Conservation of forest genetic resources with special reference to endemic and endangered forest species in East Asia

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Introduction

There are two common approaches to genetic conservation that guide both crop and forest genetic resources conservation programmes (e.g. Namkoong, 1998). The ***ex situ*** approach relies on advanced agricultural technology, the use of rapid breeding techniques for specific traits and stored seed collections as the main form of gene conservation. These techniques are widely applicable for ***ex situ*** conservation of crops while they are less applicable for forest trees owing to much longer generation time and less-straightforward multiplication, for example. The second approach is that natural regeneration maintains plant populations in an optimum and stable state regarding their genetic resources and subsequently preservation of this natural endowment is the best form of conservation. Namkoong (1998) argued that either of these approaches alone would not help us to conserve all the forest genetic resources (FGR) for the following reasons. It is often assumed that the nature of the genetic resources is static while in fact the genetic resources are continuously in a dynamic state, whether they are in ***ex situ*** conditions or ***in situ.*** The rate of change is low under ***ex situ*** conservation such as genebank and faster in natural populations exposed to various factors affecting genetic processes. In addition, the genetic resources have changed in historically constrained ways and rarely, if ever, achieved an optimum 'adaptedness' to given environmental conditions. Thus it is important to realize the need for a complementary conservation strategy.

Long-term conservation of FGR in seed banks is problematic in many tree species and therefore the long-term conservation is mostly dependent on conserving living trees (e.g. Sigaud ***et al***., 2000). While conservation of crop genetic resources is mainly focused to individual species and actions are carried out for each species independently from other crops, conservation of FGR goes beyond that as forests consist of an array of species with complex interactions (Finkeldey, 1996). Thus conservation and management of FGR is much more complex task than management of crop genetic resources, except probably when one is dealing with ***in situ*** conservation (on-farm) of the later in which, along with agroecosystem considerations, the socioeconomic and anthropogenic factors can also make conservation very complex. While objectives and expected outputs of ***in situ*** conservation of FGR are in most cases species-specific, this approach also provides additional benefits, such as conserving multi-species ecosystems and the services they provide. Managing genes of various species in forest ecosystems requires information on various phenomena and processes, such as ecological interactions between species, genetic diversity within and between populations, gene flow and mating systems, for example. In addition, the task involves seeking common understanding between conservationists, managers, users and policy-makers who all have different expectations on how forests, not only genes, should be managed to obtain various benefits and services. However, some level of ***ex situ*** conservation will be in order, considering its role in making access to FGR diversity much easier.

In this paper, we summarise the different phases of the conservation of FGR in general and present some data on the state of endemic and endangered forest species in East Asia.

The Tree Conservation Database and the Plant Database of UNEP-WCMC[1] were used to derive information on these species in East Asia focusing on China, DPR of Korea, Japan, Mongolia and the Republic of Korea. In this presentation, the term 'forest genetic resources' mainly refers to genetic resources of forest trees but some information on bamboo and rattan species is also presented. Finally, we discuss how conservation of these endemic and endangered forest species could be improved in the future.

Forest resources in East Asia

In East Asia, like in many other regions, forests have been subjected to intense human use for centuries and in China for example, intercropping of forest trees and agricultural crops has a history of almost 1000 years (Huang ***et al***., 1997; Huang, 1998). In 1995, the total forest area of East Asian countries totalled nearly 182 million ha, of which 74% were located in China (Table 1). Of the total land area of these countries, the forest cover is less than 16% (FAO, 1999) even though in some countries the coverage is considerably high (Table 1). The annual changes in forest cover were relatively small during the period of 1990-1995 indicating that the present state of forest is more or less stabilised after the long-term human exploitation. In case of China, the successful establishment of various protective forest systems since 1950s has significantly contributed to the present state of forests in the country (Li ***et al***., 1999). However, vast areas of protective forests and tree plantations in China were established as monocultures using a few tree species and, in some cases, poor-quality planting material (e.g. Gu, 2001). This has caused problems in the plantations, such as pest and disease outbreaks, and some efforts have been initiated to diversify the monocultures towards multi-species plantations (Li and Zhou, 2000).

Table 1. Forest resources in East Asian countries (FAO, 1999)

Country	Total forest area in 1995 (1000 ha)	Percentage of land area (%)	Natural forest area (1000 ha)	Annual change in forest area, 1990-1995 (1000 ha)	Annual change rate, 1990-1995 (%)
China	133 323	14.3	99 523	-87	-0.1
DPR of Korea	6 170	51.2	4 700	0	0
Japan	25 146	66.8	-	-13	-0.1
Mongolia	9 406	6.0	9 406	0	0
Republic of Korea	7 626	77.2	6 226	-13	-0.2

According to the Tree Conservation Database, there is considerable a number of endangered tree species in East Asia (Table 2). Most of the tree species (127) are classified as vulnerable, i.e. they are facing a high risk of extinction in the wild in the medium-term future (for explanation of the IUCN red list classification see endnotes of Table 2). A total of 45 tree species have been categorised as endangered (a high risk of extinction in the wild in the near future) and 32 species as critically endangered (similar risk in the immediate future). So far, two tree species have been recorded as extinct in the wild and another two species have become extinct without reasonable doubt. In addition, a number of other tree species have been classified into the lower risk categories (Table 2).

