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Framework for Sustainable Use of Medicinal Plants in China

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Abstract: China is the birth-place of Traditional Chines Medicine (TCM) and has a rich diversity of medicinal plant resources. With the rapid increase in consumer demands for crude drugs and natural health products, many medicinal plant species are threatened with extinction from overexploitation and habitat destruction. To ensure the sustainable use of medicinal plant resources, we discuss in this article, a conservation framework consisting of conservation strategies, cultivation practices and various technologies. Conservation strategies include establishing *in-situ* and *ex-situ* conservation centers, setting up government policies and regulations, establishing methods for resource surveying and trade monitoring and establishing and enforcing Good Agricultural Practices (GAP). In terms of technologies, we use a remote multi-level sensing system and DNA barcoding technologies as examples to demonstrate their roles in the conservation and sustainable use of medicinal plant resources in China.

Key words: Medicinal plant; Conservation framework; Sustainable use
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Medicinal plants are the primary sources of many small molecule drugs and herbal products, and their contribution to human healthcare is indispensible (Chen *et al.*, 2010; Nalawade *et al.*, 2003). Traditional Chinese medicines (TCM) are composed of various combinations of medical plants and have been used as natural remedies for thousands of years (Xiao, 2002). The Chinese medicinal industry represents a significant portion of the pharmaceutical industry in China. There are 1 200 Chinese medicine industrial enterprises that manufacture approximate 8000 Chinese herbal medicine products. The annual total sales of functional food, TCM preparations, medicinal plant extracts and other processed materials exceeds US $ 40 billion. The costs of natural resources for these products is also significant with an annual consumption of raw medicinal plant materials reaching over 1 million tons. The growth of the Chinese medicinal industry is manifested by the growth of the TCM pharmaceutical enterprise. For example, TongRenTong was established in 1669 in just one house. Now it is a publicly treaded company on the Hong Kong and New York Stock Exchanges with annual sales exceeding US $ 1 billion.

Today, there are many challenges facing the conservation of medicinal plant resources from overexploitation and habitat destruction (Srivastava *et al.*, 1996; Bentley, 2010). For example, 70% - 80% of natural materials were collected from the wild to meet the annual demand of approximate 1 million tons (Balunas and Kinghorn, 2005). The annual sales of these natural resources have increased to more than 100 times the levels of 1980. Many of these natural resources are derived from species that are threatened, or have become rare or endangered by large scale exploitation (Nalawade *et al.*, 2003; Cole *et al.*, 2007). For example, species like Chinese ginseng and *Dendrobium* are seldom seen in the wild nowadays. Some species have also become extinct. For example, wild *Panax notoginseng* has not been found in the wild for decades and is believed to have become extinct already (Shim *et al.*, 2005). Due to the lack of regulation, herbal medicine resources in China are facing a cri-

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sis of sustainability. This is not isolated to China. Based on a World Wide Life Fund Report (2004), most herbs consumed by human are still obtained from the wild (Lambert *et al.*, 1997; Ross, 2005). In Europe, there are over 1300 kinds of herbs used by mankind, 90% of which are wild herbs (Balunas, 2005). The collection and consumption of herbs by mankind had already brought the danger of extinction to 20% of known herbs (Newman *et al.*, 2000).

In the face of these challenges, Chinese government has taken prompt action. The government issued "Guideline for Modern Development of Chinese Medicines (2002-2010)" In the guideline, it is mentioned that "While fully utilizing the resources, we must pay attention to protecting the resources and the environment"; "We must also conserve biodiversity and ecological balance, especially to recover and regenerate Chinese medicine plant resources that are seriously threatened or in short supply". Furthermore, the protection of and promotion of sustainable utilization of Chinese medicine resources has been listed as one of the six "key tasks". With the public release of this guideline, research on the conservation of medicinal plants has become a top priority.

As the research institute in China dedicated to medicinal plants protection and development, we attempted to build a Framework for Promoting Herbal Medicine Conservation and Sustainable Use in China. There are three specific goals for this framework: (1) to guarantee the continuous supply of raw materials to the Chinese medicine industry and the market; (2) to meet the healthcare needs of the Chinese people and (3) to secure a continuous use of Chinese herbal medicines. Particularly, we intend to set up several research platforms to achieve these goals. These include: (1) establishing and applying best practices for evaluation of the conservation status and extent of Chinese plant resources for their sustainable utilization; (2) studying herb conservation and diversity through molecular authentication and phylogeny determination techniques; (3) establishing methodologies to survey herb resources; and (4) developing technologies for the sustainable use of herb resources.

As part of the framework, we established monitoring systems to closely monitor the change in medicinal plant resources and the recovery of habitats. These centers are critical for providing information and the scientific basis needed for herb conservation, cultivation and management, and to promote the recovery of medicinal plant habitats (Li and Chen, 2007). In addition, we have established in situ conservation networks including areas for Authentic/Aboriginal populations of medicinal species (Chen *et al.*, 2007). Currently, the network includes four conservation centers located in the Tibetan plateau for alpine medicinal plants; XinJiang Province for medicinal plants of northwestern China; ChangBai Mountain for medicinal plants of northeastern China and GuangXi Province for medicinal plants of southern China. An *Ex-situ* Conservation Network has also being established, which includes nine national medicinal plant gardens and material collection centers located in Beijing, Guangxi, Hainan, Yunnan, Xinjiang, Tibet, Jilin and Nanjing to expand scientific research, horticulture and education. Finally, the establishment of the Beijing National Medicinal Plant Seed Bank offers a simple and cost-effective solution for seed conservation.

