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State of Forest Genetic Resources Conservation and Management in India

by

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The Forest Genetic Resources Working Papers report on issues and activities in related to the conservation, sustainable use and management of forest genetic resources. The purpose of these papers is to provide early information on on-going activities and programmes and to stimulate discussion.

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Comments and feedback are welcome.

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1. Introduction

Forests are the world's most important and most valuable renewable natural resource and also repositories of terrestrial biological diversity. This resource is in imminent danger due to adverse abiotic and biotic stresses resulting from urban expansion, infrastructural development, agriculture and global warming (Bawa and Dayanandan 1998; Brown and Pearce 1994; Stedman-Edwards 1998). Since forests are long-living, out-breeding, generally highly heterogeneous and found in variable environments, they have developed complex mechanisms to maintain high intraspecific diversity. It is well recognized that genetic variation is essential for species to evolve and adapt to changing environmental conditions. The sustained ability of forest trees to provide goods and services thus depends on the maintenance and management of forest genetic resources (FGR). Despite the enormous threats, there have been limited concentrated efforts to address the conservation concerns of forest trees. India, for example, though being an acknowledged leader in conservation of crop genetic resources, has no systematic programme for conservation of FGR. Among others, critical information on the status, threats and extent and distribution of genetic diversity are required for planning effective conservation strategies. Though the basic principles of conservation of FGR are conceptually rooted in our understanding of crop genetic resources, the challenge lies in breaking free from this legacy and formulation of specific protocols that suit tree species.

2. Status of forest genetic resources in India

India is one of the 12 centres of biological diversity in the world and the origin of several cultivated plants. It is estimated that about 45 000 species of plants occur in India, of which flowering plants account for 15 000 species. About 5000 of the flowering plants are endemic. The wild relatives of crop plants, together with other economically important species (about 150 species) are rich sources of many important and desirable characters and constitute a gene pool of potential use. The term FGR is used variedly and encloses a range of components from intraspecific diversity to inter-specific genetic diversity among a set of taxonomically and/or ecologically related species, to the entire range of forest species that are economically important and/or potentially useful (Young *et al.* 1999). It has been reported that in India there are about 6270 economically important species (Table 1).

TABLE 1. ECONOMICALLY IMPORTANT PLANT DIVERSITY IN INDIA AS IDENTIFIED IN THE IV INTERNATIONAL CONGRESS OF ETHNOBIOLOGY, LUCKNOW, INDIA, 1994 (ICE 1994)

Economic uses	Number of species
Food	1200
Fodder	2200
Fuel and timber	1000
Medicines	1500
Fibre	150
Spices	120
Oil	100

N.B. It is likely that some of the species are being used for more than one purpose.

The rich traditions of modern scientific forest management began in 1864 under the British administration with the establishment of the Indian Forest Department. Since then, new forest policies have been issued in 1894, 1952, and 1988.

In India the protection and improvement of the environment and the safeguarding of forest and wildlife is ensured under the directive of state policy Articles 48 A and 51 A (g), Part IV of the Constitution. The Constitution directs citizens to protect nature and also provides for forests and wildlife as concurrent subjects under Schedule 8, List III, and Entry 17-A and 17-B.

A large segment of India's population depends on forests for energy, housing materials, timber and fodder. The demand for forest products and services in the country is increasing with the rapid economic growth and increase in population whereas the forested area in the country is declining (Myers *et al*. 2000). According to the projections of United Nations, India is expected to be the most populous country in the world by 2020. Both urban and rural population will continue to grow, this factor will be important from the point of view of forestry and genetic conservation. India has 2% of the world's land area, 1% of its forests and 0.5% of its rangelands but supports 16% of the human population and 15% of world's cattle population (Ahmed 1997). The increased demand for forest products, along with population growth and poverty is putting great pressure on all resources, including forests.

In the economic sphere, India is undergoing a profound change. It has moved from a slow-growing to a very dynamic economy. By 2020, the per capita income in South Asia is expected to rise from US$350 in 1995 to US$830. This will greatly change the demand for all products, including forest products and services. India is short of forest resources and the current roundwood supply shortfall of 26 million m^3 annually is expected to remain in the foreseeable future (Ganguli 2000).

According to Ahmed (1997), the total annual value of India's forest products is estimated to be Rs 300 000 million (about US$ 6662 million) compared to the meagre investments of Rs 8000 million (US$ 176 million) in this sector. Indian forests contribute significantly to meet the demand for fuelwood, fodder, and non-wood forest products and the major portion of all wood harvested (92%) is for fuelwood for cooking.

The non-timber forest products (NTFPs) play a very important role in the country's economy. They form the basic raw material for phytopharmaceuticals and various other industries. Herbal medicines in use today are derived from nearly 8200 species of medicinal plants. In the developing countries, more than 80% of the population depends on traditional plant-based medicines, and even in the USA, 25% of the prescription drugs are still based on phytochemicals. NTFPs offer an excellent potential for international trade. Ahmed (1997) reported eight categories of NTFPs some are important for tribal indigenous groups. For example, in West Bengal tribal groups collect 27 plants for commercial products, 39 plants for food, and 47 for medicines. NTFPs account for 70% of India's forest product exports and the demand for phytochemicals is expected to increase in the future. NTFPs could become a new frontier for trade and sustainable commercialization of biological resources at the international level if intellectual property rights are secured.

3. National conservation programmes and management of FGR

Many countries have national policies or special programmes for the conservation of biological diversity, including forest biological diversity and FGR. The growing attention to conservation reflects increasing concern about alterations in the forests and the long-term maintenance of the health and overall productivity of forests and forest ecosystems.

The Convention on Biological Diversity (CBD), adopted in 1992, affirms that States have sovereign rights over their biological resources and that they are responsible for conserving their biological diversity and for using them in a sustainable manner. The CBD relates to ecological, social, economic and ethical values of diversity.

National policies and programmes related to FGR cover a wide range of activities, from conservation measures to protection of rare and endangered species and populations, and regulations governing seed collection and transfer in socioeconomically important tree species to comprehensive approaches to the management of landscapes, ecosystems and FGR. With these complexities in mind, considerations related to FGR in India have been integrated within broad frameworks, such as national forest programmes and biodiversity action plans (Biodiversity Bill 2002).

The management of an appropriate combination of genetic resources in various locations under diverse environmental and silvicultural practices, such as provenance trails and progeny trials, is considered to be the most efficient way to conserve various levels of genetic variation to increase the productivity. However, it takes relatively long time to evaluate and identify the provenances suitable for conservation. However, most often genetic conservation has to be carried out without a real understanding of the genetic background of the populations and depends on population genetic models. In Indian forest ecosystems, some economically important forest tree species have been conserved in genebanks, *in situ* and *ex situ* conservation sites with wide networking between the State forest departments. National parks (87) and other protected areas in the form of biosphere reserves (12) and wildlife sanctuaries (421), which have been regarded as *in situ* conservation and management of FGR at the species level (Tables 2 and 3).

TABLE 2. BIOSPHERE RESERVES IN INDIA (FSI 2001)

Name of Biosphere reserve	State/Union Territory	Area (km^2)
Great Nicobar	Andaman Nicobar (A&N)	885.0
Manas	Assam	2837.0
Nanda Devi	Uttaranchal	2236.7
Nilgiri	Tamil Nadu, Kerala and Karnataka	5520.0
Nokrek	Meghalaya	820.0
Sunderbans	West Bengal	9630.0
Dibru-Saikhowa	Assam	765.0
Dehang-Debang	Arunachal Pradesh	5111.5
Gulf of Mannar	Tamil Nadu	10500.0
Pachmarhi	Madhya Pradesh	4926.3
Simlipal	Orissa	4374.0
Khangchendzonga (proposed)	Sikkim	2655.3
Agasthyamalai	Kerala	1701.0

TABLE 3. NATIONAL PARKS AND WILDLIFE SANCTUARIES IN INDIA (FSI 2001; RODEGERS AND PANWAR 1986)

States	National parks		Wildlife sanctuaries		Total area (km^2)
	Number	Area (km^2)	Number	Area (km^2)	
Andhra Pradesh	4	3314.5	21	12 530.1	15 844.6
Arunachal Pradesh	2	2468.2	10	7114.5	9582.7
Assam	3	1173.7	13	939.9	2113.6
Bihar	2	567.3	21	3890.3	4457.6
Chattisgarh	3	n.a.	n.a.	n.a.	n.a.
Delhi	0	0	1	27.6	27.6
Goa	1	107.0	6	648.0	755.0
Gujarat	4	479.7	21	16 422.7	16 902.4
Haryana	1	1.4	9	278.3	279.8
Himachal Pradesh	2	1429.4	32	5736.9	7166.3
Jammu & Kashmir	4	4650.1	16	10 172.2	14 822.2
Jharkahnd	1	n.a.	n.a.	n.a.	n.a.
Karnataka	5	2472.2	20	3930.6	6402.8
Kerala	3	536.5	12	2143.4	2679.9
Madhya Pradesh	11	6474.7	35	10 704.1	17 178.7
Maharashtra	5	955.9	33	14 387.8	15 343.7
Manipur	2	81.8	1	184.9	266.6
Meghalaya	2	267.5	3	34.2	301.7
Mizoram	2	250.0	4	634.0	884.0
Nagaland	1	202.0	3	24.4	226.4
Orissa	2	990.7	18	6971.2	7961.9
Punjab	n.a.	0	11	317.8	317.8
Rajasthan	4	3856.5	24	5712.8	9569.4
Sikkim	1	1784.0	5	265.1	2049.1
Tamil Nadu	5	307.9	20	2602.1	2909.9
Tripura	n.a.	0	4	603.6	603.6
Uttranchal	6	n.a.	n.a.	n.a.	n.a.
Uttar Pradesh	7	5410.8	29	7594.5	13 005.4
West Bengal	5	1692.7	16	1103.5	2796.1
A & N Islands	9	1157.1	94	372.1	1 529.3
Chandigarh	0	0	2	26.0	26.0
Dadra & Nagar Haveli	0	0	0	0	0
Daman & Diu	0	0	1	2.2	2.2
Lakshadweep	0	0	0	0	0
Pondicherry	0	0	0	0	0
Total	**87**	**40 631.6**	**485**	**115 374.4**	**156 006.1**

In addition, a variety of field repositories of genetic resources, including nature reserves and other protected areas, private and publicly owned, managed and unmanaged, natural forests and plantations, trees outside forests managed in agroforestry systems and growing on homesteads and along rivers and roads, arboreta and botanic gardens, field trials and live collections have also been developed within the framework of selection and tree improvement programmes to increase the productivity of forest.