[1] United Nations Environmental Programme-World Conservation Monitoring Centre (www.unep-wcmc.org)

Habitat destruction and forest fragmentation are common causes a forest species to become endangered, whether it is rare or not, which reduce the size of reproductive population and disturb reproductive biology. In some cases, rare tree species are threatened with extinction due to hybridisation with their more abundant relatives. Selective and large-scale exploitation of a species for wood or non-wood products is also a common reason for endangerment. A notable example of the risks of hybridisation is ***Cercocarpus traskiae*** in Santa Catalina Island off the cost of California (see Carney ***et al***., 2000). This species is one of the rarest trees in North America and its population size has dwindled to a few adult individuals. Interspecific hybridisation with its more abundant congener, ***Cercocarpus betuloides*** ssp. ***blancheae***, has considerably contributed to the decline of ***C. traskiae*** in addition to grazing and rooting by introduced herbivores.

Table 2. Number of endangered tree species in East Asian countries (data source: UNEP-WCMC Tree Conservation Database, http:// www.unep-wcmc.org, July 2001)

Country	EX	EW	CR	EN	VU	LR/cd	LR/nt	LR/lc	DD	NE
China	2	2	32	44	114	7	48	41	17	28
DPR of Korea	-	-	-	-	3	-	1	-	2	2
Japan	-	-	-	1	10	-	5	2	5	3
Mongolia	-	-	-	-	-	-	-	1	-	-
Republic of Korea	-	-	-	-	-	-	2	1	2	1

1994 IUCN red list classification: EX extinct without reasonable doubt; EW extinct in the wild; CR critically endangered; EN endangered; VU vulnerable; LR/cd lower risk, conservation dependent; LR/nt lower risks, near threatened; LR/lc lower risk, least concern; DD data deficient, inadequate information available; NE not evaluated against the criteria.

Conservation of forest genetic resources

The aims of FGR conservation and management are to safeguard the evolutionary potential of forest ecosystems and to ensure sustainable use of the genetic resources to meet the present and future human needs. The general conservation strategies for FGR are basically similar to those ones applied to crop species and consist of consecutive phases. The existing forest resources and their genetic variation are a starting point for conservation activities. Subsequently, the identification of objectives and the selection of priority species for conservation are of utmost importance because future activities will be based on the objectives and priorities established during the planning phase. After the priority species have been identified, their genetic diversity needs to be assessed and located so that the following conservation activities and possible germplasm collecting can be focused on suitable areas. Selection of conservation methods depends on the objectives of a given conservation programme and provides a framework for the actual implementation of conservation activities in practise (see Ramanatha Rao and Koskela, 2001), including the regeneration of the conserved material. In the following chapters, we highlight some issues of these different phases (for more comprehensive presentation, see Koskela and Amaral, 2002).

Setting conservation priorities

As a general guideline, genetic conservation should focus on species with current or potential economic importance and/or under immediate threat of extinction (e.g. Finkeldey, 1996). It has been estimated that more than 50,000 tree species exist worldwide (see National Research Council, 1991) but less than 500 species have been systematically tested for their usefulness for man (see Palmberg-Lerche, 1999). Less than 140 tree species are being utilised in forestry and less than 40 are under active breeding programmes. However, if the direct utilisation by forest dwelling communities is taken into account, this figure may be much larger and very difficult to estimate. In addition to timber products, many more tree species are useful for man in terms of non-wood forest products and environmental services. Thus there is a need to strengthen long-term FGR conservation efforts (e.g. National Research Council, 1991; Palmberg-Lerche, 1999).

In theory, the aims of genetic conservation are rather simple, to ensure the survival of locally adapted populations and to prevent the loss of rare alleles (Mátyás, 1998). In practise, both human and financial resources are extremely scarce as compared to the conservation needs and relatively little is known even on the very basic biology of most trees or other forest species. Thus priority-setting for conservation is urgent for national programmes, which are trying to identify priority tree species and populations for inclusion in conservation programmes. The University of British Columbia in Canada has been developing a framework for prioritising species, populations and conservation methods within an IPGRI supported research project. The project attempts to rationally prioritise species or populations based on threats, potential or present values and the means that are available for conservation (see IPGRI, 2000).

