Status of forest genetic resources conservation and management in Pakistan

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Introduction

Forest genetic resources (FGR) play an important role in offering numerous goods and services to mankind and also in mitigation pollution and providing a good source of revenue to national governments. Pakistan has about 4.8% of forest cover. Forests help to monitor the flow of rivers in the north and regulate siltation in two important dams. Forest trees also meet the demand of small scale farmers for fodder, timber and fuelwood as almost 90% of the firewood requirements are met from trees grown on farmlands. With an annual increase of 3%, the total population would reach 150 million by the end of 2003 and then the demand for timber and fodder would increase along with an increase in livestock especially among the poor rural communities who depend on these forests. The natural forests also provide good shelter for important medicinal herbs as well as suitable habitats for wildlife. Although the forest area is small, all forest types occur in Pakistan ranging from arid zones to dry/wet temperate ecosystems. Forests of Pakistan are spread over 4 263 000 ha. Based on altitude and rainfall pattern, forests can be broadly classified into the following four categories:

i) High altitude coniferous forests

The high altitude coniferous forests lie between 1200 to 3200 m asl. with a small percentage (<25%) of broad-leaved species. Important coniferous genera include *Abies, Pinus, Cedrus* and *Picea*. The few major broad-leaved genera include *Acer*, *Betula, Fraxinus* and *Taxus*. The total area of such forests is 1 928 000 ha, which constitutes about 45.2% of the total forest area. These forests provide an array of products as shown in Table 1 below:

Table 1. Multiple uses of high altitude coniferous forests in Pakistan

Use	No of species	Use	No of species
Timber	15	Fodder	20
Medicine	28	Fruit/Food	18
Fuelwood	14	Small wood	12
Ornamental	6	Resin etc.	2
Soap	2	Honey harvesting	4

ii) Low altitude (<1200 m) broad-leaved species forests

These forests cover an area of 520 000 ha of irrigated and foot hill plantations in Punjab and Sindh consisting of *Populus* sp. (poplar), *Dalbergia sissoo* (shisham), *Bombax ceiba* (semal), bakain, *Morus* sp. (mulberry) and *Eucalyptus*. The aridity is mostly compensated by irrigation.

iii) Agroforestry plantations

Farmers have been planting trees on their lands for centuries. Recently, these activities have been accelerated by the Forestry Planning and Development Project (1985–1996) and are now continued under forestry sector projects in each province. The most common species are eucalypts, bakain, semal, poplars, acacias, *Prosopis*, shisham and mulberry. The local requirements of farmers for fodder, fuelwood and poles are readily met from trees planted singly or in rows or in block plantations. A modified form of agroforestry system called "Hurry" is also practised in Sindh where 2–4 acres of land have been set aside to raise plantations of *Acacia nilotica* only. These plantations cover an area of about 200 000 ha. Farmers have also started to establish their own nurseries about two decades ago to increase tree cover especially on marginal lands.

iv) Coastal and riverine forests:
Located in the extreme southern part of Pakistan as well as along the banks of rivers *viz.* Indus, Chenab and Ravi, these tracts are rich in species like poplar and acacias. The coastal areas consist of valuable species of *Ceriops tagal*, *Aviecienia officinalis* and *Rhizophora mucronata*, which had been badly affected by river pollution in the recent past. A survey has indicated that nearly 21% of the coastal forests have been degraded and has adversely affected regeneration and growth of these species. The scarcity of water as well as the diversion of river flow due to construction of dams have degenerated *Populus euphratica* forests along riverbanks. There is a need to conserve this valuable genetic resource immediately. Such forests are spread over 345 000 ha.

Shelterwood system is generally used to manage natural stands of coniferous and broad-leaved species while irrigated plantations are managed through clear-cut felling by the provincial forest departments. Permission has to be obtained from the Forest Manager to fell a tree on a farmland by any farmer. Trees planted by the sides of roads and canals are also looked after and managed by the Forest Department. Currently national afforestation programmes are in operation to encourage tree cover on private lands through community participation. The scrub forests with sparse vegetation cover of about 1 271 000 ha mainly constitute scattered arid zone species like *Zizyphus*, *Acacia*, *Prosopis* and *Olea*. These plantations have undoubtedly reduced demand pressure of timber (as poles) and fuelwood from state forests.

Conservation of FGR
In the past, forests have been managed by the Provincial Forest Departments mainly for protection. It was only during the last three decades that production through involvement of local communities, had been given due consideration. As the FGR are mainly confined to mountainous areas of northern Pakistan, afforestation of logged over areas has been exclusively carried out by the Provincial Forest Departments sponsored by foreign aid agencies such as the World Food Programme (WFP), ADB, UNHCR, Swiss Development Agency, GTZ and FAO/UNDP. Indigenous species have been used with little consideration for conservation or use of quality planting stock. Stand conservation in the sub-continent has been practised since the mid-1940s in the form of "Preservation Plots" wherein the original flora of a compartment were maintained and preserved on scientific lines. However, no efforts were made during the last four decades to continue this system. By and large, as the human population pressure and livestock increased, the natural forests were not given due attention that they would have deserved. The genetic origin of the planting stock was of poor quality; seeds were collected from genetically inferior stands, which later on resulted in low survival and productivity in plantations. As for artificial regeneration, planting of less important species e.g. *Ailanthus* and *Robinia* in *Pinus roxburghii* (chir pine) stands has not only upset the natural ecosystem but also further masked FGR conservation efforts. These operations were supplemented by constructing check dams to improve water catchment areas, which resulted in degradation in the coniferous forests.