4. Role of the Indian Council of Forestry Research and Education in conservation of forest genetic resources

The National Bureau of Plant Genetic Resources (an independent national institute) has been working to introduce, collect and conserve plant genetic resources of mainly agricultural and horticultural species in India since 1976. Taking into consideration legal, political, economic and social issues, management of PGR has to be stratified, as these resources are imperative to sustainable development globally. The Indian Council of Forestry Research and Education (ICFRE) is an autonomous body under the Ministry of Environment and Forests, Government of India, with eight research institutes and three advanced centres in various parts of the country. ICFRE caters to the needs of different biogeographical regions of the nation to increase the productivity through genetic and silvicultural improvement, treatment of wasteland and conservation of forest ecosystems. ICFRE has expertise and research collaboration with DANIDA and collaborative ventures with various international organizations, such as FAO, FORTIP (UNDP/FAO Regional Forest Tree Improvement Project), UNDP and World Bank on economically important species. ICFRE established a National Bureau of Forest Genetic Resources (NBFGR) with a wide network of regional institutes situated at various agroecological zones for germplasm collection, *ex situ* and *in situ* conservation as well as introduction and evaluation.

To reach the desired goals, the following priority areas for research have been identified (NFRP 2001):

- Develop mitigation strategies in forestry sector to reduce and store green house gases
- Research on upland watershed management (integrated soil and water conservation to check siltation and water scarcity and to boost afforestation)
- Research on reforestation of degraded lands and problematic soils (barren, mined, waste, water-logged and salt-affected lands, etc)
- Research on conservation, protection and sustainable development of existing forests to conserve biodiversity
- Increasing productivity of existing forests and future plantations through:
    - High quality seed production
    - Production and multiplication of site matched planting stock
    - Improvement of species and varieties using traditional breeding methods and biotechnology
    - Biological rejuvenation of lands using mycorrhizae and other useful microorganisms
- Research on multipurpose trees in farming systems
- Research on improved utilization of traditional wood and paper products, including improved recovery and processing
- Research on non-wood forest products, which provide sustenance to people and supply raw materials to a large number of forest-based industries
- Research on modern tools, equipment, techniques and operations for afforestation, logging and extraction of forest products
- Protection of forest from entomological and pathological problems
- Socioeconomic research for motivating farmers/land owners to adopt tree farming in a manner similar to crop-based farming

Research on policy strategies and combination of measures desired for enlarging the area under forest has included studies on property rights and land tenure, culture and gender issues involved in conservation, non-timber products, effects of tariff and non-tariff trade barriers, legal and regulatory settings for forestry and other laws regulating tree felling, transportation and sales.

4.1. International Forest Genetic Resource Programme

ICFRE has established a National Bureau of Forest Genetic Resources (NBFGR) under its International Genetic Resource Programme, along the lines of the National Bureau of Plant Genetics Resources (NBPGR). ICFRE is managing the collection, documentation, evaluation and use of tree genetic resources available in India. ICFRE has established a similar line of action as established by the NBPGR, FAO, CIRAD, DANIDA, DFSC, FRED, FORTIP, World Bank-project and UNDP in promoting FGR research activities in India. ICFRE is interacting with various international organisations, such as the International Plant Genetic Resources Institute (IPGRI) on specific issues related to FGR conservation.

5. Present level of production and use of genetically superior propagules

Though various tree species are planted every year, 90% of the plantation programmes consist of bamboos, *Eucalyptus, Acacia, Albizia*, *Prosopis juliflora, P. cineraria, Dalbergia sissoo*, conifers and teak. During the late eighties and early nineties, $3x10^9$ plants were planted annually. Of these, a certain percentage of seeds were obtained from seed production areas (SPAs). There are 3100 ha of SPAs for teak and an additional 900 ha of clonal seed orchard (CSOs) for teak. The seeds from these can supply 30-35 % of the demand.

Similarly, nearly 8000 ha of conifer seed stands have been identified (not seed production areas). There are 24.6 ha of SPAs for *Dalbergia sissoo* available and 91 ha for eucalypts. For various other species, for which there is only limited local demand, seeds are collected from respective SPAs. An estimated 155 000 kg of teak seeds are available from the 3100 ha SPA for teak annually. With germination of 35% and survival of 60%, a little over 16 000 ha can be planted with these seeds. The CSOs produce much less than the expected amount per tree. Often many clones flower at different times resulting in poor seed set. On average, 30 kg of seeds are collected per ha. From the 900 ha of CSOs of teak in the country, 27 000 kg of seeds are collected which are sufficient for planting of 3 000 ha with 30% germination and 60% survival. While establishing CSOs, it is essential to consider the need for synchronous flowering.

For *Dalbergia sissoo*, around 300 kg of seeds can be obtained from the 24 ha of SPAs, which is sufficient to plant 9000 ha. There are 90 ha of SPAs for eucalypts providing 450 kg of seeds sufficient to plant 40 000 ha. The work done on conifers is not reliable as most of the areas classified as seed stands are unculled. The seed yield varies highly from tree to tree. In the case of bamboo, a large amount of seeds is collected, but these cannot be classified as superior seeds. They are collected in bulk when the entire plantation flowers, as for many years there may not be any collections at all.

It is obvious from the above that teak is the single most important species collected from SPAs. Significant quantities of eucalypts and *Dalbergia sissoo* are also available. The annual planting of tree seedlings in the country exceeds 3020 million seedlings with 180 million seedlings originating from SPAs; majority of the planted species being teak, *Dalbergia sissoo* and eucalypts.

6. Future requirements for superior propagules

Being a vast country with varying climatic and edaphic conditions, India has a variety of vegetation types. The cultural diversity coupled with traditional practices has made the people highly dependent on various types of local vegetation. Therefore, preferences for different species vary considerably. This results in a dilemma in the species choice, especially when the sociological aspects are taken into consideration. Various state forest departments have developed strategies to grow species taking into consideration local requirements, in addition to other species that are required in large amount. The current annual rate of planting of social forestry species is around 1.5 million ha and the number of seedlings planted is approximately 3000 million. The future annual planting target is expected to be little over 3 million ha, consisting mainly of bamboos, *Eucalyptus, Acacia, Albizia, Prosopis, Casuarina, Dalbergia,* conifers and teak. The projected annual requirement of tree seedlings is 6160 million, of which around 23.5% is expected to be raised from SPAs of certified seed sources and around 15% is expected to be raised from genetically improved sources. Fifty per cent of the teak seeds will be coming from SPAs and 25% from genetically improved stock. Likewise, about 25% of future *Eucalyptus* seeds is expected to be provided as genetically improved stock. In the case of *Acacias* and *Albizia*, not less than 30% of seeds will be collected from identified/certified seed sources. In the case of *Casuarina* and *Dalbergia sissoo*, 20 and 10%, respectively, will be made available from genetically improved plants. It is possible that the amount of seeds of these two species available from the genetically improved plants may be doubled as a result of a tree improvement programme. In the case of conifers, however, only 20% of the seeds would be collected from the SPAs and the supply of genetically improved seeds may not be more than 2% (Table 4).

TABLE 4. PROJECTED QUANTITY OF SEEDS NEEDED FOR TREE PLANTING ACTIVITIES IN INDIA, INCLUDING IMPROVED SEEDS (ALL FIGURES IN KILOGRAMS, PERCENTAGES ARE IN PARENTHESES)

Species	Seed from SPA	Genetically improved seed (C.S.)	Seed by conventional practice	Total seeds
Eucalyptus spp.	650 (18.5%)	875 (25%)	1975 (56.5%)	3500
Acacias	88 800 (30%)	29 600 (10%)	177 600	296 000
Albizia spp.	48 860 (30%)	15 620 (10%)	93 720 (60%)	156 200
Casuarina equisetifolia	114 (20%)	114 (20%)	342 (60%)	570
Dalbergia sissoo	412 (10%)	412 (10%)	3 303 (80%)	4 1276
Conifers	16 660 (20%)	1670 (2%)	64 970 (78%)	83 300
Tectona grandis	228 570 (50%)	114 285 (25%)	114 285 (25%)	457 140

7. Research and development in genetic resources

With a view to improve the productivity and profitability of planting forest species and offering an attractive land use option, many State Forest Departments have established SPAs, CSOs, seedling seed orchards (SSOs), vegetative multiplication gardens (VMGs) and modern nurseries in consultation with ICFRE for production of quality planting stock material. For example, Andhra Pradesh Forest Department has raised 10 438.8 ha of *Eucalyptus* plantations in different districts using superior quality clones.

ICFRE has also implemented a major research and development project to improve the productivity of *Casuarina*, poplar, teak and eucalypts in a short time span through the application of vegetative propagation and cloning techniques with the existing useful variation as well as development and deployment of locality-specific, high-yielding, forest-growing and disease-resistant clones (Sharma *et al.* 2002). The adopted methodology includes selection of candidate plus trees (CPTs) with most desirable qualities and cloning of the CPTs through rooting of juvenile coppice shoots under controlled environment in the green house.

In order to develop better clones than what is available presently and to widen the genetic base of clonal plantations, research and development priorities have been identified and are being carried out in various institutions of ICFRE with significant achievements. These include:

- Selection of candidate plus trees for cloning, for development and deployment of new clones for various species.
- Development of intra–specific hybrids through controlled pollination between clones.
- Development of clonal seed orchards for production of improved genetically superior seed for future plantations.
- Further improvement of technical packages of practices for field plantations and clonal nurseries.

