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Chapter 10

Ecosystem Biodiversity of India

Vivek Khandekar and Anita Srivastava

Additional information is available at the end of the chapter

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1. Introduction

Forests are amongst the most biologically-rich terrestrial systems. Tropical, temperate and boreal forests together offer diverse sets of habitats for plants, animals and micro-organisms, and harbour the vast majority of the world's terrestrial species. In the past, timber production was regarded as the dominant function of forests. However, in recent years these perception has changed towards recognizing and acknowledging the diverse ecological services and functions offered by forests. Today, it is understood that forest biodiversity underpins a wide range of goods and services for over all human well-being. Ecologically intact forests store and purify drinking water, mitigate natural disasters such as droughts and floods, help store carbon and regulate the climate, provide food and produce rainfall and provide a vast array of goods and services for medicinal, cultural and spiritual purposes. The health of forests and the provision of forest ecosystem services depend on the diversity between species, the genetic diversity within species, and the diversity of forest types.

Vegetative biodiversity, heretofore referred to forest biodiversity of the country is under severe threat due to various factors such as increasing population, environmental degradation, indiscriminate resource utilization etc. Social, economic and spatial constraints have made the value of biodiversity irredeemable. The alarming rate of loss of biodiversity particularly in terms of ecological, genetic, economic and evolutionary consequences became a matter of universal concern when the eventful Earth Summit work place at Rio de Janiero in 1992. This later culminated in 1993 in the ratification of a global agenda on biodiversity, now referred as the UN Convention on Biodiversity. India being signatory to the Convention on Biological Diversity (CBD), is committed not only to the conservation of its biodiversity but also to sustainable and equitable utilization of its genetic resources. With long history of conservation in India, the conservation of forest biodiversity becomes an integral part of the development process. Over the years, India has developed a strong legal and policy framework along with a number of programmes promoting biodiversity

conservation in the country. In this paper the intrinsic nature of biodiversity and multiple nature of its stakeholder are explored in order to explore the inextricable link between human welfare and conservation biodiversity. The paper is a compendium of practice, a synthesis of insights into biodiversity conservation related research and technology in the country, and a source of ideas for way forward.

2. Literature review

Biological diversity refers to variety within the living world, and is commonly used to describe the number, variety and variability of living organisms. Thus, biodiversity is the variation of taxonomic life forms within a given ecosystem, biome or for the entire Earth. It is often used as a measure of the health of biological systems.

The term 'Biodiversity', a contraction of the term 'biological diversity' was first coined by Walter Rosen in the 1986 Forum on Biodiversity (Wilson 1988). The term biodiversity entails more than just the accumulation of species. The 1992 United Nations Earth Summit in Rio de Janeiro defined 'biodiversity' as "the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (UNEP 1992). This comes closest thing to a single legally accepted definition of biodiversity and also the definition adopted by the United Nations Convention on Biological Diversity (CBD). The concept of biodiversity involves an "understanding that all organisms interact, like a web of life, with every other element in their local environment" (SCBD 2010).

An estimated 1.7 million species have been described to date although estimates for the total number of species existing on earth at present vary from five million to nearly 100 million. However, biodiversity is not distributed evenly on Earth. It is consistently richer in the tropics and in other localized regions. Forests are more biologically diverse than any other land-based ecosystem, and contain more than two-thirds of the world's terrestrial species (ibid).

2.1. India – A megadiverse country with diverse landscape

India is situated north of the equator between 66°E to 98°E and 8°N to 36°N. The varied edaphic, climatic and topographic conditions have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, coastal and marine ecosystems, and deserts. The mountainous region covers an area close to 100 mha, arid and semi-arid zones are spread over 30 mha and the coastline is about 8000 km long (MoEF 2009). India represents: (i) Two 'Realms'- the Himalayan region represented by Palearctic Realm and the rest of the sub-continent represented by Malayan Realm; (ii) Five Biomes e.g. Tropical Humid Forests; Tropical Dry Deciduous Forests (including Monsoon Forests); Warm Deserts and Semi-deserts; Coniferous Forests; Alpine Meadows; and (iii) Ten biogeographic zones and Twenty-seven biogeographic provinces(ibid).

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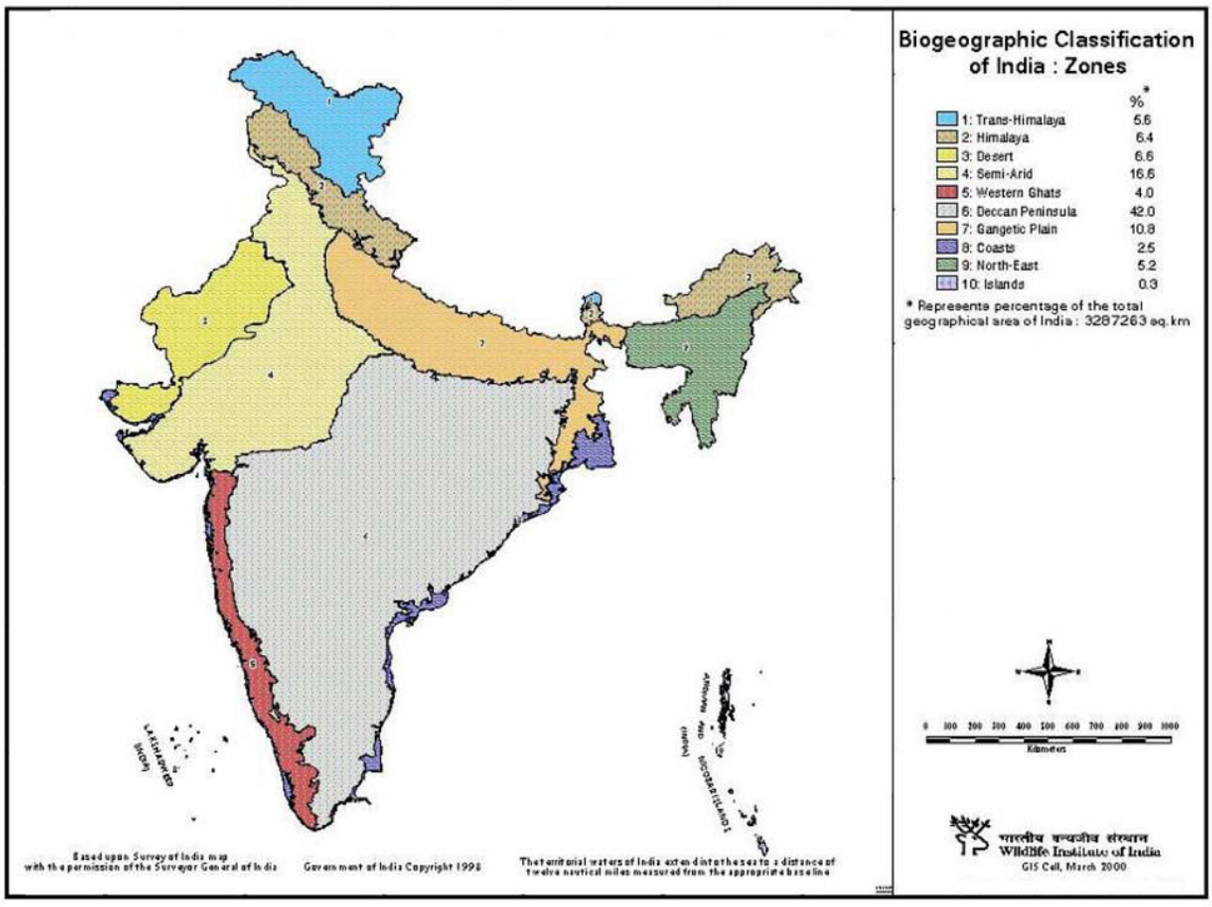


(Source: Rodgers and Panwar, 1988)