There is still a need to support such activities by establishing *ex situ* and *in situ* conservation stands. On account of the lack of proper FGR conservation measures, *Rhododendron*, an important native species associated with chir pine, is almost extinct and steps for *in situ* conservation of this species should be undertaken to rehabilitate and restore the ecosystem. There are also several other forest species that require special conservation efforts as these have several uses besides land stabilization and amelioration of the environment. These species are listed in Appendix 1. However, the species listed in Appendix 1 are not included in large-scale afforestation/artificial regeneration programmes but are important components of the ecosystems. The associated multipurpose tree food species (MPTFS) occurring in different ecological zones are also important for food security and many of these are either extinct or endangered in their native habitats (Shams R. Khan 1998).

Since seeds have often been collected from inferior trees/stands, the health status of plantations raised from such genetically poor sources may not be satisfactory (Blake 1991). There have been severe attacks of *Pinus wallichiana* (kail, blue pine) defoliators in the blue pine forests, which were later controlled by biological means. Low seeding in chir pine is a problem for the establishment of conservation stands. Provincial forest departments are not working on any FGR conservation activities. The Pakistan Forest Institute, Peshawar (PFI) did establish some species/provenance/progeny trials of over 12 ha to improve the coniferous forests of Pakistan. The study on isozymes has helped to identify highly diverse populations of chir pine to establish seed stands. Little or no research work has been done on *Abies, Picea, Cedrus, Acer, Taxus* or A*lnus* growing in coniferous forests in Himalayas. Plantations of major species in the natural stands of coniferous forests have been established in the recent past, but the provincial forest departments have ignored aspects of conservation of rare FGR. A separate R&D Directorate in the NWFP Forest Department has been created only a couple of years ago. This institute will hopefully undertake conservation and management activities in the future.

Similarly, several broad-leaved species in the plains are also either extinct or endangered as these have not been included in afforestation programmes. In order to improve seed collection and storage conditions, a seed centre has also been established in Azad Jammu & Kashmir to undertake preliminary seed testing programmes (Roshetko 1995).

Past and present research activities in conservation, utilization and management of FGR

The Pakistan Forest Institute, Peshawar (PFI) and Punjab Forestry Research Institute, Faisalabad (PFRI) are the only institutes working on forestry research at national level. The former is federally administered while the latter is a provincial organization. Under this set-up, there are little or no coordinated efforts between the two organizations for conservation and management of FGR. Located in two distinct ecological zones, the PFI has been handling genetic improvement work in the natural coniferous forests while the PFRI had undertaken studies in irrigated as well as farmland plantations. The activities of both institutes have been mainly confined to collecting and supplying quality seeds from plus trees and stands with little efforts towards conservation and management of rare and endangered species. A genebank with a storage capacity of 20 000 kg seed has been established at the PFI during early 1990s wherein *ex situ* conservation of target species has been undertaken. However, this facility could not be utilized to its full capacity due to lack of interest and knowledge of stakeholders in the conservation of FGR. Until and unless these activities are included in the national forest policy, conservation of FGR cannot be increased to the desired level. Establishment of seed stands as *in situ* conservation stands over an area of 8 ha is one step towards this direction. These stands are also ideal sites for conserving several other endangered associated species.

Conservation and use of *Pinus wallichiana*

Detailed ecogeographic studies in the natural forests of *Pinus wallichiana* suggest strict avoidance of transfer of germplasm from xeric to mesic habitats and vice versa. In addition, one ecotype (*Pinus wallichiana* var. *karakorama* Khan) has been found resistant to blister rust (Shams R. Khan 2001). This information could be effectively used to establish rust free *ex situ* conservation stands in Europe and America. However, due to geographically isolated small stands of this variety in Pakistan, there is a dire need to establish *in situ* and *ex situ* conservation stands. Besides these efforts, an area of 1000 ha (10.2% of the total area of occurrence of the species) has been declared as "protected areas" in some ecological zones, which could be used to restore this variety. *In situ* conservation studies are exclusively handled by the Provincial Wildlife Department with little coordination among field foresters and researchers. Such coordination needs to be further strengthened.

In vitro studies and micropropagation

Attempts on micropropagation (*in vitro* studies) of endangered species have not been undertaken so far on any tree species of economic importance in Pakistan. However, in case of dieback of *Dalbergia sissoo* (prevalent in Nepal and India also), use of biotechnological techniques might bring about desired results to control the disease. Similarly, such studies might be useful in the conservation of *Populus euphratica,* which is an industrially important endangered riverine tree species in the plains of Pakistan.

Choice of species for conservation

Considering, the efforts made in the past to restore important biomes and the multiple uses of several species, a number of exotic and indigenous species could be used so that the endangered native species are conserved. Proper and timely conservation measures are required for this purpose (Appendix 2). Most of the exotics have been successfully introduced recently and large-scale establishment of conservation cum demonstration plots is therefore recommended to rehabilitate the fragile ecosystem in the country. This is not an exhaustive list and could be updated at a national workshop on the conservation and management of FGR through participation and involvement of several stakeholders. Appendix 2 also indicates that so far no *in situ* conservation stands of any endangered indigenous species have been established and the number of individual tree species could still diminish unless protective measures are taken.