The framework requires basic information on the status and dynamics of genetic diversity as well as its values, threats and potential for conservation management. This kind of information range is rarely available for most tree species but the framework can be used as a tool to compile the existing information and identify research needs. Using the framework, it is possible to produce a priority ranking of species into priority groups to be subsequently used by managers for selecting and implementing the necessary activities. Koshy ***et al***. (2002) stated that the framework, which is based on a decision tree approach, is as an effective tool for rational decision-making in genetic conservation, provided that the information needed can be estimated (if not available) and if the monetary values can be assigned with reasonable accuracy. Other benefits are that the collection costs of additional information can be directly compared against the expected returns and that the framework enables sensitivity analysis to improve our understanding what factors affect most in decision-making.

Locating genetic diversity

The decision-making process demonstrates the importance of information on the extent and distribution of genetic diversity. Conservation efforts cannot be effectively focused unless adequate information on genetic diversity in the target species is available. Currently, however, this information is lacking for many tree species and it cannot be made rapidly available. Thus, different layers of information, i.e. patterns of species and forest ecosystem distribution, threats, and the amount and spatial distribution of genetic diversity, needs to be combined to achieve an adequate assessment of the state of genetic diversity in a region or country.

The combination of information provides spatially explicit framework for conservation efforts by identifying areas to be ranked according to the level of threats and the genetic diversity they hold (Boffa ***et al***., 2000). As soon as species distribution has been identified, more efforts can be invested to evaluate genetic diversity within populations. Detailed information on genetic diversity and threats is essential in designing truly effective conservation areas, which can safeguard intraspecific diversity and maintain evolutionary processes.

Conservation methods

A wide range of methods, from protected nature reserves to intensive management of breeding populations for production systems, can be applied to conserve FGR. The choice of methods depends on the objectives of conservation, available genetic material and selected time scale. The choice of methods and subsequent implementation of the conservation strategy also depends on the availability of human and financial resources.

The two common approaches are ***in situ*** and ***ex situ*** conservation. The term '***in situ***' refers to the continued maintenance of tree populations in their natural sites under the environment to which they are adapted. ***Ex situ*** conservation takes place outside the natural habitat and may consists of activities such as the establishment of live collections or ***ex situ*** conservation stands and storing of seeds, pollen or tissue. To some extent, FGR can also be conserved and maintained by tree plantations or by other land-use practises such as agroforestry systems. However, it is likely that such management interventions reduce genetic variation in tree populations (e.g. Savolainen and Kärkkäinen, 1992) and thus these efforts can only support the more active conservation efforts.

No single conservation method is adequate alone and different methods should be applied in a complementary manner (Palmberg-Lerche, 1999; Boffa ***et al***., 2000). ***In situ*** conservation, however, has a number of benefits and thus it is often used as a basis for conservation programmes. The method allows the maintenance of evolutionary processes and subsequently continuing adaptation of tree populations to changing environmental conditions. This is particularly important for breeding programmes since the future human needs and environmental conditions are difficult to predict.

The establishment of protected areas has commonly been done on the basis of ecosystem or species conservation rather than genetic diversity conservation and therefore the design of ***in situ*** conservation programmes has been considered as primitive (National Research Council, 1991). In tropical forest especially, the complexity of interacting factors and a lack of scientific information have hampered the development of ***in situ*** conservation strategies. The uncertainties are related to an adequate size of ***in situ*** conservation area, number of individuals to be included, how to select conservation areas and how genetic variation is distributed within the selected areas (e.g. Palmberg-Lerche, 1999). Natural, pristine forest ecosystems are often considered as a starting point for ***in situ*** conservation. In reality, however, rural landscapes often form a mosaic of forest patches, ranging from seemingly natural to secondary forests and ending to seriously degraded forests and other wooded lands. The most obvious genetic effects of fragmentation are loss of genetic diversity both at the population and species levels, change in genetic structure of a population and increased inbreeding (Young and Boyle, 2000).

Ex situ conservation aims at capturing and maintaining a representative sample of the genetic diversity. The three major pitfalls in collecting germplasm samples for ***ex situ*** conservation are 1) limited coverage of genetic variation, 2) the collected plant material is biased in content, and 3) there is too much sampled germplasm to deal with (Brown and Hardner, 2000). To avoid these pitfalls, the sampling of populations and germplasm require special attention during the planning phase.

Traditionally, ***ex situ*** conservation of FGR is implemented by establishing conservation stands outside a native habitat of a given species for ease of management. However, long-term maintenance of the collected genetic diversity in these stands tends to be difficult owing to genetic drift and possible contamination by gene flow from outside. Another commonly used method for ***ex situ*** conservation is storing of seeds collected from a range of natural populations. In case of many tropical tree species, however, this method is not a straightforward or simple task due to recalcitrant seed behaviour (i.e. seeds are desiccation intolerant). Nevertheless, conservation stands and seed banks enhance the ability of researchers to readily access the material, evaluate it and use it.