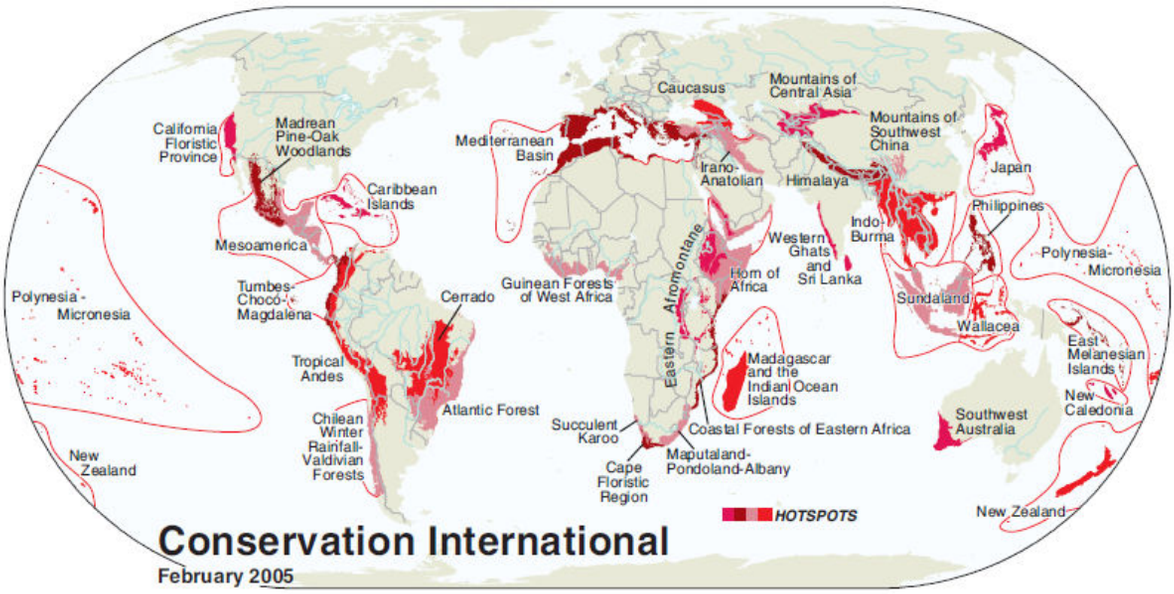
Figure 1. Biogeographic zones in India

Indian region has over 130,000 species of plants and animals which have been scientifically documented. The country has been referred to as one of the top mega diversity region of the globe with only 2.5% of the global land area. Of the 34 globally identified biodiversity hotspots, India harbours four hotspots, i.e., Himalaya, Indo-Burma, Western Ghats and Sri Lanka, Sundaland. The richness of the biodiversity of the region is largely due to the occurrence of rich diversity of species, genetic and ecological variabilities in different biogeographically and bioclimatically defined zones.

In terms of plant diversity, India ranks tenth in the world and fourth in Asia. India represents nearly 11% of the world's known floral diversity with over 45,500 plant species. The richness of Indian plant species as compared to the world is shown in Table 1.

Endemism pertains to the restricted distribution of the flora and fauna. The probable causes for same are geographical isolation, land degradation, close and distinct ecosystem like mountain and oceanic systems etc. About 11,058 species are endemic to Indian region, 6,200 of which belong to flowering plants alone. Eastern Himalaya and north-eastern region (about 2,500 species), peninsular India including western and Eastern Ghats (about 2,600 species), north-western Himalaya (about 800 species) and Andaman & Nicobar Islands (about 250

species) are the areas rich in endemic plants. Endemism in different plant groups of India is given in Table 2.



(Source: http://www.conservation.org)

Figure 2. Global biodiversity hotspots

Plant groups	No. of species		% of India to the world
	India	World	
Virus/Bacteria	850	8,050	10.6
Algae	7175	40,000	17.9
Fungi	14,500	72,000	20.1
Lichens	2223	13,500	16.4
Bryophytes	2500	14,500	17.2
Pteridophytes	1,200	10,000	12.0
Gymnosperms	67	650	10.3
Angiosperms	17,527	2,50,000	7.0

(Source: BSI, 2009)

Table 1. Number of species in major groups of plants and microorganisms in relation to same at international level showing extent of diversity

S. N.	Plant group	Total number of species in India	Nos. of Endemic Species	%
1	*Angiosperms*	17527	6200	35.3%
2	*Gymnosperms*	67	7	14.9%
3	*Pteridophytes*	1200	193	16.0%
4	*Bryophytes*	2500	629	25.1%
5	*Lichens*	2223	527	23.7%
6	*Fungi*	14500	3500	24.0%
7	*Algae*	7175	1925	26.8%

(Source: Botanical Survey of India, 2009)

Table 2. Endemism in different plant groups of India showing high % of endemism to emphasize need of conservation

As per the IUCN Red List (2008), India has 246 globally threatened floral species, which constitute approximately 2.9% of the world's total number of threatened floral species (8457). Distribution of various IUCN threat categories of Indian plants as compared to global trends is given in Figure 3 and 4.

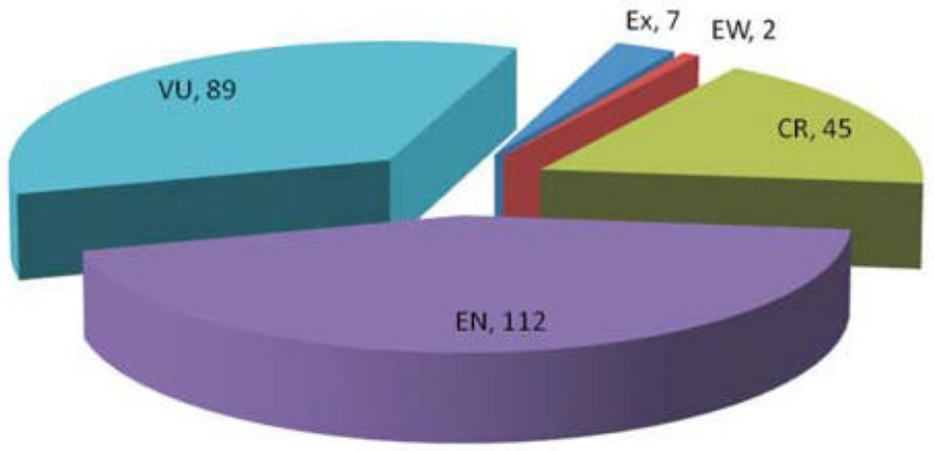


Figure 3. Indian plants – representation in IUCN threat categories

2.2. Forest biodiversity

India is endowed with vast forest resources. Forests play a vital role in social, cultural, economic and industrial development of the country and in maintaining its ecological balance. The forest resources are storehouse of biodiversity. Other land use practices are benefitted by forests. Realizing the crucial role of forests in maintaining the ecological balance and socio-economic development, the National Forest Policy, 1988 aims at maintaining a minimum of

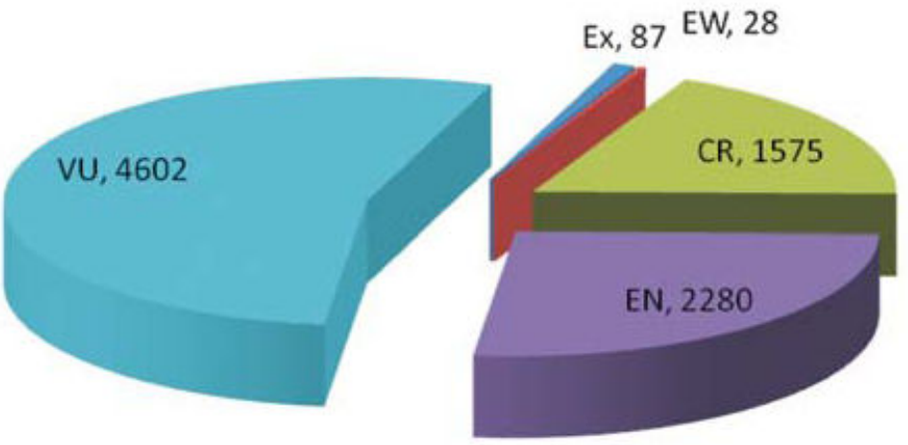


Figure 4. Plants – global representation in IUCN threat categories

33% of country's geographical area under forest and tree cover. Currently, total forest cover of India is 692,027 km^2 which forms 21.05% of the geographical area of the country (FSI 2011). The state of Madhya Pradesh has the largest forest cover (77,700 km^2) in the country followed by Arunachal Pradesh (67,410 km^2), Chhattisgarh (55,674 km^2), Maharashtra (50,646 km^2) and Orissa (48,903 km^2) in terms of percentage of forest cover with respect to total geographical area.