Natural forests in Pakistan represent a mixture of native coniferous and broad-leaved species and therefore, an ecological balance must be maintained through an appropriate mix of *ex situ* and *in situ* conservation stands. Several timber species, e.g. *Ulmus, Quercus, Fraxinus, Taxus* and *Picea* are endangered or vulnerable. Most of the fodder species like *Ficus, Prunus, Grewia* in the sub-tropical zone, and *Acer, Aelagnus* and *Quercus* in the temperate forests are disappearing at a very fast rate. These are considered low priority species by field foresters and are not included in any artificial regeneration programmes. Similarly, the inhabitants in hilly areas use the valuable wood of *Cedrus deodara* as firewood because of ignorance and easy accessibility. The pressure on these forests could be reduced if some alternatives for cooking and for heating were provided to the local people. Forest and soil degradation could be reduced if the original native flora was restored. Some surveys and regeneration studies on non-timber species have been undertaken by the PFI in the past on limited scale but these could not be developed and included in large-scale afforestation programmes at provincial level (Anwar A. Khan 1990). These native woody herbaceous and non-herbaceous genetic resources not only fulfil the basic needs of the local communities but also stabilize the eroded areas in the Himalayas, as they are the important components of the whole ecosystem.

Since species like *Quercus,* walnut, *Aesculus*, etc. are recalcitrant *ex situ* conservation as seeds is not possible. However, the establishment of *in situ* conservation areas and use of biotechnological techniques in certain species may help to promote and improve the status of FGR in the country. Conservation and management of coastal forest tree species is a challenging job because of difficulties in storage of seeds. Availability of firewood is another problem in the area as no other energy source is available.

In addition to the problems mentioned above, several biotic and abiotic factors (over-grazing, clearing of land for agriculture), pollution and construction of dams are some of the major direct causes for the genetic erosion of valuable FGR in Pakistan (Appendix 3).

In the past the PFI has successfully introduced some exotics to improve the biodiversity in different ecosystems in the country. In some cases they outperformed the native species in terms of survival and growth. If introduced species are found better and are posing no threat to the natives, they may be continued to be tested and included in tree improvement programmes and rehabilitation of degraded lands which in turn can help to reduce the pressure on natural forests. Being less aggressive, none of the above species have posed any threat so far, but rather enhanced net productivity, as these were found better than native ones (Pakistan Forest Institute's Annual Progress Reports 1980–2002).

Socioeconomic conditions and issues related to conservation, utilization and management of FGR

The activities of forest genetic resources conservation should be based upon the following three objectives for the benefit of the people:

1. Conservation efforts to meet the demand for timber for house construction
2. Conservation and management of fuelwood plantations to ensure sustainable supply of firewood especially in winter
3. Conservation and management of rangelands to ensure constant supply of endangered fodder trees to feed livestock in winter when the grasses are not available

Numerous protected areas have been established but they still do not represent and cover all forest types. So far, species/stands of high diversity have not been identified except in chir and blue pine forests. Similarly, forest habitats of rare or endangered species have not been conserved due to the weak link between field staff of forestry sector and professionals of FGR. There is also very little coordination between different sectors such as the Food, Agriculture and Livestock Department and wood-based industries. For example, an industrial woody species, *Dalbergia sissoo* has been severely attacked by dieback in the recent past, to which no concrete control measures have been developed so far. A few species occurring in riverine areas like *Tamarix aphylla* and *Populus euphratica* are excellent species for wood carving and can easily be utilized when the trees are around 10 years age. *Populus euphratica* is being threatened and needs immediate concrete steps for *in situ* or *ex situ* conservation. If a sustainable conservation and utilization effort could be put in place, the socioeconomic conditions of the rural poor could be improved, as *Populus euphratica* is the best species to develop cottage industry at village level in certain parts of Pakistan. *Populus, Morus* and *Salix* are the three important genera suitable for the sports industry largely located in the north-eastern part of Pakistan. There is a need for a strong link between production and utilization of these species and the wood industries and managers of FGR to be established at national level.

Similarly, with the collaboration of the Ministry of Education, UNESCO declared Lal Suhanara National Park as a MAB Biosphere Reserve in 1977, which was done without taking into confidence of the National Council for Conservation of Wildlife (NCCW), IUCN or WWF. The result was duplication of efforts and wastage of funds. These examples demonstrate the lack of linkages among different but highly related areas in FGR conservation and management. Based upon aforementioned discussion, a list of priority species for conservation, improvement and seed procurement is given in Appendix 4.

Identification of national priorities

In a national workshop in 1993 the following species were identified as priority species for different provinces (Table 2):

Table 2. Priority species for afforestation in different provinces in Pakistan

NTFPs	Punjab	Sindh	Balochistan	AJK & NA
Pinus wallichiana	*Dalbergia sissoo*	*A. nilotica*	*Acacia victoriae* (exotic)	*P. roxburghii*
P. roxburghii	*A. nilotica*	*E. camaldulensis*	*Acacia albida* (exotic)	*Pinus wallichiana*
Cedrus deodara	*Bombax ceiba*	*Conocarpus lancifolius*	*Pinus halepensis* (exotic)	*Robinia pseudoacacia*
Eucalyptus. camaldulensis	*P. deltoides*	*Albizia procera*	*E. camaldulensis*	*Ailanthus altissima*
Acacia nilotica	*E. camaldulensis*			*Sapindus mukorossi*
Populus deltoides				

The workshop, however, did not discuss the status of conservation of other important species found mixed in the natural stands and which are utilized to meet the needs of forest communities. It was found that almost all provinces needed large quantity of seeds of several species, and in almost all afforestation programmes quality was totally ignored in order to achieve high planting targets (Shams R. Khan 1993). Species listed in Appendix 1 indicate that some of the economically important species have been left with small populations that need immediate conservation measures. For this purpose, additional suitable protected areas have to be selected and demarcated to cover endangered tree species occurring in distinct ecological zones. No stands for *in situ* and *ex situ* conservation have been declared so far and therefore these must be immediately established either in the natural forests or in plantations. The provenance/progeny trials established in the past must be revisited to survey the current status of these trials. In view of the various threats, some species are either extinct, endangered or vulnerable as explained in Appendix 3. In some cases immediate conservation measures are needed to minimize forest and soil degradation.