In recent years, considerable amount of efforts have been put to the development of ***in vitro*** techniques to overcome these difficulties in ***ex situ*** conservation of recalcitrant tree species, cryopreservation being a notable example (Benson, 1998; Marzalina ***et al***., 1999). Cryopreservation provides great opportunities for a longer term ***ex situ*** gene preservation but problems in identifying proper protocols for a given species have limited its applicability. While it is likely that further research will ease these problems, the major potential of cryopreservation seems to be in supporting tree improvement programmes and conserving biotechnically-derived germplasm (Benson, 1998) rather than becoming a widely applied ***ex situ*** conservation method for FGR. Micropropagation, i.e. the use of tissue and organ cultures for organogenesis and somatic embryogenesis, can also be applied to maintain the genetic resources collected for ***ex situ*** conservation. Presently, however, the available technology for somatic embryogenesis is in most cases too expensive for cost-effective ***ex situ*** conservation.

Endemic and endangered tree species in East Asia

All endangered East Asian tree species in categories extinct in the wild (EW) and critically endangered (CR) are found in China (Table 3). Most of these tree species are endemic to certain locations or provinces in the country. The largest group of endangered tree species consists of the family Dipterocarpaceae despite the fact that these species only occur in southern parts of China. The six species in this family include ***Hopea*** spp., ***Shorea assamica*** ssp. ***assamica*** and ***Vatica*** spp., all having high-value timber properties. In the family Sterculiaceaea, there is one species listed in the EW category (***Firmiana major***) and other four in the CR category (***Pterospermum*** spp. and ***Reevesia rotundifolia***). The four critically endangered coniferous species consist of ***Abies*** spp. and ***Pinus squamata***. Other highly endangered families are Magnoliaceae and Cupressaceae with three and two tree species, respectively. The second species in the EW category is ***Thuja sutchuenensis*** (Cupressaceae).

Endangered tree species (category EN) in East Asia are listed in Table 4. Most of the species are found in China and only one is listed for Japan (***Picea koyamae***). In China, most of the species in this category belong to the family Magnoliaceae, including ***Magnolia*** spp. ***Manglietia ovoidea***, and ***Michelia*** spp. Eight out of the ten species in this family are endemic to China. The second largest group is the family Pinaceae with species like ***Abies fanjingshanensis***, ***Nothotsuga longibracteata***, ***Picea*** spp. and ***Pinus*** spp. Most of the species are also endemic to China. The species in the family Lauraceae include ***Alseodaphne rugosa***, ***Cinnamomum mairei***, ***Litsea*** spp. and ***Phoebe nanmu***, all endemic to China. In the families Taxaceae and Dipterocarpaceae, there are three (***Amenentotaxus yunnanensis***, ***Pseudotaxus chienii*** and ***Torrey jackii***) and two (***Parashorea chinensis***, ***Vatica mangachapsi***) species listed, respectively.

Based on the available information on the present or potential uses of the species listed in the categories EW, CR and EN, many of the tree species have potential to produce at least timber. Species like ***Hopea***, ***Shorea***, ***Vatica***, ***Erythrophleum***, ***Garcinia***, ***Abies***, ***Picea*** and ***Pinus*** spp. are all well-known for their timber qualities and sources for other wood-based products. Several species have also potential for other uses, such as fruits, oils and medicine, to name a few. Seeds of ***Horsfieldia pandurifolia*** are used to produce commercial oil while ***Cephalotaxus hainanensis*** and ***Cinnamum mairei*** have medicinal value. The most well known medicinal tree species of these is notably ***Ginkgo biloba***, which has an ancient geological record since the Jurassic period and which has been cultivated for centuries. It is also used as an ornamental species and has been introduced to many other regions like Europe, Africa, North and South

America and Oceania. ***Metasequoia glyptostroboides*** is another well known ornamental species, which has also been planted in many regions outside East Asia.

Many endemic and endangered tree species have proven and long-term use records but there is also a large number of species, which have not been studied in detail and relatively little documentation exists on the present or potential uses (e.g. ***Abies yuanbaoshanensis***, ***Cephalotaxus hainanensis***, ***Corylus chinensis***, ***Hopea mollissima***, ***Vatica xishuangbannaensis***). Some of these species have been described to science only recently while in case of other species, there seem to be differences concerning their taxonomic position between different databases. While analysing the reasons behind species becoming endangered (see Tree Conservation Database), it is seems that conversion of forest to agricultural lands and unsustainable logging have contributed in major part to habitat destruction of rare tree species or earlier more abundant species with specific site requirements. Concerning logging, it seems that large-scale, export-oriented commercial exploitation has directly caused the species to become endangered in families such as Dipterocarpaceae and Pinaceae while the indirect effects of logging (e.g. habitat destruction) have affected many other tree and plant species.