Tree improvement work in India began as early as in the 1960s. It got an impetus with the formation of ICFRE. One of the mandates of the Council is to increase the productivity of forests from 0.7 $m^3 ha^{-1}a^{-1}$ to at least 2.5 $m^3 ha^{-1}a^{-1}$. The ICFRE institutes have defined suitable species and strategies in collaboration with State Forest Departments and State Forest Research Wings for various states (Table 5).

TABLE 5. PRIORITY SPECIES FOR DIFFERENT STATES FOR THE PLANTING STOCK IMPROVEMENT PROGRAMME

State	Coordinating institute	Priority species for the establishment of...			
		Seed production areas (SPA)	**Clonal seed orchards**	**Seedling seed orchards**	**Vegetative multiplication gardens**
UP, Haryana & Punjab	FRI, Dehra Dun	*Dalbergia sissoo* *Eucalyptus tereticornis* *Pinus roxburghii*	*Dalbergia sissoo* *Eucalyptus tereticornis* *Pinus roxburghii*	*Dalbergia sissoo* *Eucalyptus tereticornis* *Pinus roxburghii*	*Eucalyptus tereticornis* *Pinus roxburghii*
TN, Kerala, A. & Nicobar	IFGTB, Coimbatore	*Eucalyptus* spp. *Acacia* spp. *Tectona grandis*	*Eucalyptus* spp. *Casuarina* spp. *Tectona grandis*	*Eucalyptus* spp. *Casuarina* spp. *Tectona grandis*	*Eucalyptus* spp. *Casuarina* spp. *Tectona grandis*
Karnataka & Andhra Pradesh	IWST, Bangalore	*Tectona grandis* *Eucalyptus camaldulensis* *Casuarina* spp.	*Eucalyptus* spp. *Tectona grandis* *Casuarina* spp	*Eucalyptus* spp. *Tectona grandis* *Casuarina* spp	*Tectona grandis* Bamboo
MP, Maharashtra & Orissa	TFRI, Jabalpur	*Tectona grandis* *Casuarina equisetifolia*	*Tectona grandis* *Casuarina* spp. *Albizia procera* Bamboo	*Tectona grandis* *Casuarina* spp. *Albizia procera* Bamboo	*Tectona grandis* *Casuarina* spp. *Albizia procera* Bamboo
Rajasthan Gujarat	AFRI, Jodhpur	*Tectona grandis* *Dalbergia sissoo* *Acacia nilotica* *Eucalyptus* spp.	*Tectona grandis* *Dalbergia sissoo* *Acacia nilotica* *Eucalyptus* spp.	*Dalbergia sissoo* *Acacia nilotica* *Eucalyptus* spp.	*Dalbergia sissoo* *Eucalyptus* spp.
J&K Himachal Pradesh	HFRI, Shimla	*Pinus roxburghii*	*Dalbergia sissoo* *Pinus* spp.	*Dalbergia sissoo* *Pinus* spp.	*Dalbergia sissoo* *Populus* spp.
UP	ISF&ER, Allahabad	*Dalbergia sissoo*	*Eucalyptus* spp.	*Acacia* spp. *Dalbergia sissoo*	*Tectona grandis* *Eucalyptus*
Bihar, Orissa W.B.	IFP, Ranchi	*Acacia auriculiformis*	*Eucalyptus* spp.	*Acacia* spp. *Eucalyptus* spp. *Dalbergia sissoo* *Gmelina arborea*	*Eucalyptus* spp. *Paulownia* sp. *Gmelina arborea* Bamboo

ICFRE has established the following SPAs, CSOs, SSOs and VMGs of various species in different parts of the country (Table 6).

TABLE 6. STATE-WISE PLANTING STOCK IMPROVEMENT AREAS FOR PRIORITY SPECIES UNDER ICFRE (AREAS IN HECTARES)

State	Coordinating institute	Seed production areas (SPA)	Clonal seed orchards (CSO)	Seedling seed orchards (SSO)	Vegetative multiplication gardens (VMG)
UP, Haryana & Punjab	FRI, Dehradun	181.8	28.0	25.2	4.1
TN, Kerala, A. & Nicobar	IFGTB, Coimbatore	82.3	27.7	38.3	13.0
Karnataka & Andhra Pradesh	IWST, Bangalore	120.0	12.0	34.0	6.0
MP, Maharashtra & Orissa	TFRI, Jabalpur	425.0	41.0	83.5	10.0
Rajasthan, Gujarat	AFRI, Jodhpur	200.0	29.0	55.0	5.0
States of N-E	IRMDFR, Jorhat	24.0	5.0	60.0	10.0
J&K Himachal Pradesh	HFRI, Shimla	32.5	12.8	6.0	6.0
UP	ISFER, Allahabad	60.0	8.0	12.0	2.0
Bihar, Orissa W.B.	IFP, Ranchi	100.0	3.0	30.5	0.0

7.1. Provenance trials

The first provenance trials for two important native species *viz. Tectona grandis* and *Pinus roxburghii* were initiated by Prof. M. L. Laurie and Sir Harry Champion, respectively, during the time when they were silviculturists at the FRI, Dehradun. Provenance trials of teak were established during 1928-30 in a number of locations in India. The tests on teak and chir pine have yielded useful information. International provenance trials of *Tectona grandis* and *Gmelina arborea* have been established in different states in collaboration with the Danida Forest Seed Centre (DFSC). ICFRE has initiated national level provenance experiments on *Tectona grandis*, *Pinus roxburghii* and *Bombax ceiba.* ICFRE has also collaborated in international provenance testing of eucalypts, particularly *Eucalyptus tereticornis*, *E. camaldulensis* and *E. grandis*. Trials have also been laid for acacias and tropical pines, such as *Pinus oocarpa*, *P. caribaea* and *P. kesiya,* etc. Technical inputs have been extended to state forest departments for provenance tests for species of interest such as *Eucalyptus grandis* and *E. globulus*.

The provenance trials have been further systematised during the last five years by ICFRE. Different institutes conducted both national and international provenance trials in collaboration with the State Forest Departments and international agencies. The details are given in Table 7.

TABLE 7. PROVENANCE TRIALS ESTABLISHED BY ICFRE

Species	States of India					
	U.P. Punjab & Haryana	T.N. Kerala & A&N Land	M.P. Maharashtra Orissa & Goa	Rajasthan Gujarat & D&N	Karnataka A.P. A&N	Bihar W.B. Orissa
Acacia nilotica	27	34	46	14	-	-
Azadirachta indica	-	-	26	19	-	-
Pinus roxburghii	23	-	-	-	-	-
Dalbergia sissoo	31	-	10	10	-	-
Prosopis cineraria	6	-	-	-	-	-
Casuarina equisetifolia	-	40	-	-	-	-
Eucalyptus grandis	-	17	-	-	-	10
E. tereticornis	-	5	4	-	-	-
E. camaldulensis	-	13	16	-	-	15
E. microtheca	-	20	-	-	-	-
Acacia lebbeck	-	13	-	-	-	-
A. mangium	-	-	13	-	-	-
Santalum album	-	-	9	-	-	-
Acacia procera	-	-	11	-	-	-
Pongamia pinnata	-	-	7	-	-	-
Jatropha curcus	-	-	25	-	-	-
Dendrocalamus strictus	-	-	11	-	-	-
Tecomella undulata	-	-	-	13	-	-
Gmelina arborea	32	-	-	13	-	-

Plus trees

The selection of plus trees was done with the help of the State Forest Departments. The ICFRE institutes maintain plus tree registers for different species. The largest number of plus trees was for teak followed by *D. sissoo, P. roxburghii*, *C. equisetifolia* and *A. indica* (neem) (Table 8).

TABLE 8. DETAILS OF PLUS TREES SELECTED IN VARIOUS STATES

Species	States of India				
	U.P. Punjab & Harayana	T.N. Kerala & A&N Land	M.P. Maharashtra Orrisa & Goa	Rajasthan Gujrat & D&N	Karnataka A.P. A&N
Azadirachta indica	47	40	-	-	-
Dalbergia sissoo	130	-	43	-	-
Casuarina equisetifolia		91	-	-	-
Tectona grandis	-	53	330	-	50
Eucalyptus tereticornis	-	42	-	-	-
Dalbergia latifolia	-	-	15	-	-
Tecomella undulata	-	-	-	15	-
Acacia nilotica	-	-	-	4	-
Prosopis cineraria	-	-	-	6	-
Acacia tortilis	-	-	-	8	-
Pinus roxburghii	97	-	-	-	-

7.2. Seed orchards

Seed orchards contribute greatly to the production of quality planting stock of the desired species. A clonal teak seed orchard established at Walayar, Kerala consists of 20 superior genotypes from Tamil Nadu, Kerala and Andra Pradesh, and is providing superior seeds for improvement programmes. Similarly, a clonal seed orchard of *Tectona grandis* consisting of 80 clones collected from superior genotypes from different states and seed orchards of *Bombax ceiba*, *Casuarina equisetifolia* and bamboos have been established at the Tropical Forest Research Institute (TFRI), Jabalpur. An excellent clonal seed orchard for sandal (*Santalum album*) has been established at Gottipura by the Institute of Wood Science & Technology (IWST), Bangalore. The seeds are made available to progressive planters and also used for development of demonstration plantation of sandal. Seed orchards established in different states are shown in Table 6.

7.3. Seed production areas

Much of the work with seed production areas is on teak with over 3000 ha established by the close collaboration between different State Forest Departments and ICFRE institutions. Different institutions have developed methods for demarcation and selection of trees in the SPAs so that trees with desirable characteristics are retained. The method for establishment of SPAs has been developed by ICFRE and the details provided to the State Forest Departments. State-wise information about seed production areas is given in Table 6 and Appendix 1.

7.4. Vegetative propagation and establishment of clonal banks

Vegetative propagation is an effective method for tree improvement as it could capture both additive and non-additive genetic variances. By using vegetative propagation techniques, it is possible to produce plants and quickly establish clonal banks, provided the plants are not recalcitrant to rooting and plageotropism in growth. Use of juvenile material or inducing juvenility in adult material greatly contributes to the success of establishing clonal lines.