The PFI can hardly meet 15–20% of seed demand of the forest departments, NGOs and farmers. The available supply includes mainly lowland broad-leaved species, as there is only one Seed Centre with a capacity of 20 000 kg. However, the demand of quality seeds of coniferous as well as few broad-leaved species of high hill forests cannot be met due to non-availability of professional staff and financial constraints. Extending Appendix 1 and Appendix 3, as well as in the light of national workshop on Seed Technology, a list of priority species has been prepared for the conservation and management of FGR (Appendix 4). The criteria for selection have been mainly based upon the current status and economic importance of these species. Holding a national workshop on conservation and management of biota could provide further selection and screening of the species. It is clear from Appendix 4 that conservation and management strategies of several multipurpose tree species in arid and temperate zones are badly needed.

Institutional framework and capacity building activities

The issues of forestry research and human resource development in the PFI were highlighted in a report submitted by the author to the FAO (Shams R. Khan 2001). Several suggestions were made to develop the institutional framework and to enhance research and training capabilities, including outlines to initiate and strengthen FGR conservation strategy in Pakistan. On account of a 50% reduction in the PFI technical staff, with no induction of fresh blood during the last decade, research capabilities have suffered in almost all disciplines of forestry research. This stagnation also led to a decline in chances of training for professional staff in research and development. It is suggested that short-term training in FGR conservation be provided to each Divisional Forest Officer (DFO) (Silva) to undertake and develop conservation strategies for both flora and fauna. As the knowledge in forest genetics and silviculture plays an important role and acts as a backbone in conservation it is suggested that long-term training in related areas be provided to the young professional staff to improve their capabilities.

Both the institutes, viz. the PFI and PFRI should undertake a detailed survey to assess the status of commercially important species so far as conservation is concerned. All such activities should be part and parcel of the national forest policy with proper monitoring and evaluation. Training programmes for local communities should be initiated to conserve woody as well as non-woody FGR. The Forest Geneticist/Silviculturist should be actively involved with the DFO (Silva) from the beginning of any conservation programmes. The team of wildlife in each province should be placed at the disposal of the Forest Geneticist to conserve critically endangered biomes.

A strong coordination is needed to strengthen the international treaties, like the CBD and the MAB-programme, to which Pakistan is a signatory. The CBD has emerged as the most powerful convention in the post-Rio era. It is now almost a decade that Pakistan signed and ratified the CBD. It has approved the Biodiversity Action Plan (BAP), submitted mandatory reports to the CBD secretariat and attended almost all the international meetings arranged by the CBD secretariat.

Since the preparation of the BAP was steered by an NGO (IUCN-P), it could be observed that the level of awareness as seen in the activities of similar NGOs is quite good. This could also be attributed to the availability of donor funds mainly from the GEF window for biodiversity. However, conservation efforts appear to revolve around wildlife, natural habitats and capacity building activities. Wildlife is one of the many components of biodiversity. Simultaneously, the association of tree growers and community-based organizations, NGOs and schoolchildren need to be involved in all activities for the conservation of genetic resources. The national TV should be used to create awareness among the people. Following these guidelines it is anticipated that the endangered species in some ecosystems may be restored.

Proposal for regional and international collaboration

Most of the *ex situ* conservation programmes and tree improvement activities in Pakistan had been sponsored by donor agencies such as the USDA, FAO and GTZ in the past. However, these activities have been discontinued in the last decade, which has badly affected the progress made on genetic improvement vis-à-vis conservation activities. Currently there is no research project at the PFI or PFRI related to conservation of woody endangered species except a small project on conservation and introduction of medicinal herbs. Some economically important coniferous and broad-leaved species are spread over several countries. It is therefore, suggested that international collaboration (especially on species that cover large distribution areas) should be strengthened. Pakistan could play a leading role in genealogical studies of endangered high hill species, including conservation and management of associated non-woody species.

Following an active collaboration with the CSIRO, research on rehabilitation of saline and waterlogged areas was initiated (Marcar *et al*. 1991). There is a need to conserve a specific source of *E. camaldulensis* (No. 15441) through the CSIRO to reclaim problematic areas in the country. In view of the results achieved by neighbouring countries in conservation and management of genetic resources, seminars and workshops may be held to exchange knowledge to bring about further genetic improvement vis-à-vis developing better strategies in the region. Following these steps it is anticipated that the endangered or regionally extinct species may be recovered in the fragile ecosystems of Himalayas, especially through the exchange of germplasm of important FGR in the region.

Conclusions

Conservation and management of endangered and rare species should be taken up at national level immediately. These species include both indigenous and exotic species, such as:

- **Indigenous:** *Aelagnus hortensis, Celtis eriocarpa, Diospyrus kaki, Ficus palmata, Fraxinus xanthoxyloides, Juniperus macropoda, Morus laevigata, Populus alba, P. ciliata, P. euphratica, P. nigra, Prunus amygdalus, P. padus, Pyrus pashia, Rhododendron spp.* and *Taxus baccata*
- **Exotics:** *Acacia albida, A. ampliceps, A. victoriae, Bombacopsis quinata, Casuarina equisetifolia, C. obesa, C. montana,* an Australian source of *E. camaldulensis, E. torelliana, Paulownia tomentosa, Pinus greggii,* a few clones of *Populus deltoides, Prosopis chilensis* and *P. pallida*

Protected areas in each ecological zone should be established and properly monitored following a listing of target species that need immediate conservation measures.