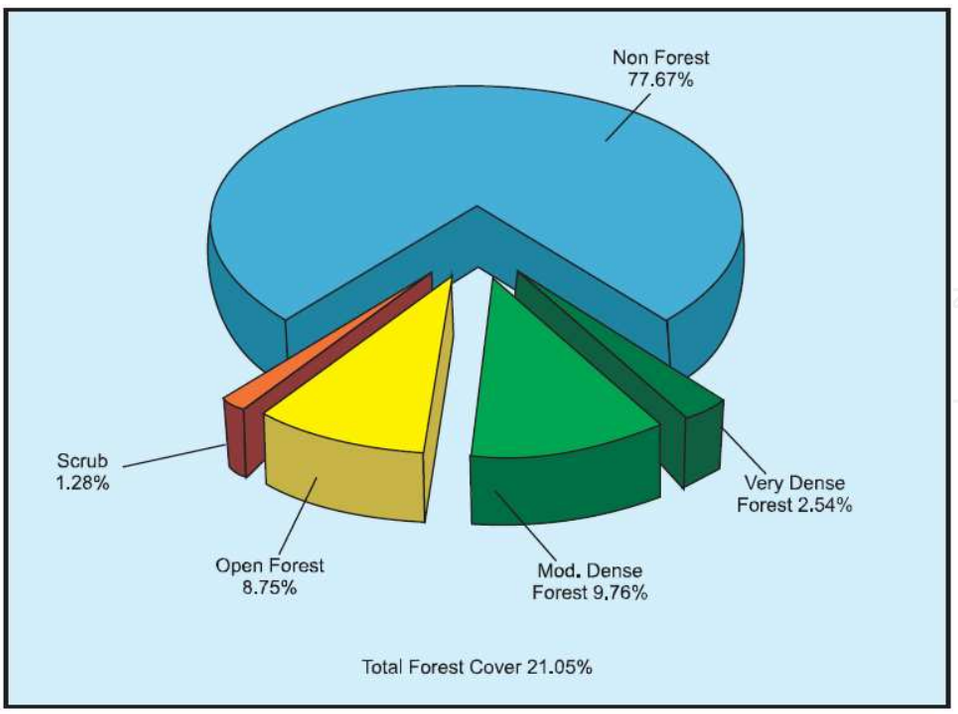


Figure 5. Forest cover of India

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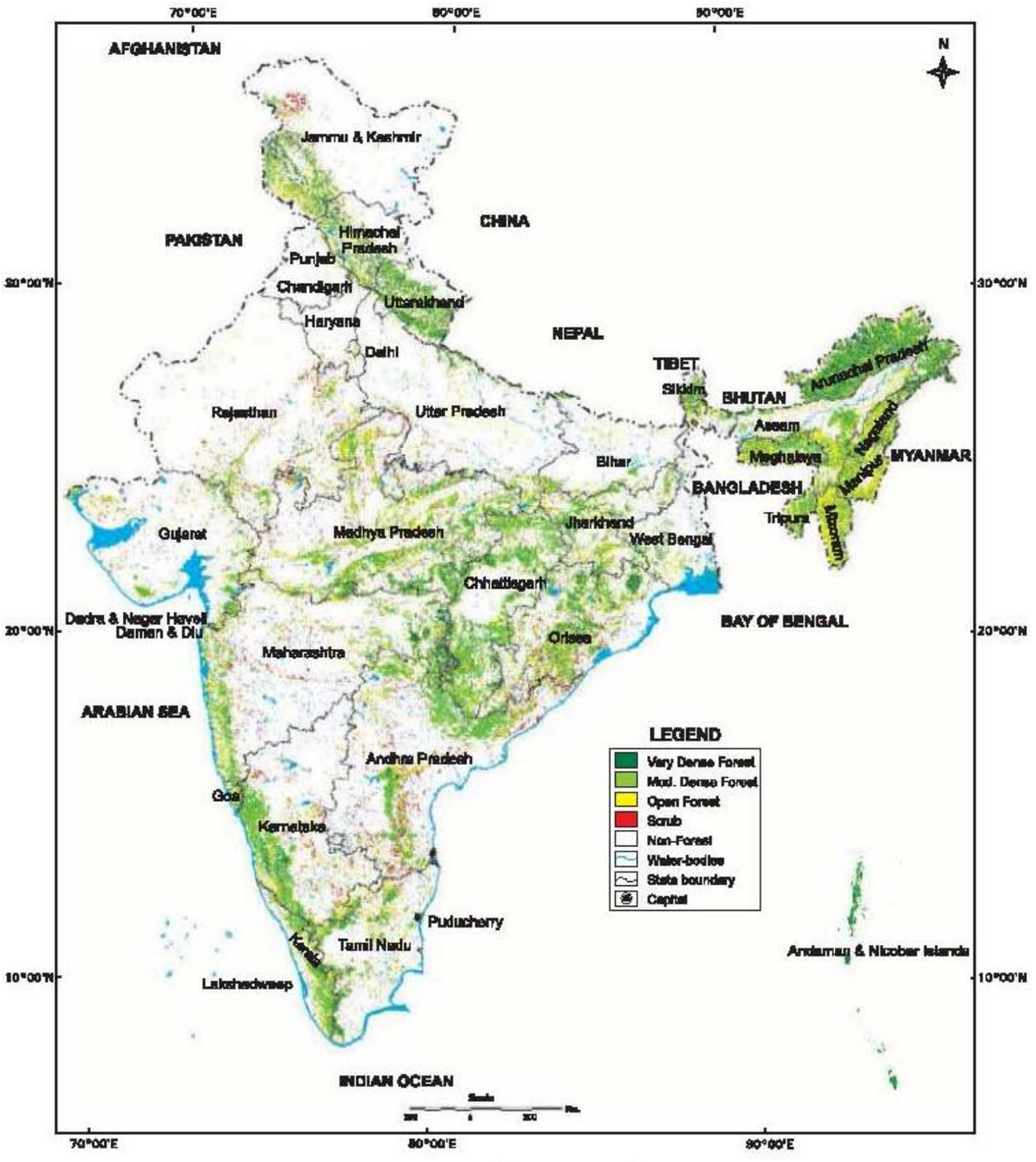

(Source: FSI 2001)

Figure 6. Forest cover map of India

The forests in the country have been classified into 16 major types and 251 subtypes by Champion and Seth (1968) on the basis of climatic and edaphic features. Forest Survey of India has mapped forest types of India, based on Champion and Seth classification on 1:50,000 scale. Distribution of diverse forest types across the country is presented in Table 3.

Sl.No	Group	% of Forest Cover
1.	Group1- Tropical Wet Evergreen Forest	2.92
2.	Group2- Tropical Semi –Evergreen Forest	13.79
3.	Group3- Tropical Moist Deciduous Forest	19.73
4.	Group 4-Littoral and Swamp Forest	0.69
5.	Group5- Tropical Dry Deciduous	41.87
6.	Group 6-Tropical Thron Forest	2.25
7.	Group 7- Tropical Dry Evergreen Forest	0.13
8.	Group 8- Subtropical Broadleaved Hill Forest	2.69
9.	Group 9 Subtropical Pine Forest	2.63
10	Group 10- Subtropical Dry Evergreen Forest	0.03
11	Group 11- Montane Wet Temperate Forest	0.69
12	Group 12- Himalayan Moist Temperate Forest	4.12
13	Group13- Himalayan Dry Temperate Forest	0.84
14	Group 14,15 ,16- Sub Alpine and Alpine Forest	2.55
15	Plantation/TOF	5.07

(Source: FSI 2011)

Table 3. Percentage of total forest cover in different forest type groups supporting harbouring diverse life forms

Forests are one of the most biologically rich terrestrial systems with diversity in their forest types. These types provide habitats for plants, animals and micro-organisms, and harbour the vast majority of the world's terrestrial species. Furthermore, forest biodiversity is interlinked to a web of other socio-economic factors, providing an array of goods and services that range from timber and non-timber forest resources to mitigating climate change and genetic resources. At the same time, forests provide livelihoods for people worldwide and play important economic, social, and cultural roles in the lives of many indigenous communities. Therefore, forests and forest biological diversity are innately linked to ecosystem and human well-being.

2.3. Salient features of India's forest phytodiversity

i. The Himalayas

Himalayas-one of the largest and youngest mountain chains in the world-cover roughly 10% of India total land surface. Variations in terms of its size, climate and altitudinal ranges have created environments unique and characteristic to this region only. The diverse climate and the varied environmental conditions of Himalayas support diverse habitat and ecosystems with equally diverse life forms.

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The Indian Himalayan flora represents 71 endemic genera and 32% endemic species. The families such as Tetracentraceae, Hamamelidaceae, Circaeasteraceae, Butomaceae, and Stachyuraceae are endemic families of flowering plants. Over 90% of the species in the family Berberidaceae and Saxifragaceae are endemic to the Himalaya, several of the species are disjunct elements of phytogeographical significance. A large number of orchids, many representing neoendemic taxa occur in Sikkim and Arunachal Pradesh.