Table 3. Endangered tree species in China (data source: UNEP-WCMC Tree Conservation Database, http:// www.unep-wcmc.org, July 2001)

Category	Species / Genus	Family	Remarks
EW	***Firmiana major***	Sterculiaceae	endemic
	Thuja sutchuenensis	Cupressaceae	endemic
CR	***Abies spp.***	Pinaceae	3 species, all endemic
	Betula halophila	Betulaceae	endemic
	Bhesa sinica	Celastraceae	endemic
	Carpinus putoensis	Corylaceae	endemic
	Craigia kwangsiensis	Tiliaceae	endemic
	Cupressus chengiana var. ***jiangeesis***	Cupressaceae	endemic
	Diospyros vaccinioides	Ebenaceae	
	Euryodendron excelsum	Theaceae	
	Gleditsia vestita	Leguminosae	endemic
	Hopea spp.	Dipterocarpaceae	3 species
	Magnolia spp.	Magnoliaceae	2 species, both endemic
	Manglietia sinica	Magnoliaceae	endemic
	Metasequoia glyptostroboides	Taxodiaceae	endemic
	Myristica yunnanensis	Myristicaceae	endemic
	Nyssa yunnanensis	Cornaceae	endemic
	Ostrya rehderiana	Corylaceae	endemic
	Pinus squamata	Pinaceae	endemic
	Pterospermum spp.	Sterculiaceae	3 species, endemic
	Reevesia rotundifolia	Sterculiaceae	endemic
	Rhododendron protistum var. ***giganteum***	Ericaceae	endemic
	Shorea assamica spp. ***assamica***	Dipterocarpaceae	
	Sonneratia hainnensis	Lythraceae	endemic
	Ulmus gaussenii	Ulmaceae	endemic
	Vatica spp.	Dipterocarpaceae	2 species, both endemic

Table 4. Endangered tree species in China and Japan (data source: UNEP-WCMC Tree Conservation Database, http:// www.unep-wcmc.org, July 2001)

Country	Species / Genus	Family	Remarks
China	***Abies fanjingshanensis***	Pinaceae	endemic, relict species
	Alseodaphne rugosa	Lauraceae	endemic
	Amnentotaxus yunnanensis	Taxaceae	
	Annamocarya sinensis	Juglandaceae	relict species
	Bretschneidera sinensis	Bretschneideraceae	
	Burretiodendron tonkinense	Tiliaceae	
	Cephalotaxus hainanensis	Cephalotaxaceae	endemic, medicinal value
	Cinnamomum mairei	Lauraceae	endemic
	Corylus chinensis	Corylaceae	endemic
	Craigia yunnanensis	Tiliaceae	
	Dipteronia dyeriana	Aceraceae	endemic
	Erythrophleum fordii	Leguminosae	timber species
	Garcinia paucinervis	Guttiferae	timber species
	Ginkgo biloba	Gingkgoaceae	endemic
	Helicia shweliensis	Proteaceae	endemic
	Horsfieldia pandurifolia	Myristicaceae	endemic, oil from seeds
	Laportea urentissima	Urticaceae	
	Litsea spp.	Lauraceae	2 species, both endemic
	Magnolia spp.	Magnoliaceae	4 species, all endemic
	Manglietia ovoidea	Magnoliaceae	endemic
	Michelia spp.	Magnoliaceae	5 species, 4 endemic
	Nothotsuga longibracteata	Pinaceae	endemic
	Paranephelium hainanensis	Sapindaceae	endemic
	Parashorea chinensis	Dipterocarpaceae	
	Pellacalyx yunnanensis	Rhizophoraceae	endemic
	Phoebe nanmu	Lauraceae	endemic, timber species
	Picea spp.	Pinaceae	4 species, 3 endemic
	Pinus spp.	Pinaceae	2 species, 1 endemic
	Pseudotaxus chienii	Taxaceae	endemic
	Torreya jackii	Taxaceae	endemic
	Ulmus chanmoui	Ulmaceae	endemic
	Vatica mangachapsi	Dipterocarpaceae	timber species
Japan	***Picea koyamae***	Pinaceae	

As economic or other values always affect genetic conservation through priority setting, it is interesting to analyse what is the status of endangerment among the priority tree species listed by the FAO Panel of Experts on Forest Gene Resources. Table 5 lists selected indigenous priority tree species for East Asia based on FAO (2000). Only those species having their main distribution area within the East Asian countries were included and in some cases, the IUCN classification may indicate the status of a subspecies.

Table 5. Indigenous East Asian priority tree species, their conservation activities and level of endangerment (FAO, 2000; UNEP-WCMC Tree Conservation Database; CAB International, 2000)