Below, we described some of the technology platforms we have developed. First, we have developed a Multi-Level Remote Sensing System using Unmanned Air Vehicle Remote Sensing Technology. This system has been applied to survey the distribution of American ginseng and *Glycyrrhiza uralensis*. First, using the unmanned air vehicle, we took photographs and then applied pattern recognition algorithms to determine the distribution of *Glycyrrhiza uralensis* (Wang *et al.*, 2006). As a control, we carried out a ground investigation to determine the communities of *G. uralensis*+*Sophora*+Artemisia, *G. uralensis*+*Artemisia* and *G. uralensis* alone. Comparison of the survey results with the ground investigation results showed that our remote sensing and classification methods were 90% consistent with that of ground investigation (Zhou *et al.*, 2009), supporting the notion that the method is feasible for surveying wild medicinal plants resources.

Second, we have developed DNA barcoding technology for the authentication of medicinal plants. DNA barcoding is a technology that has recently gained great popularity in basic and applied research. Research groups in our institute carried out work to address several critical problems: (1) what the best DNA barcode marker (s) for medicinal plants are; (2) whether or not the best markers discovered for medicinal plants also work well in much wide range of groups of plant; (3) how to apply DNA barcoding studies to the practical work of medicinal plant maintenance and development.

The plant working group of the Consortium for the Barcode of Life recommended the two-locus combination of *rbc*L+*mat*K as the plant barcode, yet the combination was shown to successfully discriminate among 907 samples from 550 species at the species level with a probability of only 72%. The group admits that the two-locus barcode is far from perfect due to the low identification rate, and the search is not over. First, we compared seven candidate DNA barcodes (*psb*A-*trn*H, *mat*K, *rbc*L, *rpo*C1, *ycf5*, ITS2, and ITS) from medicinal plant species. Our ranking criteria included PCR amplification efficiency, differential intra- and inter-specific divergences, and the DNA barcoding gap. Our data suggest that the second internal transcribed spacer (ITS2) of nuclear ribosomal DNA represents the most suitable region for DNA barcoding applications (Chen *et al.*, 2010). Furthermore, we tested the discrimination ability of ITS2 in more than 6 600 plant samples belonging to 4 800 species from 753 distinct genera and found that the rate of successful identification with the ITS2 was 92.7% at the species level (Yao *et al.*, 2010). In conclusion, the ITS2 region can be potentially used as a standard DNA barcode to identify medicinal plants and their closely related species. We also propose that ITS2 can serve as a novel universal barcode for the identification of a broader range of plant taxa .

In our next study, we carried out a general analysis on the abilities of ITS2 to distinguish species in a comprehensive sample set (Yao *et al.*, 2010). About 50 790 plant and 12 221 animal ITS2 sequences downloaded from GenBank (Release 176) were evaluated according to sequence length, GC content, intra- and inter-specific divergence, and efficiency of identification. The results showed that the inter-specific divergence of congeneric species in plants and animals was greater than its corresponding intra-specific variations. The success rates for using the ITS2 region to identify dicotyledons, monocotyledons, gymnosperms, ferns, mosses, and animals were 76.1%, 74.2%, 67.1%, 88.1%, 77.4%, and 91.7% at the species level, respectively. The ITS2 region unveiled a different ability to identify closely related species within different families and genera. The secondary structure of the ITS2 region could provide useful information for species identification and could be considered as a molecular morphological characteristic. As one of the most popular phylogenetic markers for eukaryote, we propose that the ITS2 locus should be used as a universal DNA barcode for identifying plant species and as a complementary locus for COI to identify animal species. We have also developed a web application to facilitate ITS2-based cross-kingdom species identification (http://its2-plantidit.dnsalias.org).

Last but not least, there are many other strategies that will compliment the ones described above for the sustainable use of herbal resources. Some of them are as follows: establishment of natural nurseries of medicinal plants (semi-wild cultivation); conservation through cultivation and Good Agricultural Practice (GAP) (Li and Chen, 2007; Gao *et al.*, 2002); development of substitute species for threatened medicinal plants (Caro *et al.*, 2005); conservation of traditional knowledge; development of methods to sustainably harvest wild species (Leaman, 2006); development of authentication systems; setting up of policies and regulations (Schippmann *et al.*, 2006); enhancement of public education and awareness; provision of training and increasing the number of experts in this area.

In summary, the current short review summarizes various efforts taken by our institute to face the increasing threats of the depletion of herbal resources. As we believe, with close collaboration among government agencies, research institutes and pharmaceutical industries, we will be able to provide natural resource in a sustainable manner to meet the needs of human healthcare.

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