Except perhaps in the higher elevations of Himalayas and in the more arid parts of Tahr Desert, the natural vegetation of India is essentially arboreal. It is conifers in the Himalayas, which generally resemble that from the north. The most conspicuous trees here are *Shorea robusta, Dipterocarpus tuberculatus, Dalbergia sissoo, Acacia catechu* and *Acacia nilotica*, ssp Indigenous palms like *Corypha, Phoenix sylvestris* and *Borassus flabellifer* as well as Bamboos are common here. Tree ferns are abundant in the forests of Eastern Himalays. The occurrence of *Rhododendron*, an Ericaceae member of high altitude, both in the Himalayas and in the Western Ghats is phytogeographically interesting. The tropical humid elements in the Western Himalays is represented by the Malesian-Deccanian-Pre Himalayan forms such as *Terminalia bellirica, Bombax ceiba*, *Toona cilitata, Syzygium cumini, Lagerstroemia* spp., *Daphniphyllum* spp. and *Shorea robusta*. The tropical semi-arid elements are represented by *Woodfordia* spp., *Dalbergia sissoo* and *Lannea coromandelica*.

The evergreen forests in the Eastern Himalays consist of tree species such as *Aesculus panduana, Artocarpus chamba* (*A. chaplasha*), *Michelia chmapaca, Cinnamomum* spp., *Schima wallichii* and *Dillenia indica*. The common Bamboo seen here is *Dendrocalamus hamiltonii*. The Savannas in this part of the Himalays are usually moist and consist of trees like *Albizia procera, Bischofia javanica* and *Bombax*. The vegetation in the lower region is dominated by broad leaved species of Oaks such as *Quercus lamellosa, Q. lineate, Michelia daltsopa* (*M. excelsa*), *Pyrus* spp., *Symplocos* spp., *Eurya* spp., *Meliosma* spp., and *Castanopsis* spp.

ii. Desert region

In Indo-Pacific region Thar desert ecoregion is considered the world's seventh largest desert. The eco-region lies to the west of Aravalli Range and characterized by extreme climate with temperature touching subzero in winters and nearly 50°C during the summer. Rainfall in such region ranges between 100-150 mm.

Flora of Indian desert consists of approximately 700 species (352 genera and 87 families including solitary gymnosperm family). 37 genera and 63 species are exotic to the region. A large number of plants species found in the Thar Desert are known to be endemic (Khan and Frost 2001). High endemism and the occurrence of a large number of sub-species provide evidence of high phylogenetic plasticity and intense speculation on account of extreme dynamics of the ecological conditions, and the recent geological, physiographic, topographical those of the Sahara (Quezel 1965). The plant taxa endemic to the Thar Desert include 23 species and 14 sub-species, forming 6.4 percent of the recorded total. High endemism and the occurrence of a large number of subspecies provide evidence of high phylogenetic plasticity. A complex of extreme environmental factors, the dynamics of the ecological conditions, recent geological, physiographic and topographical changes, can induce speciation. The proportion

of endemic plant species in the Indian desert is higher (6.4 percent) than that of the Sahara which has only 3 to 5 percent of endemic species (Gupta 1998). The Indian desert endemic flora includes: *Calligonum polygonoides* (Polygonaceae), *Prosopis cineraria* (Mimosaceae), *Acacia nilotica* (Mimosaceae), *Lasiurus sindicus* (Poaceae), *Cenchrus biflorus* (Poaceae), *Tecomella undulata* (Bignoniaceae), *Citrullus colocynthis* (Cucurbitaceae), *Anogeissuspendula* (Combretaceae), *Tamarix aphylla* (Tamaricaceae), *Salvadora oleoides* (Salvadoraceae),*Commiphora weightii* (Burseraceae), *Haloxylon salicornicum* (Chenopodiaceae), *Capparis decidua* (Capparaceae), *Sueda fructicosa* (Chenopodiaceae), *Aerva pseudotomentosa* (Amaranthaceae) *Crotolaria burhia* (Fabaceae), *Leptadenia pyrotechnica* (Ascelpiadaceae).

The once glorious forests in this region stand, however degraded because of the biotic interference and comprise mostly of bushy, thorny plants. The common trees found are *Acacia nilotica*, ssp. *indica, Prosopis cineraria, Acacia senegal, Anogeissus latifolia, Syzygium cumini, Dalbergia sissoo, Albizia lebbeck, Boswellia serrata, Balanites aegyptiaca* (*B. roxburghii*), *Sterculia urens, Commiphora mukul* and *Acacia leucophloea*. *Prosopis chilensis* (*P. juliflora*) is extensively planted all over the plains.

Pandey *et al.* (1983) reported 41 and Sharma (1983) reported 106 rare, endangered and threatened (RET) taxa from Rajasthan. Pandey and Shetty (1985) listed RET taxa, whereas Singh (1985) dealt with threatened taxa and their scope of conservation. The present flora of Rajasthan has 2090 species belonging to 819 genera under 159 families of vascular plants (Shetty and Singh, 1987-1993). This included 63 RET taxa, reasons for their depletion and strategies for conservation as well as 45 species of crop and other cultivated plants having 66 species of their wild relatives. However, various researchers are working on under explored areas in search of new species and re-defining the status of RET species. According to Khan et al. (2003), Thar Desert has its own importance and specific characteristics with respect to endemic and medicinal plants. In this study forty-five plant species were considered to be rare and/or endangered and a large number of plants have been categorized as of economic importance and medicinal use. The high population of the region exerts pressure on the biological resources of the Thar Desert causing lack of sustainability and necessitates conservation of biodiversity actions.

iii. Gangetic Plain

The forests of Gangetic Plain have largely been destroyed and in some tracts Sal forests are left. The Sal forests have species like *Terminalia elliptica* (*T. alata*), *Terminalia bellirica, Bauhinia* spp., *Syzygium cumini, Phyllanthus emblica* and *Woodfordia* sp. The mangrove forests of Sunderbans have species like *Aechmanthera gossypina* (*Aegiceras majus*), *Cynometra iripa* (*C. mimosoides*) and *Ceriops tagal* (*C. candolleana*).

iv. North-east India

In the north-east region, the tree flora is luxuriant, consisting of species like *Artocarpus chamba, Michelia champaca, Ficus elastica, Mesua ferrea, Alstonia scholaris, Pterygota alata, Morus macroura* (*M. laevigata*) and *Stereospermum chelonoides*. The common Bamboo available here is *Dendrocalamus hamiltonii*. The hill forests are dominated by *Alnus nepalensis, Rhododendron arboreum, Michelia champaca* and *Prunus* sp. The Pine forests are composed of *Pinus kesiya*.

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Samati and Gogoi (2007) carried out a study for the documentation of the ethnobotanical wealth of Jaintia hills. Population expulsion and unemployment also compel people to exploit these SGs, leading to a rapid dwindling of many rare and threatened taxa of both plants and animals from the region. In this context he mentions that an extensive awareness programme is needed to educate the locals about SGs. The State Forest Department and MoEF can join hands with the local NGOs to create a network of all the SGs and bring them under state-sponsored conservation programmes. The Tourism Department also should come forward to focus on SGs as a destination for tourists. The local community should be provided with adequate funds and the responsibility to manage the SGs. This will help in the protection of the SGs. Eco-restoration and afforestation programmes of the government conservation agencies should also include these degraded SGs.

Deb et al (2008) stated that the areca-nut based traditional agroforests and the natural tropical rainforests have multi-layered vegetal structures with comparable tree density, but showed significant differences in soil nutrients and microbial biomass that recorded lower values in traditional agroforests as compared to the tropical forests. Nonetheless, the percentage contribution of soil microbial biomass, litter and fine roots to soil C was similar and competitive in traditional agroforests, but substantially lower than that in the tropical forests. Litter had a major role to play in soil nutrient turnover in tropical forests followed by soil microbes and fine roots. The traditional agroforesty systems studied are, however not well-managed, but when subjected to scientific management might prove to be a sustainable food production land use system in the hills and flood plains and consequently can potentially promote conservation and sustainability of the tropical forests.

Deb and Sundriyal (2007) stated that small and medium size gaps had limited impacts on the species composition. Such gaps however are crucial for regeneration of top canopy as well as pioneer species and hence the important for maintaining species diversity in Namdapha National Park. As the gaps showed difference in species composition, it clearly illustrated that the plant species behavior in low-land tropical forest is independent of gap size and is mainly governed by availability of seeds at the time of creation of gaps. The information on the tree species gap performance has implications for the management of the forest stand.