Different ICFRE institutes have developed a vegetative propagation technique for a number of economically important species for establishment of a clonal bank and for mass multiplication. The details of species have been presented in Table 5. Currently, ICFRE is able to produce and supply good quality planting stock of *D. sissoo*, *E. tereticornis*, *E. camaldulensis*, *C. equisetifolia*, poplars and *Tectona grandis.* In addition, ICFRE is continuously adding more and more clones with defined characteristics and is also exchanging clonal material with various State Forest Departments.

7.5. Tissue culture for mass propagation

Research on tissue culture of trees was initiated in late 1970s with emphasis on teak and eucalypts for which protocols were developed. The institutes under ICFRE have taken up a number of species for mass multiplication through tissue culture, to produce adequate number of good quality planting stock material. Studies were also conducted on mass multiplication of different bamboos, including edible bamboos, and several thousands of plantlets have been transferred to the field. The technique is used in conjunction with selection strategies so that the material produced is of high quality.

7.6. Seed bank and seed exchange

The programme for the production of quality planting stock involved tree selection, seed collecting, storage and distribution, not only within the region but also to other regions where the species was of interest. Seed exchange is already in progress for neem, *Casuarina*, eucalypts and bamboos. ICFRE institutes have developed modern techniques for genetic conservation to improve the planting stock, such as storage of seeds, pollen, storage by *in-vitro* methods, growth limitation, cryopreservation and use of molecular biological methods. Seed certification is done for transportation of seeds within and outside the country. Seed certification is designed to ensure that the seed for sale is of the right variety and of good quality. Thus, legislation on seed certification has been adopted, however mostly for agriculture seeds. There is a need to develop such mechanism for forestry seeds.

8. Access to genetic resources

8.1. Plant Breeders' rights

In India, Plant Breeders' rights legislation that rewards the providers of genetic resources is being implemented in agriculture. India has phytosanitary regulations only for PGRFA (Plant genetic resources for food and agriculture), which are often poorly understood, inadequately developed and implemented or non-existent for forestry related activities. There is a general need to review and assess existing laws and adapt them or to develop new ones in line with specific needs. There is also a general need to harmonize the national legislation, especially concerning access to FGR and intellectual property rights (IPR). International legal assistance is required to draft suitable legislation covering IPR for forestry varieties in line with international agreements and national needs.

With its expertise and as a notified agency for seed, ICFRE could link phytosanitary certification with other aspects of legal regulations related to FGR. ICFRE may also deal with seed quarantine, seed technology, seed movement regulation and legal aspects.
It may also be vital to develop a Forest Tree Seed Corporation (FTSC), which will not only help producing large quantities of improved seed material but also systemise the forest tree seed production, collection, handling, storage and export in large scale, and also conserve the biological diversity of the genetic resources.

8.2. Acts of the Government

Based on the recommendations of the international negotiations, concerned with biodiversity and conservation, India has enacted laws to protect its biological resources. The following acts of the Government of India are intended to regulate the natural resources:

8.2.1. Forest Acts

- The Indian Forest Act, 1927
- The Forest (Conservation) Act, 1980
- The Forest (Conservation) Rules, 1981

8.2.2. Wildlife Protection Acts

- The Wildlife (Protection) Act, 1972, as amended up to 1993
- The Wildlife (Transactions and Taxidermy) Rules, 1973
- The Wildlife (Stock Declaration) Central Rules, 1973
- The Wildlife (Protection) Licensing (Additional matters for consideration) Rules, 1983
- The Wildlife (Protection) Rules, 1995
- The Wildlife (Specified plants—conditions for possession by License) Rules, 1995

These Acts are the basis for the protection of the flora and fauna of the country. Within the framework of the legislation, there are 87 national parks and 421 wildlife sanctuaries, wetlands and a network of biosphere reserves.

9. Status of medicinal plants in India

In India, medicinal plants are widely used by all sections of the population and it has been estimated that, in total over 7500 species of plants are used by several ethnic communities (AICEP 1994; Anthropological survey of India 1994).

Presently, medicinal plants play a very important role in the modern economy. NTFPs account for 70% of India's forest product exports and the demand for phytochemicals is expected to increase in future as a new frontier for trade. India has probably the oldest, richest and most diverse cultural traditions in the use of medicinal plants (Table 9).

TABLE 9. MEDICINAL PLANTS: SPECIES DIVERSITY AND REPRESENTATIVE SPECIES OF DIFFERENT BIOGEOGRAPHIC ZONES OF INDIA (VED *ET AL.* 2001)

Biogeographic region	Estimated no. of medicinal plants	Examples of some typical medicinal species
Trans Himalayas	700	*Ephedra geradiana* Wall., *Hippophae rhamnoides* L., *Arnebia euchroma* (Royle) John
Himalayan	2500	*Aconitum heterophyllum* Wall. ex Royle,.*Ferula jaeshkeana* Vatke and *Saussurea costus* (Balc). Lipsch., *Nardostachys grandiflora* D.C. *Taxus wallichiana* Zucc,. *Rhododendron anthopogon* D.Dun and *Ponax pseudoginseng* Wall.
Desert	500	*Convolvulus microphyllus* Seib ex Spreng.,*Tecomella undulata* (Sm.) Seem., *citrulus colocynthis* (L.), Schrader and *Cressa crertica* L.
Semi-Arid	1000	*Commiphora wightii* (Arn.) Bhandari, *Caesalpinia bonduc* (L.) Roxb, *Balanites aegyptiaca* (L.), Delilie and *Tribulus rajasthanensis* Bhandari & Sharma.
Western Ghats	2000	*Myristica malabarica* Lam., *Garcinia indica* (Thou.) Choisy, *Utleria salicifolia* Bedd and *Vateria indica* L.
Deccan Peninsula	3000	*Pterocarpus santalinus* L.f., *Decalepis hamiltonii* Wigh & Arn, *Terminalia pallida* Brandis and *Shorea tumbuggaia* Roxb.
Gangetic Plain	1000	*Holarrhenaq pubescens* (Buch-Ham.) Wall. ex DC., *Mallotus philippensis* (Lam.) Muell –Arg., *Pluchea lanceolata* C.B. Clarke and *Peganum harmala* L.
North-East India	2000	*Aquilaria malaccensis* Lam., *Smilax glabra* Roxb., *Ambroma augusts* (L.) L.f. and *Hydnocarpus hurzii* (King) Warb.
Islands	1000	*Claophyllum inophyllum* L. *Adnanthera pavonina* L., *Barringtonia asiatica* (L.), Kurz and *Aisandra butyracea* (Roxb.), Baehni.
Coasts	500	*Rhizophora mucronata* Lam., *Acanthus ilicifolius* L., *Avicennia marina* Vierth and *Sonneratia caseolaris* (L.) engl.

Exploration for forest-based plant products for new pharmaceuticals and the demand for medicinal plants are increasing in both developing and developed countries especially among the youth (Farnsworth and Soejarto 1991). Surprisingly, the bulk of the traded material is still from the wild and a very small number of species are cultivated. According to the data compiled by the International Trade Centre, Geneva, India is ranked second amongst the exporting countries, after China, with an annual export of 326 000 tonnes with a value of Rs 45.95 million (about US$ 1.4 million) during 1992-95. Recent trends have indicated further increase in this trade with the herbal cosmetic industry playing a major role in fuelling the demand for herbals worldwide. In addition to the international trade, there is a substantial volume of internal trade in medicinal plants in India. One estimate (Ved 1997; Ved *et al*. 2001) has projected the turnover of the herbal industry in India to be Rs 4000 million (about US$ 88 million) for the year 2000. The expanding trade in medicinal plants has serious implications on the survival of several plant species, many of which are under threat of becoming extinct. Today this rich biodiversity of medicinal plants is facing a serious threat because of the rapid loss of natural habitats and overexploitation of plants from the wild. To meet the demands of the Indian herbal industry, which has an annual turnover of about US$ 300 million medicinal plants are being harvested every year from some of 165 000 ha of forests (FRLHT 1997).

The following species of medicinal plants from India have been considered to be endangered and threatened for over a decade (Ayensu 1986): *Acorus calamus, Alpinia galanga, Commiphora wightii, Dendrobium nobile, Dendrobium pauciflorum, Dioscorea deltoidea, Diplomeris hirsuta, Gentiana kurroo, Nelumbo nucifera, Paphiopedilum druryi, Podophyllum hexandrum, Rauvolfia serpentina, Santalum album* and *Saussurea lappa*. A very large number of other species of medicinal plants can be added to this list, for example *Saraca asoca, Picrorrhiza kurroa, Costus speciosus, Berberis aristata*, *Gloriosa superba*, etc.

The Medicinal Plant Specialist Group met in September 1996 in Nairobi and resolved to identify the 'Top 50' medicinal plant species for conservation. The Group listed five steps to identify both global and regional priority species. The Indian Subcontinent Plant Specialist Group that met in January 1998, identified the following species of medicinal plants for detailed study and protection: *Abrus precatorius, Adhatoda vasica, Centella asiatica, Costus speciosus, Gloriosa superba, Rauvolfia serpentina, Saraca asoca, Streblus asper, Tribulus terrestris* and *Withania somnifera*.

State Forest Departments (SFDs) of Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Maharashtra, in consultation with the Foundation for Revitalisation of Local Health Traditions (FRLHT) and with the support of DANIDA and UNDP have established 54 forest genebank sites called Medicinal Plant Conservation Areas (MPCA). The network of 54 MPCAs, measuring 200 ha to 500 ha each, has been established gradually since 1993 and represents all forest types with large bio-climatic and soil regime variation. These gene banks harbour 45% of recorded populations of flowering and medicinal plants of Peninsular India, including 70% of the red-listed. The intra-specific diversity, that is germplasm conserved in the MPCA network can be used to provide authenticated quality planting material for commercial cultivation to meet rising demands of the herbal industry. MPCAs also constitute 'study sites' for threatened species recovery research. MPCAs have proved crucial in capacity building of forestry staff, local communities and researchers in the conservation of medicinal plants for sustainable use and equitable benefit sharing. This experience can help in implementing plans and programmes under the Biological Diversity Act 2002, National Biodiversity Strategy and Action Plan (NBSAP) and Medicinal Plants Board. Various states have established Medicinal Plan Boards to improve the status of existing medicinal plants in their respective areas either by *in situ* or *ex situ* conservation.