Establishment of species, provenance and progeny trials and genealogical studies of both local and exotic useful species would not only help to improve productivity and biomass of timber, fodder and fuelwood species but could also be an important component of biodiversity conservation and *ex situ* conservation of prioritised species. Since species do not recognize or respect political barriers and are widely distributed across several countries, there is a need to initiate network trials of the following important but neglected projects through the establishment of *ex situ* and *in situ* conservation stands:

1. *Ex situ* and *in situ* conservation of rust resistant stands of *P. wallichiana* var. *karakorama* in the Himalayas
2. Conservation and management of multipurpose tree food species
3. Exchange of germplasm and establishment of conservation areas of endangered species through network trials

It is recommended that the forestry sector in Pakistan should identify and recognize important stakeholders for the conservation and development of the nation's forests. They should be actively involved in policy making, implementation and monitoring. Establishment of a Provincial Forest Stakeholders' Forum should be considered to ensure the institutionalization of continued stakeholder participation in different policy making initiatives including coordination between provinces and between different domains of the federal forest policy. Analogous national forest conservation and coordination council is also suggested.

The tree improvement component should be an integral component in management plan of protected areas. Production of timber and fuelwood should not be the primary objective of the natural forests. They should be managed to maximize the ecological benefits of biodiversity conservation, watershed regulation and mitigation of climatic change. Research projects are needed to assess the relative performance of tree species in order to determine most appropriate treatments to enhance their performance. The management of natural stands of coniferous species should be based on best species combinations in order to achieve the aforementioned objectives.

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Appendix 1

Value and use of target species in Pakistan, including exotics

Species name	Value code	Present, future or potential use											
		ti	po	wo	nw	pu	fo	fd	sh	ag	co	am	xx
Abies pindrow	1	+	+	+									
**Acacia albida*	2	+	+	+	+			+	+	+			
**A. ampliceps*	2							+		+	+	+	+
A. catechu	1		+	+	+		+		+	+		+	
A. nilotica var. *cupressiformis*	1	+	+	+	+	+			+	+	+	+	
A. senegal	1	+	+	+	+			+	+		+		
**A. tortilis*	2	+	+	+				+	+		+		
**A. victoriae*	2	+	+	+				+	+				
Acer caesium	1	+	+					+			+	+	
Aelagnus hortensis	2		+	+				+	+	+	+	+	
Alnus nitida	2	+	+	+				+	+	+	+		
Atropa acuminata	2				+					+			
Avicennia officinalis	1	+	+	+							+		+
Azadirachta indica	2			+	+			+	+	+		+	
**Bombacopsis quinata*	2	+	+	+		+				+	+	+	
**Casuarina equisetifolia*	2	+	+							+		+	Salinity
**C. glauca*	2	+	+							+		+	Salinity
**C. obesa*	2	+	+							+		+	Salinity
Celtis eriocarpa	1	+	+	+			+	+	+	+	+	+	
Ceratonia siliqua	1		+				+	+	+	+	+	+	
Dalbergia sissoo	1	+	+	+				+	+	+		+	
Diospyros kaki	1		+				+	+		+	+		
**Eucalyptus camaldulensis* (15441)	2	+	+	+	+	+			+	+			Salinity
E. citriodora	2	+	+	+	+	+			+				
E. microtheca	2	+	+	+	+			+	+	+			Salinity
**E. torelliana*	2	+	+	+	+				+		+	+	
Fraxinus xanthoxyloides	1	+	+	+				+					
Grewia asiatica	1							+	+	+	+		
Juglans regia	1	+	+		+	+	+		+	+	+	+	
Juniperus macropoda	1	+	+	+							+	+	
Morus alba (wild)	1	+	+	+	+		+	+	+	+	+		
**Morus alba* (Chinese)	2		+	+			+	+		+	+		Sericul.

Species name	Value code	Present, future or potential use											
		ti	po	wo	nw	pu	fo	fd	sh	ag	co	am	xx
**Paulownia tomentosa*	2	+	+	+					+	+		+	
**Pinus greggii*	2	+	+	+									
P. gerardiana	1	+	+	+	+		+						
P. wallichiana var. karakorama	2	+	+	+	+								Blister rust
Pistacia khinjuk	1	+	+	+			+	+					
Populus alba	1	+	+	+				+			+	+	
P. ciliata	1	+	+	+				+			+		
**P. deltoides* (American)	2	+	+		+			+	+	+	+		Match
P. euphratica	1		+					+			+		
P. nigra	1	+	+		+			+		+	+	+	
**Prosopis chilensis*	2		+		+			+	+	+			
**P. pallida*	2		+		+			+	+	+			
Prunus amygdalus	1		+				+	+					
P. padus	1		+				+	+					
Pyrus communis	1		+				+	+		+			
P. pashia	1		+				+	+		+			
Quercus dilatata	1				+			+					
Q. ilex	1							+					
Q. incana	1							+					
Q. semecarpifolia	1				+			+					
Rhizophora mucronata	1	+	+		+								
Rhododendron spp.	2		+		+	+	+	+				+	
Salix babylonica	2		+					+		+	+	+	Sport
S. tetrasperma	2		+					+		+	+	+	Sport
Saussurea lappa	2					+							
Tamarindus indica	1		+		+		+						
Taxus baccata	2	+	+			+							
Tecoma undulata	1		+		+			+				+	
Ziziphus jujuba	1						+	+	+	+	+		
Z. nummularia	1		+				+	+	+	+	+		