Mishra *et al* 2005 conducted a study in a subtropical humid forest (sacred grove) at Mawnai, West Khasi hills district of Meghalaya. *Citrus medica* (Rutaceae), the dominant species, was the only species exhibiting random distribution. All other species showed contagious distribution. *Cryptocarya amygdalina*, family Lauraceae, was the co-dominant species. Lauraceae (17 species) was the species rich family in the grove and exhibited maximum tree density and basal area. However, generic composition was highest (9 genera) in the case of Euphorbiaceae, which is the co-dominant family in the grove. Majority of the families were represented by single genus and single species. Log-normal dominance-distribution curves at the levels of species and family, and wide girth structure signify the complexity and stability of the community.

v. The Western Ghats

The Western Ghats are the main peninsular hill range extending over 1400 Km, starting in the north from near the Tapti River and ending in the south near Kanyakumari. Undoubtedly it

is the most important topographic feature of peninsular India. It is more or less homogenous but biologically distinctive geographical zone with total area of about 1,60,000 sq. Km of which about one third is forests. It is known that 90% of the country's medicinal flora occurs in these forests.

The Western Ghats region is considered as one of the most important biogeographic zones of India as well as one of the 34 'Hot Spots' of biodiversity recognized in the world. About 1500 endemic species of dicotyledonous plants have been reported from the Western Ghats. It is one of the richest centers of endemism. Due to varied topography and micro-climatic regimes, some areas within the region are considered to be active zones of speciation. The region has 490 arborescent taxa, of which as many as 308 are endemics. 56 genera and 1500 species of flowering plants and 63% of India's evergreen forest plants are endemic to the Western Ghats.

The Western Ghats forests are characterized by conditions of high humidity and temperature, favouring vigorous growth of trees that often attains a height of 60 m or more. The tropical wet evergreen and semi-evergreen forests are typically rain forests. Luxuriant vegetation in more or less virgin condition is a characteristic feature of the Malabar region of the Western Ghats. The region has tropical evergreen rain forests, mixed deciduous or monsoon forests and subtropical or temperate forests. Majority of the tree species in this region belong to the families like Dipterocarpaceae, Guttiferae, Myristicaceae, Tiliaceae, Euphorbiaceae, Annonaceae, Anacardiaceae, Fabacae, Caesalpiniaceae, Mimosaceae, Meliaceae, Myrtaceae, Rutaceae, Rubiaceae, Sapotaceae, Urticaceae and Palmaceae. The tropical evergreen forests consists of tree species such as *Toona ciliata*, *Dysoxylum malabaricum, Vateria indica, Dipterocarpus indicus, Hopea parviflora, Hopea ponga, Cullenia exarillata, Artocarpus hirsuta, Vitex altissima, Hydnocarpus laurifolia*, *Humboldtia* spp., *Haldinia cordifolia* and *Garcicina* spp.

The mixed deciduous or monsoon forests consist of dominant tree species like *Terminalia elliptica* (*T. alata*), *T. paniculata, T. bellirica, T. chebula, Lagerstroemia* spp., *Dalbergia latifolia, Xylia xylocarpa, Pterospermum* spp., *Sterculia urens, S. guttata* and *Stereospermum* spp. The bamboos occurring commonly in this forests are *Bambusa bambos* and *Dendrocalamus strictus*.

The subtropical or temperate evergreen forests are commonly known as "Sholas" and they usually exist above an altitude of 1800 m. They are composed mainly of *Gordonia obtusa, Michelia nilagirica, Ternstroemia japonica, Syzgium mudagam, Eugenia* spp., *Meliosma simplicifolia, Symplocos cochinchinensis, Litsea coriacea, Litsea floribunda* and *Actinodaphne* spp. The flora of the Nilgiri hills are interesting, as it shows affinities with Assam flora and with that of the southern slopes of Himalayas. Shola forests in the mountain slopes with trees of *Rhododendron arboreum*, ssp. *nilagiricum*, *Turpinia nepalensis, Elaeocarpus serrtus, E. recurvatus* and *Viburnum* spp. are unique in composition.

Fresh water swamps with characteristic vegetation occur in the Malabar region of the Western Ghats, dominated by different species of *Myristica*. Therefore, they are also called as "Myristica Swamps". The Myristica species in the swampy areas produce "Knee roots" which are very unique. The Myristica swamps consist of species such as *Myristica fatua* var. *magnifica* (*M. magnifica*), *M. malabarica, M. dactyloides, M. beddomei, M. contorta* and *Knema attenuata*

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The vegetation of the Western Ghats of the Malabar region is very rich and phytogeographically interesting. The species occurring here show affinities with that of Sri Lanka and Malaysia. The region is also rich in endemic species. The conifer, *Nageia wallichiana (Podocarpus wallichianus),* confined to the hills of Tirunelveli and Southern Kerala is known only from Burma and South East Asia.

vi. Deccan Plataeu

The deciduous forests of Deccan have species like *Sterculia urens, Boswellia serrata* and *Cochlospermum religiosum*. The dry slopes have *Anogeissus latifolia, Ougenia oojeinensis, Lannea coromadelica, Cleistanthus collinus, Zizyphus xylopyrus, Buchanania* spp., *Terminalia* spp., *Bauhinia* spp., *Shorea* spp., Dalbergia spp., *Maduca longifolia*, var. *latifolia* (*Bassia latifolia*), *Diospyros* spp., *Pterocarpus marsupium*, *Pterocarpus santalinus*, *Eugenia* spp. and *Wendlandia thyrsoidea*. The areas of having black cotton soil are covered by *Capparis divaricata*, *Acacia nilotica*, ssp. *indica*, *Prosopis cineraria, Parkinsonia aculeata* and *Zizyphus mauritiana*.

Except the more arid margins, the whole of Peninsular India was formerly densely forested, but at present only *Acacia* shrubs occur here. The thorn forests in the west, the closed monsoon forests of *Shorea* in Chota-Nagpur and the open deciduous forests in between are only relics.

vii. Andaman Islands

The vegetation of Andaman Islands consist of Mangrove forests, Littoral forests, Evergreen forests, Deciduous forests and the hill forests on shallow soiled slopes of hills. The major tree species of the island are *Pterocarpus dalbergioides* (Andaman Padauk), *Thespesia populnea, Pongamia pinnata, Barringtonia* sp., *Erythrina indica, Calophyllum inophyllum, Gyrocarpus americanus, Terminalia catappa, Rhizophora mucronata, Brugueira gymnorrhiza* and *Ceiops tagal* (Parkinson, 1923). The Andamans and the Nicobar Islands possess the best quality of mangrove forests. The total area estimated under mangrove vegetation in India is 4827 km^2 and out of this, 966 km^2 area of mangroves occurs in Andaman and Nicobar Islands (i.e. 20 per cent of the total mangrove area of the Indian territory) (Ramakrishana *et al.* 2010). There are 45 species of mangroves, coming under 27 genera, represented in the island zone.

viii. Coastal zone and Lakshadweep

The distribution of different mangrove genera shows that the greatest number of genera and species occur along the shores of the Indian and Western Pacific oceans. The Indian mangorves comprise approximately 59 species of 41 genera, belonging to 29 families. Of these, 32 species belonging to 24 genera and 20 families are present along the west coast. There are about 21 mangrove species reported from Gujarat coast, 28 from Maharashtra, 20 from Goa, 21 from Karnataka, 14 from Kerala and 4 from Lakshadweep. The Arabian Sea coast is characterised by the typical funnel shaped estuaries of the major rivers like Narmada and Tapti and numerous small rivers. The entire west coast is thus dominated by estuarine backwater type of mangroves, unlike the deltaic mangroves of the east coast. Mangrove forests of the west coast are evergreen or deciduous, characterized by the presence of *Avicennia marina, Rhizophora mucronata*, *Kandelia candel*, *Brugueira gymnorrhiza* and *Carallia brachiata*. *Sonneratia caseolaris* reported by Blatter in 1905 is fast disappearing from the west coast, while *S. apetala* is found

only along the Maharashra coast. Species like *Ceriops decandra, Xylocarpus* spp., *Lumnitzera littoralis, Nypa fruticans, Phoenix paludosa* and *Cerbera manghas* are limited along the east coast. The species, which commonly occur and uniformly distributed along the east and west coast of India are *Rhizophora mucronata, R. apiculata, Ceriops tagal, Brugueira gymnorrhiza, Lumnitzera racemosa, Sonneratia apetala, Acanthus ilicifolius, Avicennia marina, A. officinalis, Excoecaria agallocha* and *Acrostichum aureum*. The east coast of India has deltaic type of mangroves and it covers about 70 percent of the total mangrove forested area in India (Deshmukh, 1991).