9.1. Conservation and cultivation strategies for medicinal plants

Since the beginning of this century, more than half of the world's tropical forest area has been destroyed. Experts estimate that only 5-10% of all plants in the world have been systematically investigated for their pharmacological activity. Many of them are threatened in the tropical forest. A strong strategy in terms of conservation through biotechnology and legal matters has to be developed. Institutes of ICFRE have established herbaria and medicinal plant gardens and developed packages for cultivation of economically important medicinal plants with modern techniques including tissue culture, and genetic engineering. To address the need for conservation of native medicinal plant species of India, the country needs to establish a network of forest sites across the biogeographic regions of the country. However, a network of *in situ* (field) genebanks, in the forest habitats is the most cost-effective way to manage the intra- and interspecific diversity. Various institutes under ICFRE are working on specific species for the conservation of germplasm.

10. Bamboo diversity in India

India is the second richest country in bamboo genetic resources after China. These two countries together have more than half the total bamboo resources globally. Sharma (1987) reported 136 species of bamboos occurring in India. Fifty-eight species of bamboo belonging to 10 genera are distributed in the northeastern states alone.

The forest area, over which bamboos occur in India, on a conservative estimate, is 9.57 million hectares, which constitutes about 12.8% of the total area under forests (Bahadur and Verma 1980). Out of the 22 genera in India, 19 are indigenous and three exotic. The annual production of bamboo in India is about 4.6 million tonnes; about 1.9 million tonnes is used by the pulp industries. The annual yield of bamboo per hectare varies between 0.2 and 0.4 tonnes with an average of 0.33 tonnes per hectare, depending upon the intensity of stocking and biotic interferences. The economic impact of the agroforestry-based bamboo system may influence general economic development considerably. On average, 250 air-dried culms weigh one tonne and the price per tonne of dry bamboo is Rs 1000 (auction rate) (about US$ 22).

10.1. Need for collection and conservation of germplasm

With the increasing population pressure, natural stands of bamboo are being indiscriminately cut for fuelwood and furniture. The common practice of 'jhum' (a form of shifting cultivation) cultivation in the northeastern states has resulted in genetic erosion of several bamboo species; overexploitation of some species for fuelwood and for the cottage industry has endangered others. Since natural variation is the genetic resource base required for selection and improvement, conservation of available genetic resource needs to be accorded the highest priority (Rao and Ramanatha Rao 2000). Efforts have been taken by the NBPGR, New Delhi and its stations in Trichur, Shillong and Ranchi, ICFRE and ICAR (Indian Council of Agricultural Research) to collect and build up genetic diversity of bamboo for evaluation and maintenance.

10.2. Strategies for conservation

Large areas where bamboos occur have been declared as National Bamboo Reserve areas and provenances in the natural habitats are being maintained. Considering the limitation in seed supply, vegetative methods for *ex situ* conservation and tissue culture work have been started in Asian countries. The excellent work on bamboo micropropagation by Mehta *et al.* (1982) in Delhi University using seeds of *Bambusa arundinacea* resulted in callus, which differentiated into many embryiods. These regenerated into plantlets *in vitro*. This has laid the foundation for bamboo micropropagation and *in vitro* conservation, as it is a quick method with high multiplication rate. ICFRE has perfected the macropropagation techniques for bamboo and transferred them to users for mass multiplication. The Kerala Forest Research Institute (KFRI) at Kerala has established a Bamboo Information Centre (BIC) for disseminating all relevant information on 137 species Indian bamboo. State-wise growing stock, area and distribution of bamboo are given in Tables 10, 11 and 12.

ICFRE has taken up the systematic research on bamboo under its various research institutes at different agroecological regions of the country. The work is coordinated by the Chief Technical Adviser with the main objective to work on quick-growing annual, biennial and perennial bamboos suitable for the cottage and paper industries.

TABLE 10. STATE-WISE BAMBOO GROWING STOCK AND POTENTIAL YIELD (FSI 1995)

States/Uts	Bamboo crop ('000 m^3)	Bamboos (no.)	
		1994-95	1995-96
Andhra Pradesh	652	143573.00	83732.00
Assam	6558	409877.00	n.a.
Bihar *	1621	6691.00	8125.00
Goa	--	21000.00	10000.00
Gujarat	---	50006.00	12636.59
Haryana	---	678125.00	1423590.00
Karnataka	49	33618.00	59504.00
Kerala	--	1596297.00	1339741.00
Madhya Pardesh	--	284143.00	---
Maharastra	5156	300989.00	245910.00
Manipur	3081	810950.00	900865.00
Meghalaya	11795	--	--
Nagaland	1077	--	--
Mizoram	2452	1097344.00	1277525.00
Orissa	6574	--	217802.00
Punjab	--	165743.00	151357.00
Rajasthan	--	165743.00	151357.00
Tamil Nadu		1410.18	1154.00
Tripura	510	544.09	695.55
Uttar Pradesh	579	208675.00	185851.00
West Bengal		9950	10550.00
A&N Islands		1661665.00	2068352.00

* Bamboos in metric tonnes

TABLE 11. AREA UNDER BAMBOO IN INDIA (FSI 2001) * = Estimate based on forest types

States/Union territories (year of inventory)	Bamboo area (km^2)
Andhra Pradesh (1968-74)	6598
Arunachal Pradesh (1985-90)	4590
Assam (1988-90)	8213
Bihar (1971-74)	795
Goa, Daman & Diu	249
Gujarat (1977-78)	2806
Haryana	42
Himachal Pradesh (1974-76)	60
Jammu & Kashmir	15
Karnataka (1983-94)	4925
Kerala	517
Madhya Pradesh (1970-86)	18124
Maharashtra	8893
Manipur (1986-88)	3692
Meghalaya (1986-88)	3102
Mizoram (1988-89)	9210
Nagaland (1984-87)	758
Orissa (1976-84)	7822
*Punjab	50
Rajasthan (1984-86)	529
*Tamil Nadu	3101
Tripura (1989-90)	939
Uttar Pradesh (1981-85)	2010
*West Bengal	1751
Andaman & Nicobar Islands	784
Total	**89575**

TABLE 12. DISTRIBUTION OF MAIN BAMBOO SPECIES IN INDIA (ICFRE 2001)

Species	States/UTs
Bambusa arundinacea	Arunachal Pradesh, Karnataka, Orissa, Maharashtra, Himachal Pradesh, Andhra Pradesh and Gujarat
Bambusa balcooa	Arunachal Pradesh, Mizoram
Bambusa pallida	Arunachal Pradesh, Nagaland, Mizoram, Tripura
Bambusa tulda	Arunachal Pradesh, Assam, Mizoram, Nagaland, Tripura
Bambusa polymorpha	Tripura
Dendrocalamus hamiltonii	Arunachal Pradesh, Assam,Mizoram, Nagaland
Dendrocalamus longispathus	Mizoram
Dendrocalamus strictus	Andhra Pradesh, Assam, Gujarat, Maharashtra, Himachal Pradesh, Madhya Pradesh, Manipur, Orissa, Karnatak, Uttar Pradesh, Rajasthan
Melocanna bambusoides	Assam, Mizoram, Nagaland, Tripura, Manipur, Meghalaya
Neebenzia balcooa	Nagaland
Oxytenanthera nigrociliata	Tripura, Assam
Oxytenanthera parviflora	Assam
Pseudostachyus polymorphium	Arunachal Pradesh
Polystachia pargracile	Orissa

Bamboos are aptly called the poor man's timber and are found in great abundance. Their strength, straightness and lightness combined with extraordinary hardness, range in sizes, abundance, easy propagation and the short period in which they attain maturity make them suitable for a variety of purposes. The diversity of this fascinating plant has to be conserved, not just for financial reasons, but also more importantly in the revitalization of traditional sciences and technologies.

11. Forestry extension

The forestry extension programme of ICFRE plays a vital role in connecting research institutes with the end users through transfer of technology and extension support to State Forest Departments, non-governmental organizations (NGOs), etc. The Programme also facilitates research collaboration with various organizations and establishment of synergic linkage with user groups.

Extension is carried out in a two-way process. On one hand, tested technologies and scientific information are transferred to the users and, on the other hand, requirements of the users are ascertained for evolving research priorities and researchers are kept abreast with the realities in the field. The extension methodologies presently adopted are demonstrations on the field and the use of extension materials such as films, videos, brochures, hand arts, and exhibitions, workshops, seminars and conferences, as well as by personnel contracts.

12. Training

To provide up-to-date training and educational exposures to foresters and scientists, arrangements were made for visits abroad for short and long term training courses, meetings, symposia and workshops. Financial assistance was provided by World Bank, UNDP, British Council, IPRC, FAO, INBAR and USDA under various forestry research and educational support programmes. In order to strengthen education in forestry disciplines, technical and financial assistance were also extended to various universities. Many students, industry representatives, teachers and various user groups, including farmers, were also trained on advanced technologies developed by ICFRE institutes.

13. Constraints to forestry research

13.1. Lack of funding for tree improvement programmes

Tree improvement is an activity that requires adequate input and gestation period. Therefore, various user agencies should be provided with external funding for the establishment of clonal seed orchards, seed production areas, tissue culture techniques, establishment of trial plots for clonal forestry using rooted cuttings as well as plants raised by tissue culture. In addition, funds are also needed to upgrade the existing seed storage facilities: mist chambers and tissue culture laboratories in order to mass-produce quality planting stocks for large scale planting programmes.

13.2. Mobilization of funds in the past

Since the commencement of the First Five Year Plan (FYP) in 1951, in total Rs 85 billion have been spent by the end of the Eighth FYP in 1996-97 on forestry development planning activities. During this period, afforestation of about 26.9 million ha has been carried out. Financial allocation to the forestry sector has increased from Rs 76 million in the First FYP to Rs 40 818 million in the Eighth FYP, but is has always been less than 1% of the total plan outlay of the country. This is one of the main reasons for the continuous deterioration of forest resources (Table 13).

