a need for interdisciplinary network and exchange of expertise – for instance among botanic gardens, forestry, agriculture, environment and educational sectors – as highlighted by the participants of the Parties to the CBD. To accomplish this, China should continue to nominate national focal points and encourage the participation of a wide variety of sectors in achieving the targets of the GSPC.

4. Progress, problems and recommendations

Since the adoption of the GSPC in China in 2002, varying degrees of progress have been made towards achieving the targets. Substantial progress has been made towards Targets 1, 2, 4, 5, and 7, and those targets were met before 2018. China is on track towards meeting Targets 3, 8, 9, 14, and 16 by 2020. Limited progress has been made so far in the achievement of Targets 6, 10, 11, 12, 13, and 15. Most of those targets are related to sustainable utilization. Although China has undertaken tremendous efforts and achieved significant progress, it should develop and implement more effective strategies towards overall achievement of all the targets by 2020.

The GSPC provides a useful framework for China to address issues related to sustainable development, poverty alleviation, economic-social development, and eco-civilization construction while ensuring that communities continue to derive benefits from plant diversity. As a developing country, China has a large population, a large land area, varied geographical environment, abundant biological diversity, an underdeveloped economy, and unbalanced regional economic development. In this context, it is very difficult to complete all targets on conservation, restoration, and utilization of plant diversity at the national scale, especially targets on sustainable utilization and management of plants. Questionnaire results for these targets also differ widely. Constraints to the national implementation of the GSPC include limited institutional integration, lack of mainstreaming, and at national level, lack of taxonomic capacity, lack of data (e.g., taxonomy, biology and conservation), tools and technologies, limited sectorial collaboration and coordination, and limited financial and human resources (Gratzfeld and Wen, 2012). However, the Chinese government has recognized the importance of the ecological environment and biodiversity conservation, and has invested enormous labor, materials and financial resources in implementing the GSPC.

China has greatly improved its protection policies, strengthened its comprehensive protection systems, restored degraded ecosystems, controlled environmental pollution and invasive plants, enhanced scientific and technological research, promoted public participation and public education, increased capital investment, and actively carried out international cooperation. As a result, ecological destruction has been mitigated, ecosystem functions in some regions have been restored, and some key endangered plants have been effectively protected and their populations have increased. Therefore, there is no doubt that GSPC implementation has greatly promoted the conservation and restoration of plant diversity in China.

Our review suggests that the lack of guidance and assessment

criteria on how to implement the GSPC for Targets 6, 10 and 13 may lead to potentially poor performance by national scale initiatives, and that more detailed methodological guidance, action plans, policies, and investment are needed to ensure that the GSPC delivers on its promise for plant conservation and sustainable use. The Chinese government adopted GSPC (2002–2010) in 2008 and reviewed the progress in implementing the GSPC in 2011. China also made efforts to commit to the CBD and the Sustainable Development Goals under the UN's Agenda 2030 in forestry, desertification, grasslands, and agriculture. Although the GSPC was not formally updated to align it with the revised GSPC 2011–2020, progress on the GSPC has been highlighted in the national report to the CBD in 2014 (CBD, 2014). China might issue further guidance including documenting the existing status of plant diversity, threats and utilization information. Revised objectives should more clearly describe the species or ecosystems that will be conserved, and include quantitative, time-bound targets that permit later assessment of whether the goals have been met (Panfil and Harvey, 2016; Dai and Wu, 2017). To enhance the achievements made, ensure their sustainability and promote upscaling, further and more ambitious measures should be considered in particular related to conserving and/or restoring ecological regions and vegetation types, including integrated native species recovery initiatives (Targets 4, 5, 7 and 8).

Climate change is influencing Chinese plant diversity conservation by affecting ecosystem sensitivity, phenology, migration, species adaptation and extinction (Lv, 2009; Li and Chen, 2014), and this will affect the implementation of targets 2, 4, 5, and 7. Climate change would cause changes in the distribution of an estimated 68 rare or endangered plant species. Among these, 25% would be potentially lost, 12% would greatly reduce their distribution range, 54% would decrease their distribution range, and only 9% would expand their distribution range. Climate change would also change the distribution pattern of rare or endangered species, *i.e.* about 31% would shift their ranges towards high altitude or high latitude regions, 21% would be fragmented, and the current distribution center of 16% of the species would be reduced (Lv, 2009). For these reasons, the Chinese government should adjust China's national biodiversity conservation policy to address climate change. For example, key areas of plant diversity should be delineated and protected, with a focus on climate-sensitive taxa and plants that are dependent on plant-animal interactions affected by climate factors. The impacts of global climate change should be taken into account in the further development and management of nature reserves. A national information network for the long-term monitoring of wild plant distribution and population dynamics should be established and technologies for *ex-situ* conservation, pollination and long distance seed dispersal of wild plants should be developed.

It is also important to improve the national coordination of conservation policies and actions. China should accelerate adjustments for policies that are not favorable to biodiversity conservation, strengthen research on biodiversity assessment indicators, construct biodiversity monitoring networks, improve the ecological representation and management effectiveness of protected area systems, strengthen the protection of endangered species and precious genetic resources, strengthen the prevention and control of alien invasive species, carry out quantitative studies on traditional knowledge and benefit-sharing issues, and carry out scientific activities among citizens that enhance public participation. In particular, China should strengthen the linkages between *in situ* and *ex situ* conservation at species and ecosystem levels, as well as stakeholder and policy levels. Effectively conserving plant diversity needs a comprehensive framework to address the integration of *in situ* conservation, *ex situ* conservation, restoration and re-introduction (Hua et al., 2018). We also recommend that China set up and strengthen the official and authoritative online network for bio-conservation, and maintain and strengthen a dedicated team to conduct risk assessments, recovery planning, and spatial prioritization to implement GSPC targets, and establish and strengthen a network for learning and technology exchange among countries.

China set up the Ministry of Natural Resources in March 2018 which will administer all matters on biodiversity conservation. This newly structured Ministry may have a greater potential to carry out comprehensive conservation plans by enhancing partnerships among scientists, conservationists, education specialists, and policy makers, and by increasing communication among stakeholders, and mobilizing additional financial support. This will help to secure comprehensive implementation of the GSPC in China, in turn benefiting the world.

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