2.4. Value of forest biodiversity

Life has value and meaning beyond monetary measure, and so does biodiversity. While it is not really possible to put a monetary figure on the value of forests, it is now widely recognized that we need to improve the way our societies and economies account for ecosystem services. We often take these services for granted, such as the ability of the forest to filter water or produce oxygen. Human well-being depends on the goods and services provided by nature —Earth's "natural capital". Recent initiatives, such as the global study on 'The Economics of Ecosystems and Biodiversity' (TEEB) have resulted in a better understanding of the economic value of forests and other ecosystems for societies.

Sl.No	Ecosystem services	Value of Ecosystem Services (US$/ha/year-2007 values)	
		Average	Maximum
Provisioning services			
1.	Food	75	552
2.	Water	143	411
3.	Genetic resources	483	1756
4.	Medicinal resources	181	562
Regulating services			
1.	Influence on air quality	230	449
2.	Climate regulation	1965	3281
3.	Water flow regulation	1360	5235
4.	Waste treatment/ water purification	177	506
5.	Erosion prevention	694	1084
Cultural services			
1.	Recreation and tourism opportunities	381	1171
Total		**6120**	16362

(Source: TEEB Climate Issues Update 2009)

Table 4. Values of ecosystem services in tropical forests for influencing economic decisions about the future of forests for Societies

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The TEEB study estimates that, on average, one hectare of tropical forest provides US$ 6,120 per year in ecosystem services, such as watershed protection, climate regulation; soil stabilization, coastal protection, nutrient cycling, and carbon storage (Table 4). This also includes the numerous products from tropical forests, such as timber, wild food and non-timber forest products—rubber, oils and fibres that are economically important both locally and nationally in many tropical forest countries. Yet, only a fraction of this value is currently accounted for when we make economic decisions about the future of forests. The Green Economy Initiative of the United Nations Environment Programme (UNEP) and other efforts are now underway to improve the way we value and account for nature in our economic decision-making.

2.5. Support for people's livelihoods

Forests, with their rich biodiversity are essential for human livelihoods and for sustainable development. For example, fuel wood is the primary source of energy for heating and cooking for an estimated 2.6 billion people. The World Bank estimates that forests directly contribute to the livelihoods of some 90 per cent of the 1.2 billion people living in extreme poverty. The Millennium Ecosystem Assessment also found that as many as 300 million people, many of them very poor, depend substantially on forest ecosystem services for their subsistence and survival. Many non timber forest products derived from forest biodiversity, such as wild cocoa, honey, gums, nuts, fruits, flowers, seeds, rattan, fungi and wild meat and berries are essential for the food, medicine and confectionary building material used by indigenous and local communities to sustain their way of life, including their cultural and religious traditions.

India has a huge population living close to the forest with their livelihoods critically linked to the forest ecosystem. There are around 1.73 lakh villages located in and around forests (MoEF, 2006). Though there is no official census figures for the forest dependent population in the country, different estimates put the figures from 275 million (World Bank, 2006) to 350-400 million (MoEF, 2009). People living in these forest fringe villages depend upon forest for a variety of goods and services which includes collection of edible fruits, flowers, tubers, roots and leaves for food and medicines; firewood for cooking (some also sale in the market); materials for agricultural implements, house construction and fencing; fodder (grass and leave) for livestock and grazing of livestock in forest; and collection of a range of marketable non-timber forest products. Therefore, with such a huge population and extensive dependence pattern, any over exploitation and unsustainable harvest practice can potentially degrade forest. Moreover, a significant percentage of the country's underprivileged population happened to be living in its forested regions (Saha and Guru, 2003). It has been estimated that more than 40 per cent of the poor of the country are living in these forest fringe villages (MoEF, 2006). Apart from this, a significant percentage of India's tribal population lives in these regions. Several field based studies have documented the adverse impact of such dependence pattern on the forest quality. The forest fringe communities not just collect these forest products for their own consumption but also for commercial sale, which fetch them some income. The income from sale of the forest products for households living in and around forest constitutes 40 to 60 per cent of their total income (Bharath Kumar *et al*, 2011; Sadashivappa *et al*, 2006; Mahapatra and Kant, 2005; Sills *et al*, 2003; Bahuguna, 2000). A study (Saha and Sundriyal,

2012) on the extent of NTFP use in north east India suggest that the tribal communities use 343 NTFPs for diverse purposes like medicinal (163 species), edible fruits (75 species) and vegetables (65 species). The dependence for firewood and house construction material is 100% and NTFPs contributed 19–32% of total household income for the communities under study (Saha and Sundriyal, 2012). Forests are not only a source of subsistence income for millions of poor households but also provide employment to poor in these hinterlands. This makes forests an important contributor to the rural economy in the forested landscapes in the country. The widespread poverty and lack of other income generating opportunities often make these people resort to over-exploitation of forest resources. The collection of firewood for sale in the market, though it is illegal, is also extensive in many parts of the forested regions in the country and constitutes the source of livelihood for 11 per cent of the population (IPCC, 2007). However, many other forest products have been sustainably harvested by local communities for many years, and are a constant source of household income.

2.6. Threats to the biodiversity

Threats to species are principally due to decline in the extent of their habitat, fragmentation of habitat, decline in habitats quality, shrinking genetic diversity; invasive alien species; declining forest resource base; climate change and desertification; over exploitation of resources; impact of development projects and impact of pollution. For terrestrial species decline habitat quality and quantity arise from conversion of forest and grasslands to agriculture, of natural forests into monoculture plantations and from grazing and firewood collection. In some areas, invasion of exotic species also results in habitat degradation. For aquatic and semi aquatic species, decline in habitat quality are due to diversion of ground and surface water resulting in drying of streams and other water bodies apart from siltation and pollution from pesticides. In this century, the Indian cheetah, Lesser Indian rhino, Pink-headed duck, and the Himalayan mountain quail are reported to have become extinct and several other species (39 mammals, 72 birds and 1,336 plants) are identified vulnerable or endangered.

The constraints and challenges to biodiversity conservation which flow inter alia from these threats include: biodiversity information base; implementation of Biological Diversity Act and safeguarding traditional knowledge; new and emerging biotechnologies; economic valuation and natural resource accounting; policy, legal and administrative measures; and institutional support. Taking clue from the preceding lines, the Cold Desert areas lie in the Trans-Himalayan zone and some species in the region those are endemic to Tibetan plateau and also include oasitic elements that comprises a variety of exotic as well as indigenous species. The area represents common herbaceous, shrubby and woody elements of temperate vegetation and alpine species also dot the region. The region is also a house of species growing in glacial moraines and also harbours threatened medicinal plants. Talking of faunal diversity this area harbours rare and endangered fauna pointed out earlier and avifauna endemic to the region or migrating adds to its uniqueness. Livestock rearing, agricultural & horticultural practices and mode of agro-forestry are entirely different and the people living here have succeeded in developing their own distinguish culture.

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The above explanation reveals that the area is unique to the region and hence requires special attention especially with respect of ecology of India. Hence laxity on our part in conserving the cultural and natural resources will put the area under severe thereat thereby exposing the region to all sorts of ecological disasters.

2.7. Habitat fragmentation, degradation and loss, and shrinking genetic diversity

Habitat destruction is identified as the main threat to biodiversity. Under diverse natural conditions, over a billion people in rural and urban areas live in harmony under a democratic system in India. Their pressing needs for food, fiber, shelter, fuel and fodder combined with compelling need for economic development exert enormous pressure on natural resources. With half the total land under agriculture, and approximately 23 or 20% per cent under forests, the protection of diverse habitats poses a formidable challenge. The loss and fragmentation of natural habitats affects all animal and plant species. We need to not only stop any further habitat loss immediately but also to restore a substantial fraction of the wilderness that has been depleted in the past. Various species of plants and animals are on the decline due to habitat fragmentation and over-exploitation, e.g. habitats of Great Indian Bustard in Madhya Pradesh, Gujarat and Rajasthan and of the Lion-tailed Macaque in Western Ghats. The major impact of developmental activities involves diversion of forest land. Since the enactment of Forest (Conservation) Act in 1980, about 14,997 development projects involving diversion of 11.40 lakh hectare forest area for non forestry uses, have been granted clearance. Against this diversion, Compensatory Afforestation has been stipulated over 12.10 lakh hectare.

Habitat fragmentation is also one of the primary reasons leading to cases of man animal conflict. Common property resources like pastures and village forests, which served as a buffer between wildlife habitat and agriculture, have been gradually encroached upon and converted into agricultural fields and habitation. Due to this, the villagers are brought into a direct conflict with wild animals.