A provision of Rs 68 billion has been made for the Ninth Plan. During 1997-98, afforestation of 1.48 million ha was completed which involved the distribution of 1033 million seedlings. Thus, up to 1997-98, the total area afforested is 28.38 million ha, which includes a national target of 4.65 million ha (equivalent of 9309 million seedlings distributed).

The average annual plan outlay for the forestry sector during the Eighth FYP was about Rs 8.16 billion (approx. US$ 240 million) whereas the estimated annual value of harvests (recorded and unrecorded) from the forests was worth Rs 300 billion during the same period, which is about 36 times more than the planned investment.

TABLE 13. A GLIMPSE OF BUDGET ALLOCATION FOR FORESTRY UNDER THE FIVE YEAR PLANS, 1951-2002 (MILLION RS) (GOI)

Plan/Year	Total Plan		Agriculture Plan		Forest and Wildlife Plan		Forest Outlay
	Outlay	Actual	Outlay	Actual	Outlay	Actual	(% of total)
First Plan (1951-1956)	23 780	19 600	3 540	2 900	76	85	0.32
Second Plan (1956-1961)	45 000	46 720	5 100	5 490	212	212	0.47
Third Plan (1961-1966)	75 000	8 577	10 860	10 890	458	459	0.61
Annual Plan (1966-1969)	66 250	66 225	10 370	11 070	419	421	0.63
Fourth Plan (1969-1974)	159 020	157 790	27 280	23 200	894	938	0.56
Fifth Plan (1974-1979)	393 220	394 260	47 660	48 650	2 088	2 088	0.53
Annual Plan (1979-1980)	126 010	121 760	18 150	19 960	683	683	0.54
Sixth Plan (1980-1985)	975 000	1 092920	125 390	152 010	6 924	NA	0.71
Seventh Plan (1985-1990)	1 800 000	2 187 300	222 330	315 090	18 519	19759	1.09
Annual Plan (1990-1991)	647 170	583 690	91 420	85 420	6 299	5 764	0.97
Annual Plan (1991-1992)	723 170	647 500	100 580	90 600	7 831	7 153	1.08
Eight Plan (1992-1997)	4 341 000	-	636 420	-	40 820	39 930	0.94
Ninth Plan (1997-2002)	-	-	-	-	68 228		
Total up to 8th FYP	**9 374 620**		**1 299 100**		**85 295**		**0.90**

Tables 14 and 15 provide information on the planned investments in forestry activities. Proposed investments have been estimated on the basis of the requirements of the sector irrespective of the source of funding.

TABLE 14. SUMMARY OF INVESTMENT ESTIMATE FOR THE COUNTRY (STATE AND CENTRAL SECTORS) BY PROGRAMME (MILLION RS)

S. no.	Programme	First 5-year	Second 5-year	Third 5-year	Fourth 5-year	Total for 20 years
I.	Improve forest productivity	82252.3	100761.3	110349.0	119554.9	412917.5
II.	Expand forest area	88928.4	103634.0	1054812.4	113344.2	411719.0

TABLE 15. SUMMARY OF INVESTMENT ESTIMATE FOR 20 YEARS BY PROGRAMME (MILLION RS)

Programme	State Sector	Central Sector	Total	Area to be regenerated /planted (million ha)
Improve Forest Productivity	391479.9	21437.6	412917.5	26.43
Expand Forest Area	405605.5	6113.6	411719.1	21.80

14. Conclusions

Forest genetic resources are facing multiple threats from habitat loss, forest fires, climate change and from the invasion of exotic species. Conservation is compounded by the number of species that require protection. Some priority species for India are listed in appendixes 2-6. Plant resources, many of which come from forests, are the biological basis of the world security and directly or indirectly support the livelihoods of every person on earth by providing food, feed for domestic animals, fibre, clothing, shelter, wood, timber, medicine, energy, etc. These resources are also the raw material used in the production of new plant varieties through traditional plant breeding or through biotechnology. The erosion of these resources poses a severe threat to the world's food security in the long term. Thus, there is an urgent need to conserve and utilize the genetic resources as a safeguard against an unpredictable future.

Today, increasing direct and indirect access to the benefits created by forests is causing damage to the ecosystem as a whole as well as loss of biodiversity in particular. Reliable and sustainable improvements in plantation yield are necessary to meet the growing demand and to protect the natural forests from pressures. The conservation and sustainable utilization of PGR is the key to improving the productivity and sustainability of forests, thus contributing to national development, food security and the alleviation of poverty. A multifaceted approach to biodiversity conservation is needed at this junction. We should not allow a single species to depart from us.

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APPENDICES

Appendix 1. State-wise seed production areas of various species
(Forest Statistics India 2001)

States/Union territories	Species	No. of locations	Area (ha)
Andhra Pradesh	*Tectona grandis* (teak)	76	811.10
	Anogeissus latifolia	4	25.00
	Terminalia alata	5	36.00
	Pterocarpus santalinus (red sanders)	1	12.40
	Pterocarpus marsupium	2	15.00
Arunachal Pradesh	N.A	N.A.	N.A.
Assam	Teak	5	64
	Chukrasia tabularis	4	29
	Artocarpus chaplasha	1	2
	Gmelina arborea	2	16
	Acacia catechu	1	4
	Bombax ceiba	2	22
	Shorea robusta	3	11
	Dipterocarpus turbinatus	1	2
	Dalbergia sissoo	2	4
	Dipterocarpus macrocarpus	5	39
	Phoebe cooperiana	1	4
	Phoebe goalparens	1	14
	Amoora wallichi	1	11
	Lagerstroemia reginae	2	3
	Canarium resiniferum	1	5
	Morus laevigata	1	1
	Sterculia villosa	1	4
	Terminalia myriocarpa	2	4
Bihar	N.A.	N.A.	N.A.
Delhi	N.A.	N.A.	N.A.
Goa	Nil	Nil	Nil
Gujarat	*Acacia nilotica*	2	40
	Tectona grandis	6	100
Haryana	*Eucalyptus tereticornis*	1	2.1
Himachal Pradesh	N.A.	N.A.	N.A.
Jammu & Kashmir	*Pinus wallichiana* (kail)	4	77
	Cedrus deodara (deodar)	4	51.8
	Robinia pseudoacacia (robinia)	4	53
	Pinus roxburghii (chir)	3	43.5
	Abies pindroa	1	13.25
Karnataka	*Acacia auriculiformis*	3	182.00
	Anogeissus latifolia	1	25.00
	Cassia siamea	1	1.00
	Casuarina equisetifolia	2	50.00
	Eucalyptus camaldulensis	5	70.00
	Hardwickia binata	3	60.00
	Hopea parviflora	3	20.00
	Hopea wightiana	1	4.00
	Annona squamosa	2	10.00

	Emblica officinalis	2	10.00
	Feronia elephantum	2	3.50
	Gmelina arborea	1	1.50
	Leucaena leucocephala	2	20.00
	Morinda tinctoria	1	10.00
	Pterocarpus marsupium	2	15.00
	Borassus flabellifer	1	15.00
	Buchanania lanzan	1	12.00
	Chloroxylon swietenia	1	8.0.0
	Dalbergia sissoo	1	8.00
	Madhuca latifolia	1	10.00
	Acacia catechu	1	10.00
	Calamus travancoricus	1	10.00
	Grevillea robusta	1	8.00
	Lagerstroemia lanceolata	1	2.00
	Pinus caribaea	1	4.00
	Acacia mangium	1	50.00
	Adina cordifolia	1	150.00
	Calophyllum inophyllum	1	200.00
	Dalbergia latifolia	1	10.00
	Garcinia indica	1	40
	Eucalyptus citriodora	2	40.00
	Eucalyptus hybrid	2	25.00
	Pterocarpus santalinus	1	20.00
	Samanea saman	1	1.00
	Santalum album	1	5.00
	Sapindus trifoliatus	1	200.00
	Semecarpus anacardium	1	130.00
	Syzygium jambos	1	3.00
	Tamarindus indica	1	5.00
	Tectona grandis	3	464.00
	Terminalia bellirica	1	35.00
	Terminalia tomentosa	1	448.00
	Vateria indica	1	4.00
	Xylia xylocarpa	1	16.00
	Ziziphus jujuba	2	14.5
Kerala	Teak	6	1337.42
	Eucalyptus spp.	2	5.74
	Bombax ceiba	2	12.50
	Santalum album (sandal)	1	22.60
	Venteak	1	6.52
	Terminalia alata (laurel)	1	15.74
	Dalbergia latifolia (rosewood)	1	5.25
	Swietenia spp. (mahogany)	1	10.00
	Ailanthus triphysa	1	7.00
	Emblica officinalis	1	10.00
Madhya Pradesh	Teak	47	1360.17
	Eucalyptus spp.	2	8.00
	Gmelina arborea (khamar)	2	24.00
	Ougeinia oojeinensis (tinsa)	1	10.00
	Emblica officinalis (aonla)	1	10.00