Species	Conservation activities[1]		End uses[2]	IUCN classification[3]	Natural distribution in East Asia
	In situ	Ex situ			
Alnus cremastogyne	1	1	1-4		China
A. formosana	2	2	1-4		endemic to China
A. japonica	1	1	1-4		China, Japan, Korea
A. mandshurica	1	1	1-4		
Camellia oleifeira	2	1	4		endemic to China
Castanea mollissima	3	3	1-4		China, Korea
Chamaecyparis obtusa	1	1	1-4		China, Japan
Cinnamomum camphora	2	2	1-4		China, Japan, Korea
Cryptomeria japonica	1	1	1-4		China, Japan
Cupressus duclouxiana	2	2	1-4	DD	endemic to China
C. funebris	2	2	1-4		endemic to China
Cunninghamia lanceolata	1	1	1-4		China
Eucommia ulmoides	1	1	1-4	LR/nt	endemic to China
Fokienia hodginsii	1	1	1-4	LR/nt	endemic to China
Fraxinus mandshurica	1	1	1,3,4		China, Japan, Korea
Ginkgo biloba	1	1	1-4	EN B1+2c	China
Haloxylon ammondendron	2	2	2-4		China, Mongolia
Juglans mandshurica	2	2	1-4	NE	China, Japan, Korea
Ketaleeria pubescens	3	3	1-4		
Larix gmelini	2	2	1-4		China, Korea, Mongolia
L. potaninii	2	2	1-4	VU D2	China
L. sibirica	2	2	1-4		China, Mongolia
Paulownia elongata	2	2	1,3,4		endemic to China
P. fortunei	2	2	1,3,4		China
P. tomentosa	3	3	1,3,4		China, Japan, Korea
Phellodendron amurense	1	1	1-4	DD	China, Japan, Korea
Picea asperata	2	2	1-4		endemic to China
P. jezoensis	1	1	1-4		China, Japan, Korea
P. koraiensis	1	1	1-4	VU D2	China, Korea
P. meyeri	2	2	1-4		
Pinus densiflora	1	1	1-4	DD	China, Japan, Korea
P. koraiensis	1	-	1-4		China, Japan, Korea
P. massoniana	1	1	1-4	EN B1+B2	China
P. sylvestris var. mongolica	2	2	1-4		China, Mongolia
P. tabuliformis	1	1	1-4	LR/nt	endemic to China
P. yunnanensis	1	1	1,3,4		endemic to China
Populus euphratica	1	1	1,3,4		China, Mongolia
P. simonii	2	2	1,3,4		endemic to China
P. tomentosa	2	2	1,3,4		endemic to China
Quercus mongolica	1	1	1-4		China, Japan, Korea
Salix matsudana	2	2	1-4		China, Korea
Sapium sebiferum	2	2	1-4		China, Japan
Taiwania cryptomerioides	1	1	1-4	VU A1d	endemic to China
Tilia amurensis	2	2	1-4		China, Korea
Toona sinensis	2	2	1-4		China
Tsuga chinensis	2	2	1-4		endemic to China
Ulmus parviflora	1	1	1-4		China, Japan, Korea
Zelkova schneideriana	2	2	1-4		Japan

[1] Highest priority=1, prompt action recommended=2, important but less urgent than (1) and (2)=3.
[2] Industrial wood=1, industrial non-wood products=2, fuelwood, posts, poles=3, other uses=4
[3] 1994 IUCN classification: EW extinct in the wild; CR critically endangered; EN endangered; VU vulnerable; LR/cd lower risk, conservation dependent; LR/nt lower risks, near threatened; LR/lc lower risk, least concern

All of the listed priority tree species have more than one end use (except ***Camellia oleifera***, which is mainly used for producing high-quality edible oil in addition to its ornamental use). In many of these priority species, ***in situ*** or ***ex situ*** conservation activities have been recommended as high priority. However, only relatively a few of the species are included as endangered in the IUCN red list and none in the high-level endangerment categories (EW and CR). ***Gingko biloba*** and ***Pinus massoniana*** are listed in the EN category while priority species in the VU category include ***Larix potanii***, ***Pinus koraensis*** and ***Taiwania cryptomerioides***. The lower risk (LR) category includes three priority tree species, i.e. ***Eucommia ulmoides***, ***Fokienia hodginsii*** and ***Pinus tabuliformis***. In addition, ***Cupressus duclouxiana***, ***Phellodendron amurensis*** and ***Pinus densiflora*** are classified as data deficient (DD) and ***Juglans mandshurica*** as not evaluated (NE).

Endangered bamboo and rattan species in East Asia

There are more than 500 bamboo species in East Asia and of these about 450 are found in China (Li, 2000). Some 155 species is said to be endemic, endangered and rare (Hui, 2000). Presently southern and southwestern parts of China have more than 4 million ha of bamboo forests and their utilisation began 4000–5000 yeas ago (Yang and Xue, 2000). Some of the major priority bamboo species in this region include ***Bambusa bambos***, ***B. textilis***, ***B. vulgaris***, ***Cephalostachyum pergracile***, ***Dendrocalamus giganteus***, ***D. latiflorus*** and ***Phyllostachys pubescens*** (Rao ***et al***., 1998).