Sacred groves (India has over 19,000 sacred groves) are also getting eroded or getting converted to plantations. Because there are several medicinal plants and wild relatives of crop plants occurring naturally in these areas, the sacred groves need to be conserved. Traditional norms and practices for conservation of neighborhood forest and common land are also diminishing, although certain rural and tribal communities continue to safeguard their biological resource base even at the cost of their livelihood and sustenance. Himalayan Forest Research Institute (HFRI), Shimla is in the process of documenting the sacred groves of Kullu Valley and it is proposed that such efforts are required to be replicated elsewhere in this part of the country. It is pertinent to add here that strengthening the database of sacred groves will usher in development of strong bonds between ecological and social ethos relevant to the society at last ultimately reflecting upon the conservation of biodiversity. The point gains significance here, because the areas under sacred groves, otherwise the property of local deity, are being encroached upon by the local population thereby creating loss of biodiversity (Horticulture is now being tried in these areas) on one hand and threatening the social ethos of the area on the other.

2.7.1. Invasive alien species

Among the major threats faced by native plant and animal species (and their habitats), the one posed by the invasive alien species is truly scaring since it is considered second only to that of the habitat loss. The major plant Forest Invasive Species (FIS) include *Lantana camara, Eupatorium glandulosum, Parthenium species, Mimosa* species, *Eichhornia crassipes, Mikania micrantha, Ulex europaeus, Prosopis juliflora, Cytisus scoparius, Euphorbia royleana* etc. Alien aquatic weeds like water hyacinth and water lettuce are increasingly choking waterways and degrading freshwater ecosystems. Lantana and carrot grass cause major economic losses in many parts of India. Highly invasive climbers like *Chromolaena* and *Mikania* species have over-run the native vegetation in North-East Himalayan region and Western Ghats. Numerous pests and pathogens such as coffee berry borer, turnip stripe virus, banana bunchy top virus, potato wart and golden nematode have invaded agro-ecosystems becoming serious menace. HFRI, Shimla has identified some of the plant and insect species which though invasive have naturalized itself in the region thereby, posing a serious threat to the ecology. No particular attention to these invasive species have been paid over a period of time which had then resulted into the present alarming situation and all the countries have now converged over a single platform for fighting the menace caused by the same. Accordingly special efforts towards assessment of these invasive species are required to be made and if we fail in this direction it will lead to loss of endemic biodiversity on one hand and will expose the area to the exotic species on the other.

2.7.2. Impact of development projects

India, with its large population, is poised for rapid economic growth. Large infrastructural and industrial projects, including highways, rural road network and the special economic zones (SEZs), are coming up. With cities and townships expanding often at the cost of agriculture, and agriculture expanding at the cost of tree cover, fresh threats to biodiversity are emerging. In addition, changing lifestyles of the people with rising incomes, in both rural and urban areas, are placing increasing demands on biodiversity.

No doubt that infrastructural development is essential for the welfare of human beings inhabiting the planet since; it brings more comfort to the society. However, it may specifically be mentioned over here that over utilization of the resources for substantial increase in the comforts is directly impinging upon the environmental health. Developmental activities no doubt, are essentially required for the larger interest of the human kind yet, over utilization of natural resources in the process certainly require a relook into some of the criterion otherwise required to be fitted in the process for sustainable development. The government machinery should therefore, be not averse to the development but should ask the implementers and managers to devise suitable strategies for paying required attention towards the development of issue based parameters for ultimate protection of the environment.

Many river valley projects are being implemented for the last 100 years or so all across the world. These projects besides providing safeguards against floods also provide electricity for increasing overall productivity of the region or of the country. Though efforts in the direction are still continuing, yet it is estimated that approximately 99 per cent of precipitation in the

form of rain, snow etc. directly merges with the oceans without being utilized properly on their way. This certainly requires sincere thoughts/ efforts to harness it for the ultimate benefit of the mankind.

In order to harmonize developmental activities with protection of environment, environmental impact assessment (EIA) was made mandatory by the EIA Notification issued in 1994 for notified categories of developmental projects in the sectors of industry, thermal and nuclear power, mining, river valley and infrastructure projects. This Notification has been revised and notified on 14 September 2006 to make the EIA process more efficient, decentralized and transparent. What is required now is the effective implementation of these legislations by making it site and species specific. So that such plans become more relevant to the Environmentalists, implementers and managers. The issue gains significance in the state of Himachal Pradesh. Since large reservoirs are repeatedly coming over on the same river within a short distance and hence, are damaging the fragile ecology of Himalayas and directly impinging upon the loss of biodiversity. Large tunnel projects are also affecting the aquatic fauna-due to diversion of water through these tunnels especially during the winters when the water flow in the rivers gets reduced considerably.

2.7.3. Pollution

Biodiversity in India is facing threat from various sources of pollution, both point and non-point, sources. The major threats are from improper disposal of municipal solid waste, inadequate sewerage, excessive use of chemical pesticides and continuous use of hazardous chemicals even where non-hazardous alternatives are available. New industrial processes are generating a variety of toxic wastes, which cannot be dealt with by currently available technology in the country. Besides, economic constraints and problems related to the indigenization makes the substitution of these technologies difficult.

3. Major findings and management status

India has a long history of conservation and sustainable use of natural resources and over a period of time has developed a stable organizational structure for environment protection. Conservation and sustainable use of biodiversity has been integrated into national decision making through:

1. Policy statements (e.g. National Forest Policy, National Conservation Strategy, National Wildlife Action Plan, Draft National Environment Policy.)
2. Legislative measures (e.g. Environment (Protection) Act, Wildlife (Protection) Act, Biological Diversity Act, Environment Impact Assessment Notification, Coastal Regulation Zone Notification, Notifications on ecologically fragile areas)

India's strategies for conservation and sustainable utilization of biodiversity in the past have comprised providing special status and protection to biodiversity – rich areas by declaring them as National Parks, Wildlife Sanctuaries, Biosphere Reserves, ecologically fragile and

sensitive areas, off loading pressure from reserve forests adopting by alternative measures for fuel wood and fodder by afforestation of degraded areas and wastelands, creation of *ex-situ* conservation facilities such as gene banks etc.

Although there were several Acts existed in India for ensuring conservation of biodiversity, the International Convention on Biological Diversity that came in to effect in 1993 and the Biodiversity Act, 2002 enacted by the Indian Parliament subsequently gave impetus to the conservation efforts in the country.

3.1. The Convention on Biological Diversity

The Convention on Biological Diversity (CBD) is a landmark in the environment and development field, as it envisages for the first time a comprehensive rather than a sectoral approach to the conservation of Earth's biodiversity and sustainable use of biological resources. It was in the year 1984 that the need to have in place a global convention on biological diversity started gaining momentum. In response to it, the United Nations Environment Programme (UNEP) in the year 1987 recognized the need to streamline international efforts to protect biodiversity. The Convention on Biological Diversity (CBD) was negotiated and signed by nations at the UNCED Earth Summit at Rio de Janeiro in Brazil in June 1992. The Convention came into force on December 29, 1993. India became a Party to the Convention in 1994. At present, there are 175 Parties to this Convention (NBA, 2004).

The main objectives of the Convention are:

- Conservation of biological diversity
- Sustainable use of the components of biodiversity and
- Fair and equitable sharing of benefits arising out of the utilisation of genetic resources.

3.2. Biological Diversity Act, 2002

The Central Government has brought Biological Diversity Act, 2002 with the following salient features:-

1. To regulate access to biological resources of the country with the purpose of securing equitable share in benefits arising out of the use of biological resources and associated knowledge relating to biological resources.
2. Conservation and sustainable use of biological diversity.
3. To respect and protect knowledge of local communities related to biodiversity;
4. To secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information relating to the use of biological resources.
5. Conservation and development of areas of importance from the standpoint of biological diversity by declaring them as biological diversity heritage sites.
6. Protection and rehabilitation of threatened species.

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7. Involvement of institutions of State governments in the broad scheme of the implementation of the Biological Diversity Act through constitution of committees (NBA, 2004).

3.3. Conservation of forest biodiversity in protected areas

In order to conserve variability within and among different species in its authority Protected Areas (PAs) have been established for coordinated conservation of ecological units and corridors with multilateral cooperation of the neighbouring nations. There are different types of PAs like Biosphere Reserve (BR), National Parks (NPs), Wildlife Sanctuaries (WLS), Conservation Reserves (CR) and Community Reserves (Com.R).