	Anogeissus pendula (kardhai)	1	23.50
	Acacia catechu (khair)	3	153.00
	Leucaena leucocephala (subabul)	1	10.00
	Prosopis juliflora	1	10.00
	Miscellaneous	9	220.00
Maharashtra	Teak	17	749.24
	Cenchrus ciliaris (anjan)	3	20.00
	Cleistanthus collinus (garadi)	1	10.00
	Pterocarpus marsupium (bija)	1	10.00
	Acacia catechu (khair)	4	35.00
	Bombax ceiba (semal)	1	5.00
	Surya	1	5.00
	Diospyros melanoxylon (tendu)	1	5.00
	Mitragyna parvifolia (kalam)	1	5.00
	Casuarina equisetifolia	2	6.00
	Eucalyptus grandis	2	4.84
	Acacia auriculiformis	1	2.00
	Shivan	2	10.00
	Pinus caribaea	1	2.00
	Terminalia chebula (hirda)	1	5.00
	Acacia nilotica ssp. indica (babul)	1	10.00
	Dalbergia sissoo (sissoo)	1	10.00
	Schleichera oleosa (kusum)	1	5.00
	mixed	1	2.00
	Ficus carica (ain)	2	8.00
	Cleistanthus collinus	1	5.00
Meghalaya	N.A.	N.A.	N.A.
Manipur	N.A.	N.A.	N.A.
Mizoram	Teak	3	20.00
Nagaland	Nil	Nil	Nil
Orissa	*Casuarina equisetifolia*	2	60.75
	Teak	3	217.62
Rajasthan	*Acacia nilotica ssp. indica*	2	35.00
	Dalbergia sissoo	2	30.00
	Eucalyptus camaldulensis	1	10.00
	Prosopis cineraria	1	10.00
	Acacia senegal	1	10.00
	Acacia catechu	1	10.00
	Acacia tortilis	1	10.00
	Ailanthus excelsa	1	1.00
	Salvadora oleiodes	1	10.00
Sikkim	Teak	1	1.50
	Shorea robusta (sal)	1	1.00
	Michelia spp. (rani champ)	1	0.50
	Pinus roxburghii (chir pine)	1	1.50
	Tsuga dumosa (hemlock)	1	2.50
	Michelia champaca (champ & okhar)	1	1.00
	Rhododendron arboreum	1	0.50

	Pinus patula	1	1.50
Tamilnadu	*Acacia mearnsii*	1	4.5
	Acacia planifrons	1	9.75
	Anacardium occidentale	1	21
	Eucalyptus tereticornis	1	8.9
	Hardwickia binata	1	0.4
	Tectona grandis	1	52.77
Tripura	Nil	Nil	Nil
Uttar Pradesh	*Eucalyptus* hybrid	3	11.79
	Dalbergia sissoo (shisham)	9	110
	Teak	1	10
West Bengal	Misc.	3	640.80
A&N Island	Nil	-	Nil
D& N Haveli	Nil	-	Nil
Chandigarh	Nil	-	Nil
Lakshadweep	N.A.	N.A.	N.A.
Pondicherry	N.A.	N.A.	N.A.

Appendix 2. List of priority species for conservation, improvement or seed procurement (FAO-coordinated activities)

(Sharma et al. 2002)

Species	End users of species				Operations/activities needed							
					Exploration & collection		Evaluation		Conservation		Germplasm uses	
	1	2	3	4	5	6	7	8	9	10	11	12
Acacia catechu	-	+	-	-	2	2	-	3	2	2	2	2
A. nilotica	-	+	+	+	2	2	2	2	2	2	2	2
A tortilis	-	-	+	+	-	3	-	3	-	3	-	-
Albizia procera	+	-	+	+	1	1	2	2	2	2	3	2
Azadirachta indica	+	+	+	+	1	1	2	1	1	1	1	1
Bamboo	-	+	+	+	1	1	-	1	1	1	1	1
Rattans	-	+	-	-	2	2	2	2	2	2	3	3
Casuarina equisetifolia	-	+	+	+	-	2	2	2	2	2	1	2
Cedrus deodara	+	+	+	+	2	2	2	2	2	2	2	2
Dalbergia sissoo	+	+	+	+	1	2	1	1	1	1	2	1
Eucalyptus spp.	+	+	+	-	2	3	-	3	-	3	3	2
Pinus roxburghii	+	+	+	+	1	2	-	2	1	2	2	1
Populus ciliata	+	-	+	+	1	1	1	1	1	1	1	1
P. euphratica	+	-	+	+	1	1	1	1	1	1	1	1

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.

Priority ranking for columns 5-12: **1 =** Highest priority; **2 =** Prompt action recommended; **3 =** Action is important, but of less urgency than that for species

Appendix 3. List of priority species identified at national level in India
(FAO 2002)

Species	End uses of species				Operations/activities needed							
					Exploration & collection		Evaluation		Conservation		Germplasm uses	
	1	2	3	4	5	6	7	8	9	10	11	12
Acacia pindraw	+	-	-	+	2	3	3	3	2	-	-	3
Acacia nilotica	+	+	+	+	1	1	-	2	2	2	2	2
A. catechu	-	+	-	-	-	-	-	-	-	-	-	-
Ailanthus excelsa	+	+	-	-	2	2	2	2	2	2	2	2
Ailanthus grandis	+	+	+	+	2	2	2	2	2	2	2	2
Albizia procera	+	-	+	+	1	1	-	3	1	1	-	1
Annona squamosa	+	-	-	+	3	3	3	3	3	3	3	3
Artocarpus heterophyllus	-	+	-	+	3	3	3	3	3	3	3	3
Azadirachta indica	+	+	+	+	1	1	1	1	1	1	1	1
Bamboo	-	+	+	+	1	1	1	1	1	1	1	1
Bombax ceiba	+	+	+	-	3	1	-	1	1	1	1	1
Casuarina equisetifolia	+	-	+	-	-	-	2	2	2	2	2	2
Cedrus deodara	+	-	-	+	1	1	-	1	1	1	1	1
Cinnamomum camphora	+	+	+	+	2	2	-	2	-	-	-	-
Dalbergia latifolia	+	-	-	-	1	1	-	1	1	1	1	1
Dalbergia sissoo	+	+	+	+	1	1	1	1	1	1	1	1
Dipterocarpus spp.	+	-	-	-	1	1	-	2	1	1	1	1
Emblica officinalis	-	+	-	+	3	3	3	3	3	3	3	3
Eucalyptus spp.	+	+	+	-	2	3	-	3	-	3	3	2
Gliricidia sepium	-	+	-	+	3	3	3	3	3	3	3	3
Gmelina arborea	+	-	+	+	-	1	1	1	1	1	1	1
Hardwickia binata	+	-	+	-	1	1	-	2	1	1	1	1
Paulownia fargesii	+	-	-	+	1	1	-	1	-	-	-	-
Paulownia spp.	+	-	-	+	1	1	1	1	2	2	2	2
Moringa oleifera	-	+	-	+	1	1	-	-	-	1	-	1

Species	End uses of species				Operations/activities needed							
					Exploration & collection		Evaluation		Conservation		Germplasm uses	
	1	2	3	4	5	6	7	8	9	10	11	12
Melia azedarach	+	-	+	+	1	1	-	-	-	1	-	1
Madhuca indica	-	-	-	+	-	-	-	-	-	-	-	-
Lagerstroemia lanciolotor	-	+	-	+	3	3	3	3	3	3	3	3
Juglans regia	+	+	+	+	1	-	1	-	1	-	-	1
Paulownia kawakami	+	-	-	-	2	2	-	2	-	-	-	-
P. smithania	+	-	-	-	1	1	-	1	-	1	1	1
Pinus caribaea	+	+	+	-	-	-	1	-	1	-	1	-
Pinus gerardiana	-	+	-	+	1	1	-	-	1	1	1	1
Pinus kesiya	+	-	-	+	1	1	-	1	1	1	1	1
Pinus patula	+	-	-	-	2	2	-	2	2	-	-	-
Pinus oocarpa	+	-	-	+	1	1	-	-	1	-	3	-
Pinus roxburghii	+	+	+	+	1	1	1	1	2	2	1	1
Pinus wallichiana	+	-	-	+	3	1	-	3	1	1	1	1
Populus deltoides	+	-	+	+	2	1	-	1	-	1	1	1
Populus ciliata	+	-	-	-	2	2	-	2	-	-	-	-
P. euphratica	+	-	+	+	1	1	-	1	1	1	1	1
P. yunnanensis	+	-	+	-	3	1	-	1	-	-	1	1
Prosopis cineraria	+	+	+	+	1	1	1	1	1	1	1	1
P. juliflora	+	+	+	+	1	1	1	1	1	1	1	1
Rattan	-	+	+	+	1	1	1	1	2	2	2	2
Salix alba	+	-	-	-	2	2	-	2	-	-	-	-
Salix babylonica	+	-	-	+	2	2	-	2	-	-	-	-
Santalum album	+	-	-	+	1	1	-	-	1	1	1	1

For denotes, please refer to Appendix 2 above.

Appendix 4. Priority species for different agro-climatic regions in India
(FSI 2001)

Agro-climatic region	Priority				
	1	2	3	4	5
Western Himalayan	*Grewia optiva*	*Populus ciliata*	*Toona ciliata*	*Casuarina australis*	*Acacia catechu, Robinia pseudoacacia*
Eastern Himalayan	*Michelia champaca*	*Alnus nepalensis*	*Gmelina arborea*	*Morus laevigata*	*Pinus kesiya*
Lower Gangetic Plains	*Populus deltoides*	*Anthocephalus auriculiformis*	*Gmelina arborea*	*Acacia nilotica*	*Azadirachta indica*
Middle Gangetic plains	*Populus deltoides*	*Anthocephalus cadamba*	*Eucalyptus hybrid*	*Dalbergia sissoo*	*Acacia nilotica,* bamboo
Upper Gangetic plains	*Populus deltoides*	*Eucalyptus* hybrid	*Dalbergia sissoo*	*Anthocephalus cadamba*	*Leucaena leucocephala*
Trans-Gangetic plains	*Populus deltoides*	*Eucalyptus* hybrid	*Dalbergia sissoo*	*Melia azadirachta*	*Acacia nilotica*
Eastern Plateau and Hills	*Gmelina arborea*	*Tectona grandis*	*Eucalyptus* hybrid	*Casuarina equisetifolia*	*Leucaena leucocephala*
Central Plateau and Hills	*Azadirachta indica*	*Eucalyptus* hybrid	*Tectona grandis*	Acacia nilotica	*Leucaena leucocephala, Hardwickia binata*
Western Plateau and Hills	*Azadirachta indica*	*Acacia nilotica*	*Eucalyptus* hybrid	*Leucaena leucocephala*	*Tectona grandis*
Southern Plateau and Hills	*Ailanthus excelsa*	*Eucalyptus camaldulensis*	*Tamarindus indica*	*Ceiba pentandra*	*Casuarina equisetifolia*
East coast Plains and Hills	*Casuarina equisetifolia*	*Gmelina arborea*	*Acacia mangium*	*Terminalia tomentosa*	*Dalbergia sissoo*
West coast Plains and Ghats	*Casuarina equisetifolia*	*Eucalyptus* hybrid	*Acacia mangium*	*Terminalia tomentosa*	*Artocarpus heterophyllus,* bamboo
Gujarat Plains and Hills	*Prosopis cineraria*	*Eucalyptus* hybrid	*Ailanthus excelsa*	*Dalbergia sissoo*	*Leucaena leucocephala*
Western dry	*Prosopis cineraria*	*Acacia nilotica*	*Azadirachta indica*	*Ailanthus excelsa*	*Dalbergia sissoo*
The islands	*Casuarina equisetifolia*	*Gmelina arborea*	*Gliricidia sepium*	*Samanea saman*	*Terminalia catappa*