* = Exotic species

VALUE: 1 = Species of current socioeconomic importance; 2 = Species with clear potential of future value; 3 = Species of unknown value given present knowledge and technology

UTILIZATION: ti = timber production; po = posts, poles, roundwood; wo = fuelwood, charcoal; nw = non-wood products (gums, resins, oils, tannins, medicines, dyes, etc.); pu = pulp and paper; fo = food; fd = fodder; sh = shade, shelter; ag = agroforestry systems; so = soil and water conservators; am = amenity, antithetic, ethical values; xx = other (specify)

Appendix 2

Conservation and management of economically important forest genetic resources by ecogeographic zone in Pakistan (number of individual trees in each ecological zone)

Species	Ecological zone	Nature reserves, protected areas	*In situ* conservation stands	Managed forests	Plantations	*Ex situ* conservation stands	Villages, fields, homesteads	Experiment. fields, trials
Abies pindrow	DWT	>1000	–	>10000	–	–	–	–
Acacia catechu	ST	–	–	<100	–	–	–	–
A. nilotica var. *cupressiformis*	ASA	>100	–	>500	<100	>500	>1000	<1000
A. senegal	T	>1000	–	>10000	>1000	–	–	–
Acer caesium	WT	>500	–	>10000	–	–	–	–
Aelagnus hortensis	DT	<100	–	>1000	–	–	>1000	<100
Alnus nitida	ST	–	–	<100	–	–	>500	–
Atropa acuminata	DWT	<100	–	>100	–	–	–	<100
Avicennia officinalis	T	–	–	>10000	>10000	–	–	–
Azadirachta indica	ASA	–	–	–	>10000	>500	>1000	–
Celtis eriocarpa	ST	–	–	>100	–	–	<100	–
Ceratonia siliqua	A	<100	–	>500	<100	–	<100	–
Dalbergia sissoo	ASA	>10000	–	–	>10000	–	>10000	>1000
Diospyros kaki	ST, WT	–	–	>100	–	–	<100	–
Eucalyptus citriodora	ASA	–	–	–	>1000	–	–	–
E. microtheca	ASA	–	–	–	>1000	–	–	<100
Fraxinus xanthoxyloides	WT	–	–	>100	–	–	–	–
Grewia asiatica	ST	–	–	>100	–	–	<100	–
Juglans regia	DWT	<100	–	>1000	>1000	<100	<100	–
Juniperus macropoda	DT	>10000	–	>10000	–	–	–	–
Morus alba	ST	–	–	–	>10000	–	>500	–
Pinus gerardiana	DT	>10000	–	>10000	>10000	–	–	–
P. wallichiana var. *karakorama*	DT	1000	–	>10000	–	>500	–	>100
Pistacia khinjuk	DT	–	–	>1000	–	–	<100	–
Populus alba	WT	<100	–	>500	–	–	–	<100
P. ciliata	WT	<100	–	>500	–	–	–	<100

Species	Ecological zone	Nature reserves, protected areas	*In situ* conservation stands	Managed forests	Plantations	*Ex situ* conservation stands	Villages, fields, homesteads	Experiment. fields*, trials
P. euphratica	T	–	–	>1000	–	–	–	<100
P. nigra	DWT	–	–	<100	>1000	–	>10000	–
Prunus amygdalus	WT	–	–	<100	–	–	<100	–
P. padus	WT	–	–	<100	–	–	<100	–
Pyrus communis	WT	–	–	<100	–	–	<100	–
P. pashia	WT	–	–	<100	–	–	<100	–
Quercus dilatata	DWT	–	–	>1000	–	–	–	–
Q. ilex	ST	–	–	>1000	–	–	–	–
Q. incana	WT	–	–	>1000	–	–	–	–
Q. semecarpifolia	WT	–	–	>1000	–	–	–	–
Rhizophora mucronata	T	–	–	>10000	–	–	–	–
Rhododendron spp.	ST	–	–	<100	–	–	–	–
Salix babylonica	WT	–	–	>1000	–	–	<100	–
S. tetrasperma	ST	–	–	<100	–	–	<100	–
Saussurea lappa	WT	–	–	>1000	–	–	–	–
Tamarindus indica	T	–	–	–	–	–	>1000	–
Taxus baccata	WT	–	–	<100	–	–	–	–
Tecoma undulata	A	–	–	–	–	–	>500	–
Ziziphus jujuba	A	–	–	>1000	–	–	>1000	<100
Z. nummularia	ST	–	–	–	–	–	<100	–

Ecological zone: A = Arid; SA = Semi-arid; ASA = Arid, semi-arid; ST = Sub-tropical; T = Tropical; DT = Dry temperate; WT = Wet temperate; DWT = Dry-wet temperate

Note: Exotics were deleted as small plots (<500 trees) are being tested on experimental basis.