Apart from the more popular and economic bamboo species, the conservation status of many species is uncertain. Along with human exploitation and rapid conversion of forested areas to other land uses, the natural habitats of numerous bamboo species have been destroyed and the species threatened by extinction – a similar situation as in many tree species. The number of endangered bamboo species is not yet fully assessed in China but several species have been listed, namely ***Acidosasa chinensis***, ***Ampelocalamus actinotrichus***, ***Bashania spanostachya***, ***Chimonobambusa marmorea***, ***C. quadrangularis***, ***Ferrocalamus strictus***, ***Leptocanna chinensis***, ***Monocladus amplexicaulis***, ***M. saxtilis***, ***Qiongzhuea tumidinoda***, ***Sasa qingyuanensis*** and ***Yushania baishanzuensis*** (Fu Jinhe (INBAR), pers. comm.). Of these, only ***Q. tumidinoda*** is listed in the IUCN red list as rare (www.unep-wcmc.org). In addition, Hui (2000) listed a number of important endangered bamboo species, i.e. ***Cephalostachyum scandens***, ***Gaoligongshania megathyrsa***, ***Gigantochloa felix***, ***Dendrocalamus sinicus***, ***Ampelocalamus yongpingensis***, ***Teinostachyum yunnanensis*** and ***Melocalamus errectus***.

As many of the bamboo species flower only once in several years and the whole clump dies after flowering, long-term conservation and management of some of these species is more complex than in tree species. Comparing the few priority species listed above and the endangered species, it can be seen that there is no overlap, i.e. no endangered species have been identified as important which obvious make their long-term conservation a challenging task. However, as bamboos are highly valued species in general, their conservation has received some level of attention. In Yunnan for example, a total of 108 nature reserves exist hosting most of the bamboo species native to the area and about ten bamboo gardens have been set up for ***ex situ*** conservation (Hui, 2000).

The distribution of rattan resources in East Asia is mainly limited to the humid tropical forests of southern China, forming the northern most range of their distribution in Asia. Globally, there are some 600 rattan species of which 40 species and 21 varieties are native to China and 29 species and 15 varieties are endemic, respectively (Xu ***et al***., 2000). These include one species in the genus ***Daemonorops***, 35 species and 21 varieties in the genus ***Calamus***, and four species in the genus ***Plectocomia***. Some 21 priority rattan species (***Calamus*** spp.) have been identified and only two are found in China, i.e. ***Calamus palustris***(italics) (and two of its close relatives) and ***Calamus tetradactylus***(italics), which are endemic to China

(Rao ***et al***., 1998). Two rattan species in China are listed as vulnerable in the IUCN red list, i.e. ***Calamus erectus*** var. ***birmanicus*** and ***Plectocomia microstachys***. Like bamboos, also rattans have been intensively studied in China, especially their utilisation and cultivation. However, ***in situ*** conservation of rattans mainly relies on ***in situ*** conservation of forest trees as active efforts on rattans in this respect seem to be scarce (Xu ***et al***., 2000). Like in bamboos, botanical gardens are important for e***x situ*** conservation of rattans in China although intensive efforts have also been done applying in vitro techniques (Zeng ***et al***., 2000). An additional obstacle for the conservation of rattans is that their taxonomy is relative poorly studied, limiting our understanding on the number of endangered rattan species.

Discussion

The lists of endangered tree, bamboo and rattan species we have presented are not comprehensive but provide an overview on the situation in East Asia. In Japan, for example, there are a total of about 130 woody species considered to be threatened and rare (Yamamoto, 1996). These include species like ***Pseudotsuga japonica***, ***P. koraensis*** and ***Morus boninensis***, which are not included in the Tree Conservation Database but which are considered as endangered in Japan (Yamamoto, 1996). Similarly, a total of 345 tree species have been listed as endangered and rare in China (Gu, 2001). Also, the IUCN red list includes only few bamboo and rattan species in China. Obviously, the situation is similar in other East Asian countries and subsequently the actual number of endangered species is higher than we have now presented.

Typically the number of individuals of endangered species ranges from less than ten to several hundred, commonly distributed as isolated populations, and often the number of reproducing individuals is even less. In small populations, it is important to understand the difference between ecological or demographic processes and genetic processes, such as genetic drift (see Savolainen and Kuittinen, 2000). Without immediate conservation activities, small populations can be destroyed practically over-night as a result of habitat destruction making concerns about the effects of genetic processes irrelevant. In case we can assume that immediate extinction is not the main concern, it is relevant to analyse the effects of genetic drift and inbreeding. Small population size does not necessary indicate low levels of genetic variability although species with narrow distributions have often less variability than widely distributed species (Savolainen and Kuittinen, 2000). In small populations, genetic drift can considerably change allele frequency already over a few generations but usually the genetic effects take place slowly. Inbreeding, on the other hand, can result in deleterious alleles, which further reduce survival and reproduction potential even in relatively large populations but the level of inbreeding depression varies between species. In case of endangered species, the major genetic concern is to increase population sizes large enough so that mutation and recombination can generate enough variability within populations to respond to current selection pressures (Savolainen and Kuittinen, 2000).