Appendix 5. Priority species for different zones / regions in India
(FSI 2001)

Zone / Region	Preferred species
Submontane low hills Subtropical	*Grewia optiva, Albizia chinesis, Bauhinia variegata, Celtis australis,* Bamboo species*, Morus alba, Bombax ceiba, Anogeissus latifolia, Acacia catechu, Toona ciliata*
Mid-hills Subhumid	*Grewia optiva, Celtis australis, Quercus leucotricophora, Bauhinia variegata, Ficus* spp*., Albizia chinensis, Acacia catechu, Anogeissus latifolia*
High hills Temperate wet	*Quercus spp., Morus* spp*, Robinia pseudoacacia, Celtis australis, Alnus nitida, Populus* spp.
High hills Temperate dry	*Robinia pseudoacacia, Salix* spp*., Quercus* spp*., Fraxinus* spp*.*
Punjab lower hill zone (Kandi)	*Acacia nilotica, Dalbergia sissoo, Acacia catechu, Ziziphus* spp*,. Butea monosperma, Grewia optiva, Anogeissus latifolia*
Alluvial zone	*Populus deltoides, Eucalyptus* spp*.*
Hayarana	*Populus deltoides, Eucalyptus* hybrid*, Prosopis cineraria, A. nilotica, A. tortilis, Dalbergia sissoo*
Western Uttar Pradesh	*Dalbergia sissoo, A. nilotica, Populus deltoides, Eucalyptus* hybrid, *Albizia lebbeck, Morus alba, Syzygium cumini*
Central Uttar Pradesh	*Dalbergia sissoo, A. nilotica, A. catechu,* Eucalyptus*, Prosopis* spp*.,* bamboo*, Madhuca latifolia, Ficus religiosa, Derris indica*
Eastern Uttar Pradesh	*Dalbergia sissoo, Eucalyptus* spp*., bamboo, neem, Madhuca latifolia, Syzygium cumini, Ficus* spp.
Bihar (NW Dist.)	*Dalbergia sissoo, Morus alba, A. nilotica, Bombax ceiba, Tectona grandis, Cassia fistula, Azadirachta indica, Emblica, Dendrocalamus strictus, Wendlandia exserta*
West Bengal	*A. nilotica, Dalbergia sissoo, Azadirachta indica, Terminalia arjuna, Butea monosperma, Leucaena leucocephala*
Arid	*Prosopis cineraria, P. juliflora, Tecomella undulata*
Semi-arid	*A. nilotica, Dalbergia sissoo, Azadirachta indica, Prosopis cineraria*
Bundel khand (including Central Plateau region)	*Azadirachta indica, Madhuca latifolia, Acacia leucophloea, Butea monosperma, Anogeissus pendula, Albizia lebbeck*
Deccan Plateau	*Albizia lebbeck, A nilotica, P. juliflora, A. leucophloea, Hardwickia binata, A. ferruginea*
Tropical highlands	Jackfruit, drumstick, tamarind*,* teak, *Sesbania grandiflora, Lawsonia inermis*
Tropical plains	Neem, *Acacia nilotica, A. leucophloea, A. planiformis, Casuarina, Ailanthus excelsa*
Coastal	*Casuarina, A. planiformis, P. juliflora, E. tereticornis*
Humid (rainfall > 2500 mm)	Silver oak*, Casuarina* spp.
Rainfall 1500-2500 mm	Teak, jackfruit, curry leaf*, Casuarina* spp., *Ceiba pentandra, Bombax ceiba*
Rainfall < 1500 mm	*Acacia nilotica, Ceiba pentandra, Ailanthus excelsa*

Bihar (NW Dist.)	*Dalbergia sissoo, Morus alba, A. nilotica, Bombax ceiba, Tectona grandis, Cassia fistula, Azadirachta indica, Emblica, Dendrocalamus strictus, Wendlandia exserta*

Appendix 6. Level and nature of threats to the integrity of populations of important tree species in India

Species in ecogeographic (geo-ecological) zones	Reserves, natural areas	*In situ* conservation stand	Managed forest	Unmanaged forest	Plantation/ cultivated	*Ex situ* cons. stand, naturalized from cultivation	Villages, fields, homesteads	Experimental fields, trials	Degree of threat index
1. *Abies delavayi* (EH)	-	-	-	+	-	-	-	-	5, High
2. *Acer caesium* (WH)	-	-	-	+	-	-	-	-	3, Medium
3. *Actinodaphne lanata* (WG)	+	-	-	+	-	-	-	-	2, Low
4. *Ailanthus kurzii* (A.Is.)	+	-	-	+	-	-	-	-	3, Medium
5. *Albizia gamblei* (EH)	-	-	-	+	-	-	-	-	5, High
6. *Amentotaxus assamica* (EH)	-	-	-	+	-	-	-	-	5, High
7. *Aquilaria malaccensis* (EH&NEI)	+	-	-	+	+	-	-	-	4-5, Medium-High
8. *Artocarpus hirsutus* (EG & SI)	+	-	-	+	-	-	-	-	3-4, Medium
9. *Bentinckia coddapanna* (EG&WG)	-	-	-	+	-	-	-	-	3-4, Medium
10. *Boswellia ovalifoliolata* (EG)	-	-	-	+	-	-	-	-	3, Medium
11. *Cephalotaxus griffithi* (NEI)	-	-	-	+	-	-	-	-	4-5, Medium-High
12. *Commiphora wightii* (GP & WI)	-	-	-	-	+	-	-	-	3-4 Medium
13. *Cochlospermum religiosum* (N & SI)	-	-	-	+	+	-	-	-	2-3 Low-Medium
14. *Dalbergia lanceolaria* (NWI)	-	-	-	+	-	-	-	-	3-4 Medium
15. *Dipterocarpus kerrii* (A & N)	+	-	-	-	-	-	-	-	4-5 Medium-High
16. *Gleditsia assamica* (NEI)	-	-	-	-	+	-	-	-	3-4, Medium
17. *Gmelina arborea var. canescens* (GP)	-	-	-	-	-	-	+	-	5, High
18. *Hopea jacobi* (WG)	+	-	-	-	-	-	-	-	2-3, Low-Medium
19. *Kingiodendron pinnatum* (SW Ghats)	+	–	–	+	-	-	-	-	2-3, Low-Medium
20. *Lagerstroemia hypoleuca* (A. Is.)	-	-	-	+	-	-	-	-	1-2, Low
21. *Madhuca bourdillonii* (SWG)	-	-	-	+	-	-	-	-	2-3, Low-Medium

Species in ecogeographic (geo-ecological) zones	Reserves, natural areas	*In situ* conservation stand	Managed forest	Unmanaged forest	Plantation/ cultivated	*Ex situ* cons. stand, naturalized from cultivation	Villages, fields, homesteads	Experimental fields, trials	Degree of threat index
22. *Mangifera andamanica* (A. Is.)	+	-	_	+	-	-	-	-	1-2, Low
23. *Mesua manii* (A. Is.)	-	-	-	+	-	-	-	-	2-3, Low-Medium
24. *Michelia punduana* (NEI)	-	-	-	+	-	-	-	-	3-4, Medium
25. *Picea spinulosa* (E H)	-	-	-	+	-	-	-	-	4-5, Medium-High
26. *Podocarpus neriifolius* (A. Is., NEI)	+	-	-	+	+	+	-	-	2-3, Low-Medium
27. *Populus gamblii* (EH)	+	-	+	-	+	-	-	+	1, Low
28. *Pterocarpus santalinus* (EP)	+	-	-	-	+	+	-	+	1, Low
29. *Rhododendron johnstoneanum* (NEI)	-	-	-	+	-	-	-	-	4-5, Medium - High
30. *Shorea thumbaggaia* (EG)	+	-	-	+	-	-	-	-	5, High
31. *Syzygium bourdillonii* (SI)	-	-	-	+	-	-	-	-	4-5, Medium - High
32. *Syzygium palghatensis* (WG)	+	-	-	+	-	-	-	-	2-3, Low – Medium
33. *Taxus baccata* ssp. *wallichiana* (NW & EH)	+	-	+	+	-	-	-	-	3-4, Medium-High
34. *Trachycarpus takil* (WH)	+	-	-	+	-	+	-	-	4-5, Medium - High
35. *Vateria macrocarpa* (EP&WG)	+	-	-	+	-	-	-	-	2-3, Low Medium

Direct causes of threats may include Unmanaged use and harvesting; unmanaged grazing / browsing (domestic animals, wildlife); wildfires, environmental biotic/ abiotic factors (drought, pests, diseases, floods, pollution); clearing for agriculture and pasture land; infrastructure development (dams, mining, urban expansion); biological incompatibility for reproduction/interdependence for dispersal and regeneration; monotypic taxa

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.

Abbreviations:

A.Is. = Andaman Islands; **A &N**. = Andaman & Nicobar Islands; **DP** = Deccan Peninsula; **EG** = Eastern Ghats; **EH** = Eastern Himalaya; **EP** = Eastern Peninsula; **GP** = Gangetic Plains; **NEI** = North East India; **SI** = South India; **SWG** = South Western Ghats; **WC** = Western Coast; **WH** = Western Himalaya; **WI** = Western India; **WP** = Western Peninsula