Appendix 3

Level and nature of threats to the integrity of populations of important tree species in Pakistan

Species in ecogeographic (or genecological) zones	Ecological zone	Direct causes of threats (1–6)							
		Reserves, natural areas	*In situ* conservation stands	Managed forests	Plantations	*Ex situ* conservation stands	Villages, fields, homesteads	Exper. fields, trials	Degree of threat i ndex (1 – 5)
Abies pindrow	DWT	1,2	–	1	–	–	–	–	5
Acacia albida	ASA	–	–	–	–	1	–	1	1
A. ampliceps	ASA	–	–	–	–	1	–	1	1
A. catechu	ST	–	–	–	–	–	–	1	2–4
A. nilotica var. *cupressiformis*	ASA	1,2	–	–	1,2	1	4	1,2	5
A. senegal	T	–	–	1,6	2	–	–	–	2–4
A. tortilis	ASA	–	–	–	2	–	–	–	1
A. victoriae	ASA	–	–	–	2	–	–	–	1
Acer caesium	WT	–	–	1	–	–	–	–	2–4
Aelagnus hortensis	DT	1,2	–	–	1,2	–	–	–	2–4
Alnus nitida	ST	–	–	–	–	–	1,2,4,6	–	5
Atropa acuminata	DWT	1,2,4	–	1	–	–	–	–	5
Aviecinia officinalis	T	3	–	1	–	–	–	–	2–4
Azadirachta indica	ASA	–	–	1,2	1,2	–	2,4	–	2–4
Bombacopsis quinata	T	–	–	–	–	–	–	1	1
Casuarina equisetifolia	ASA	–	–	–	–	–	–	1	1
C. glauca	ASA	–	–	–	–	–	–	1	1
C. obesa	ASA	–	–	–	–	–	–	1	1
Celtis eriocarpa	ST	1,2	–	1,2	–	–	2,4	–	5
Ceratonia siliqua	A	–	–	1,2	–	–	2,4,5	–	2–4
Dalbergia sissoo	ASA	–	–	–	1	1	3	1	2–4
Diospyrus kaki	ST	1,2	–	2	–	–	4	–	5
Eucalyptus camaldulensis (15441)	ASA	–	–	–	–	1	–	1	1
E. citriodora	ASA	1	–	–	1	1	4,5	1	5
E. microtheca	A	1	–	–	1	1	4	1	5
E. torelliana	ASA	–	–	–	1	1	–	1	1
Fraxinus xanthoxyloides	WT	1,2	–	1,2	–	–	–	–	5
Grewia asiatica	ST	2	–	1,2	–	–	2,4	–	5
Juglans regia	DWT	1	–	1	1,2	–	2,4,5	–	2–4
Juniperus macropoda	DT	2	–	1	–	–	–	–	2–4
Morus alba (wild)	ST	2	–	2	–	–	4,5	–	5
Morus alba (Chinese)	ST	–	–	–	1	–	–	–	2–4
Paulownia tomentosa	T	–	–	–	–	–	1	1	1

Species in ecogeographic (or genecological) zones	Ecological zone	Direct causes of threats (1–6)							
		Reserves, natural areas	*In situ* conservation stands	Managed forests	Plantations	*Ex situ* conservation stands	Villages, fields, homesteads	Exper. fields, trials	Degree of threat i ndex (1 – 5)
Pinus greggii	ST	1	–	–	–	2,4	4	1	1
P. gerardiana	DT	1,2,3,4	–	–	–	–	–	1	2,4
P. wallichiana var. *karakorama*	DT	1,2,3,4	–	–	1,2	1	–	1	2–4
Pistacia khinjuk	DT	1,2	–	–	–	–	–	–	2–4
Populus alba	WT	1,2	–	1	–	–	–	–	5
P. ciliata	WT	1,2	–	1	–	–	–	–	5
P. deltoides (American)	T&ST	–	–	–	3	–	–	–	2–4
P. euphratica	T	–	–	–	1,2,3,6	–	–	–	5
P. nigra	DWT	–	–	–	1,6	–	1,5	1	2–4
Prosopis chilensis	ASA	–	–	–	–	–	–	1	1
P. pallida	ASA	–	–	–	–	–	–	1	1
Prunus amygdalis	WT	1	–	1,2	–	–	–	–	5
P. padis	WT	1	–	1,2	–	–	–	–	5
Pyrus communis	WT	1,2	–	1	–	–	–	–	5
P. pashia	WT	1	–	1	–	–	–	–	5
Quercus dilatata	DWT	1,2	–	–	–	–	–	–	2–4
Q. ilex	ST	1,2	–	–	–	–	–	–	2–4
Q. incana	WT	1,2	–	–	–	–	–	–	2–4
Q. semicarpifolia	WT	1,2	–	–	–	–	–	–	2–4
Rhizophora mucronata	T	1,2,3	–	–	–	–	–	–	2–4
Rhododendron spp.	ST	1,2,6	–	–	–	–	–	–	5
Salix babylonica	WT	1,2,3	–	–	–	–	4	–	5
S. tetrasperma	ST	1,2	–	–	–	–	4	–	5
Saussuria lappa	WT	1,2,4	–	1,2	–	1	–	–	5
Taxus baccata	WT	1,2,4,6	–	1,2	–	–	–	–	5
Zizyphus jujuba/Z. nummularia	A	–	–	1	1,2	–	3,4	–	2–4

Direct causes of threats include the following categories:

1 = Unmanaged use and harvesting;
2 = Unmanaged grazing and browsing (domestic animals, wildlife);
3 = Wildfires, environmental biotic/abiotic factors (drought, pests, diseases, floods, pollution);
4 = Clearing for agriculture or pasture;
5 = Infrastructure development (dams, mining, urban expansion);
6 = Other, e.g. lack of knowledge/ignorance; fuelwood collection

Threat Index (1–5):

1 = Implementation/enforcement of regulations probable and regulations scientifically sound. Low level of threat.
5 = Implementation/enforcement of regulations unlikely; or threat severe with high probability of genetic degradation or loss. High level of threat.
2–4 = Intermediate between 1 and 5.