Habitat destruction and genetic deterioration may not be the only threats to endangered and rare species. Under certain circumstances, hybridisation with congeners may become an additional threat and accelerate the rate of extinction. Recently, Carney ***et al***. (2000) highlighted the role hybridisation as an extinction factor and concluded that it is a real threat to the survival of many rare plant species. Hybridisation can decrease the fitness of rare species by outbreeding depression or by a cascade effect producing more and more hybrids and ultimately causing ‘genetic assimilation’. Ironically, controlled hybridisation with a common congener can also enhance genetic conservation in extremely rare species and save considerable amount of genetic material from inbreeding depression and a total loss (Carney ***et al***., 2000).

For critically endangered species, urgent ***ex situ*** conservation is the only reasonable short or medium term management alternative instead of passive protection of habitats or the remaining individuals. Many tree species are already so called ‘living dead’, i.e. they still exist but no regeneration takes place. For this kind of species, it is necessary to give high priority for immediate ***ex situ*** conservation, coupled with active efforts to promote reproduction and regeneration. As viable seeds are difficult or impossible to obtain, their reproduction have to rely on other means, such as vegetative propagation. Recently, the development of micropropagation techniques, such as shoot tissue culture and somatic embryogenesis, has opened new opportunities for conserving rare species and presently these applications are available for several tree species (e.g. Park and Son, 1996). In the future, it is also likely that the further development of ***in vitro*** techniques provides practical tools to apply controlled DNA modifications to increase mutation rates (Park and Son, 1996). This would be especially useful for increasing genetic variability in critically endangered species while it would also allow faster diversification than natural mutation or hybridisation.

As an active conservation measure, locally isolated gene pools of critically endangered species could be combined into new ***ex situ*** and ***in situ*** conservation stands, or into so called ‘forest gene banks’ in which large range of gene sources are purposely put together (e.g. Uma Shaanker and Ganeshaiah, 1997). These conservation stands could be established with micropropagated seedlings originating from as many individuals as possible. If available, seedlings propagated from seeds and wildings collected from natural stands could also be used to establish the conservation stands. Combining the remaining gene pools would reduce inbreeding rate and enhance outcrossing and mutation rates subsequently increasing the level of heterozygosity. The conservation stand should be established in areas where the threats by hybridisation to endangered gene pools can be eliminated.

Conclusion

Conservation of forest genetic resources is not an independent activity from forest management and utilisation for human needs (e.g. Finkeldey, 1996). Subsequently, conservation of endangered and endemic forest species is neither an independent effort from FGR conservation in general. The fundamental question in conservation of endemic and endangered forest species is related to financial and human resources. As both are scarce, it is obvious that conservation of economically more attractive species have received and will continue receive more attention as compared to rare species. Endangered species will be conserved if their economic values are recognised. ***Pinus koraensis*** is a good example of this. Although classified as endangered, it is a relative well-conserved species as it is important for plantation forestry (Wang and Hong, 2002). Inevitable fact is that many endangered species are already ‘living dead’ on their way to extinction unless immediate conservation efforts are carried out. Changing this situation would require high-cost ***ex situ*** conservation measures and obviously this is a task that many national conservation programmes are unable to do.

One cannot deny the importance of conserving rare and endangered species and thus alternative ways to increase awareness on the importance of these species should be developed. One way to do this is to obtain more basic information not only on the biological and ecological features of the species but also their present and potential uses. Often especially the uses are poorly documented and increasing the collection of traditional knowledge from local people could fill this gap. Once it is better known what can be lost, it is easier to justify urgent and possibly high-cost conservation measures while setting priorities.

Also, we should not only focus on analysing what species are endangered at the moment but also focus on how to prevent more species of becoming endangered, whether they are currently rare or abundant. Forest management practises can significantly contribute to this task. Recent development in the ‘sustainable forest management’-concept has also paid a lot of attention on management of FGR, which is ultimately a corner stone for applying this concept in practise. A number of criteria and indicators for sustainable forest management have been established and tested in the field (e.g. ITTO, 1990, 1992,1993; Prabhu ***et al***., 1999). Specific criteria and indicators to conserve genetic diversity in forest ecosystems have also been developed (Boyle, 2000). Thus it is expected that FGR management and conservation in general will be improved in the future but as this takes place slowly in the field, it cannot replace the need for immediate action to conserve endangered forest species and their habitats.

Since 1991, China has implemented its new FGR conservation strategy, which also pays special attention to endangered species and rescue conservation efforts have already been started for a number of species (Gu, 2001). What is noteworthy is that these efforts are an integral part of a national FGR conservation strategy with clearly defined short-term, mid-term and long-term objectives, and not an independent conservation activity as such. The conservation task in China is still enormous but the national FGR conservation strategy is the first step to tackle this challenge and other East Asian countries should follow this example. While doing so, it is also important to link FGR conservation strategies to national programmes for forestry and biodiversity to ensure overall coordination of natural resources management and conservation.

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