Appendix 4

List of priority species for conservation, improvement or seed procurement, their uses and conservation activities needed

Species	End use				Operations / activities needed								REMARKS
	W	NW	FW	O	Exploration & collection		Evaluation		Conservation		Germplasm use		
	1	2	3	4	5	6	7	8	9	10	11	12	13
Abies pindrow	+				+								(2)
Acacia albida	+		+	+		+				+	+		(2)
A. ampliceps			+	+		+				+	+		(2)
A. nilotica var. *cupressiformis*	+	+	+	+	+	+		+		+	+	+	PGT
A. senegal	+	+	+	+	+	+							(2)
A. tortilis	+		+	+		+				+	+		(2)
A. victoriae	+		+	+		+				+	+		(2)
Acer caesium	+			+	+								(1)
Aelagnus hortensis			+	+	+			+		+	+		MPTS (1)
Alnus nitida	+		+	+	+								E (1)
Atropa acuminata		+	+	+	+	+				+	+		E (1)
Avicennia officinalis	+		+		+								
Azadirachta indica		+		+	+		+	+		+	+	+	PVT/PGT (2)
Bombacopsis quinata	+		+	+						+	+		SO (2)
Casuarina equisetifolia	+		+	+		+				+	+		MPTS (2)
C. glauca	+		+	+		+				+	+		MPTS (2)
C. obesa	+		+	+		+				+	+		MPTS (2)
Celtis eriocarpa			+	+									(1)
Ceratonia siliqua				+	+						+		(2)
Dalbergia sissoo	+			+	+	+	+	+		+	+	+	SO (2)
Diospyros kaki			+	+	+								E (1)
Eucalyptus camaldulensis (15441)	+	+	+	+	+	+	+			+	+		SO (2)
E. citriodora	+	+	+	+	+					+	+		
E. microtheca	+	+	+		+					+	+		MPTS
E. torelliana	+	+	+	+		+				+	+		SO (2)
Fraxinus xanthoxyloides	+		+	+									E (1)
Grewia asiatica			+	+	+								E (1)
Juglans regia	+	+	+	+	+					+	+		SO (2)
Juniperus macropoda	+		+	+	+	+				+	+		(3)
Morus alba (wild)	+		+	+	+					+			MPTS (1)
Morus alba (Chinese)				+	+	+				+	+		MPTS (2)
Paulownia tomentosa	+			+		+				+	+		MPTS (3)
Pinus greggii	+		+	+						+			SO (2)

Species	End use				Operations / activities needed								REMARKS
	W	NW	FW	O	Exploration & collection		Evaluation		Conservation		Germplasm use		
	1	2	3	4	5	6	7	8	9	10	11	12	13
Pinus gerardiana	+			+	+						+		SO (3)
P. wallichiana var. karakorama	+	+	+		+		+	+		+	+	+	PVT (2)
Pistacia khinjuk			+	+	+								(3)
Populus alba	+		+	+	+	+	+	+		+	+	+	CLT (2)
P. ciliata	+		+	+	+	+	+	+		+		+	PGT (2)
P. deltoides (American)	+		+	+	+	+		+		+		+	PGT (3)
P. euphratica	+		+	+	+	+	+	+		+		+	PGT (1)
P. nigra	+		+	+	+								PGT (3)
Prosopis chilensis			+	+		+				+	+		MPTS (2)
P. pallida			+	+		+				+	+		MPTS (2)
Prunus amygdalus			+	+	+								MPTS, E (1)
P. padis			+	+	+								MPTS, E (1)
Pyrus communis			+	+	+								MPTS, E(1)
P. pashia			+	+	+								MPTS, E(1)
Quercus dilatata				+	+								(2)
Q. ilex				+	+								(2)
Q. incana				+	+								(2)
Q. semecarpifolia				+	+								(2)
Rhizophora mucronata	+		+		+								(3)
Rhododendron spp.				+	+								E (1)
Salix babylonica	+		+	+	+								MPTS (2)
S. tetrasperma	+		+	+	+								MPTS (2)
Saussurea lappa		+			+	+				+	+		E (2)
Taxus baccata	+	+			+								E (1)
Ziziphus jujuba				+	+	+				+	+		MPTS (2)

End uses: 1 = Industrial wood products (logs, sawtimber, construction wood, plywood, chip and particle board, wood pulp etc.); **2 =** Industrial non-wood products (gums, resin, oils, tannins); **3 =** Fuelwood, posts, poles (firewood, charcoal, roundwood used on-farm, wood for carving); **4 =** Other uses, goods and services (food, medicinal use, fodder, land stabilization/amelioration, shade, shelter, environmental values).

Exploration & collection: 5 = Biological information (natural distribution, taxonomy, genecology, phenology etc.); **6 =** Collection of germplasm for evaluation

Evaluation: 7 = *In situ* (population studies); **8 =** *Ex situ* (provenance and progeny tests)

Conservation: 9 = *In situ*; **10 =** *Ex situ*

Reproductive use/germplasm use: 11 = Semi-bulk/bulk seedlots, reproductive materials; **12 =** Selection and improvement

Remarks (13): Specific uses not obvious from columns 1-4 are mentioned. Also, work in progress is reported in this column.

PVT = provenance trials; E = endangered at species or provenance level; PGT = progeny trials; MPTS = multi-purpose tree species; CLT = clonal trials; SO = seed orchard

Rating: 1 = Highest priority, action should start, or be continued, with immediate effect; **2 =** Prompt action recommended, action should start within next two biennia; **3 =** Action required in next five to ten year.