Different workers have carried out isolated work on evaluation of genetic conservation of forest trees and woody species in the country. Nageswara Rao *et al.* (2001) assessed the genetic diversity parameters of Sandal (*Santalum album*) populations of peninsular India and suggested that *in-situ* conservation of Sandal genetic resources to be focused at populations and sites in the Deccan plateau. Similarly, Ravikanth *et al.* (2001) mapped the genetic diversity of rattans in central Western Ghats and suggested to have conservation stands at three sites in southern Western Ghats. Anandarao (2003) and Tikader *et al*. (2001) studied the germplassm of different species of *Morus* and identified diverse populations in different locations in Andamans, North-East India. Padmini *et al.* (2001) analysed Genetic diversity of *Phyllanthus emblica* in forests of South India and identified different locations with high diversity for *in-situ* conservation. However, these findings couldn't be utilized fully as certain identified sites fall outside the already established PAs. Vasudeva *et al* (2002) studied the available population of *Semecarpus kathalekanensis,* an Endangered tree and its diversity in Myristica swamp in Karnataka and suggested the requirement of special *in-situ* conservation measures.

3.4. Biosphere Reserves, National Parks and Wildlife Sanctuaries

Biosphere Reserve is an international conservation designation given by UNESCO under its Programme on Man and the Biosphere (MAB). According to "The Statutory Framework of the World Network of Biosphere Reserves," biosphere reserves are created to promote and demonstrate a balanced relationship between humans and the biosphere. Under article 4, biosphere reserves must "encompass a mosaic of ecological systems," and thus consist of combinations of terrestrial, coastal, or marine ecosystems. In India there are 15 biosphere reserves with total area of 58,645 sq.km (MoEF, 2009) (Table 5). They encompass one or more protected areas like National Parks, sanctuaries or conservation reserves.

A network of 667 PAs has been established, extending over 157826.773 sq. kms. (4.80 % of total geographic area of the country), comprising 102 National Parks, 514 Wildlife Sanctuaries, 47 Conservation Reserves and 4 Community Reserves. The State / Union Territory wise details of PAs in the country with extent are given in (Table 5.). The protected areas in India are mainly meant for large mammals, birds and some specific conservation dependant flagship species. However, when the whole habitat or ecosystems are protected, whole forest biodiversity also enjoys the protection. Some protected areas have also been designated recently for the conservation of certain plant species, considering their importance. They are Kurinjimala

S.No.	Name	Area of Biosphere (sq km)	Date of establishment	State
1	Achanakmar-Amarkantak	3835.51	2005	Madhya Pradesh & Chhattishgarh
2	Agasthyamalai	3500.36	2001	Tamilnadu & Kerala
3	Dehang-Debang	5111.5	1998	Arunachal Pradesh
4	Dibru-Saikhowa	765.00	1997	Assam
5	Great Nicobar	885.00	1989	Andaman and Nicobar
6	Gulf of Mannar	10500.00	1989	Tamil Nadu
7	Khangchenjunga	2619.92	2000	Sikkim
8	Manas	2837.00	1989	Assam
9	Nanda Devi	5860.69	1988	Uttaranchal
10	Nilgiri	5520.4	1986	Tamil Nadu, Kerala, and Karnataka
11	Nokrek	820.00	1988	Meghalaya
12	Pachmarhi	4926.00	1999	Madhya Pradesh
13	Simlipal	4374.00	1994	Orissa
14	Sunderbans	9630.00	1989	West Bengal
15	Kachcha	12454		Gujarat
	Total			

(Source: MoEF, 2009)

Table 5. Biosphere Reserves in India encompass a mosaic of ecological systems consist of combinations of terrestrial, coastal, or marine ecosystems

National Park, in Idukki district, Kerala for *Strobilanthes;* the *Rhododendron* Sanctuary at Singba in Sikkim, the *Nepenthes* Sanctuary at Jarain in Meghalaya and the Orchid Sanctuary at Sessa in Arunachal Pradesh.

3.5. Conservation of forest biodiversity outside protected areas

In addition to the PAs, there are several other means of *in-situ* conservation like Sacred Groves (SG), Gene Pool Conservation Areas (GPCA), Seed Production Areas (SPAs) Medicinal Plant Conservation Areas (MPCA) and Permanent Preservation Plots (PPP).

3.6. Sacred groves

Conservation of habitats and individual species has been practiced in India since time immemorial. Concern for nature conservation is deeply embedded in the multiracial Indian

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society. The Sacred groves are patches of natural vegetation, which are protected through some religious faiths and they exist throughout India. They shelter many economically important, medicinal, endemic, rare and endangered species. The extent of sacred groves varies from $1m^2$ to 1000000 m^2. Although, there has been no comprehensive study on the Sacred groves of the entire country, experts estimate the total number of sacred groves in India could be in the range of 100,000 – 150,000. As per some reports, India is having 13270 sacred groves (Malhotra *et al*. 2001; Kunhikannan and Gurudev Singh, 2005; Warrier *et al*. 2008) (Table 6).

State/Union Territories	National Parks (NP)	Wildlife Sanctuaries (WS)	Conser. Reserves (CR)	Community reserve (Com.R)	Area of state (sq km)	Total Area covered (sq km)	% of protected area in State
Andhra Pradesh	6	21	0	0	275068	13006.514	4.73
Arunachal Pradesh	2	10	0	0	83743	9778.57	11.68
Assam	5	18	0	0	78438	3909.80	4.98
Bihar	1	12	0	0	94163	3187.33	3.39
Chhattisgarh	3	11	0	0	135194	6382.27	4.79
Goa	1	6	0	0	3702	754.91	20.39
Gujarat	4	23	1	0	196024	17323.48	8.83
Haryana	2	8	2	0	44212	348.84	0.75
Himachal Pradesh	5	32	0	0	55673	10016.85	17.99
Jammu & Kashmir	4	15	34	0	222235	11688.36	5.26
Jharkhand	1	11	0	0	79714	2182.14	2.74
Karnataka	5	22	2	1	191791	6482.52	3.38
Kerala	6	16	0	1	38863	2382.52	6.13
Madhya Pradesh	9	25	0	0	308252	10814.76	3.51
Maharashtra	6	35	1	0	307690	15429.75	5.02
Manipur	1	1	0	0	22327	224.4	1.01
Meghalaya	2	3	0	0	22429	301.68	1.35
Mizoram	2	8	0	0	21081	1240.75	5.89
Nagaland	1	3	0	0	16579	222.35	1.34
Orissa	2	18	0	0	155707	7959.85	5.11
Punjab	0	12	1	2	50362	344.72	0.68
Rajasthan	5	25	3	0	342239	9548.60	2.79
Sikkim	1	7	0	0	7096	2183.10	30.76
Tamil Nadu	5	21	1	0	130058	3829.82	2.95

State/Union Territories	National Parks (NP)	Wildlife Sanctuaries (WS)	Conser. Reserves (CR)	Community reserve (Com.R)	Area of state (sq km)	Total Area covered (sq km)	% of protected area in State
Tripura	2	4	0	0	10486	603.62	5.76
Uttar Pradesh	1	23	0	0	240926	5711.00	2.37
Uttaranchal	6	6	2	0	53485	7376.33	13.79
West Bengal	5	15	0	0	88752	2896.53	3.26
Andaman & Nicobar	9	96	0	0	8249	1543.33	18.71
Chandigarh	0	2	0	0	114	26.009	22.81
Dadra & Nagar Haveli	0	1	0	0	491	92.16	18.77
Daman & Diu	0	1	0	0	112	2.18	1.95
Delhi	0	1	0	0	1483	27.82	1.88
Lakshadweep	0	1	0	0	32	0.01	0.031
Pondicherry	0	1	0	0	493	3.90	0.79
Total			47	4			4.80

(Source: MoEF, 2012)

Table 6. State-wise details of the Protected Area Network of the country for conservation of certain plant species, mammals and birds

A recent study conducted by (Sambandan and Dhatchanamoorthy, 2012) on the floristic composition of angiosperms occurring in a sacred grove of 0.2 ha area, located in Karaikal area of the UT of Puducherry brought out presence of 59 plants species of flowering plants coming under 55 genera and 30 families. They also found that, many rural people in the district were using the plants from the sacred groves to cure many common diseases. They suggested that, this kind of degraded sacred groves should be immediately restored or regenerated using appropriate technologies and by creating awareness among the rural people regarding the importance of sacred grove and its conservation.

3.7. Gene Pool Conservation Areas

Gene pool conservation is necessary for human welfare. Several species have become extinct and some others are already threatened and may become extinct if appropriate measures for their conservation are not taken. Some State Forest Departments like Kerala, Tamilnadu and West Bengal have initiated establishment of Gene Pool Conservation Areas (GPCA) for providing specific protection to certain areas through participatory approaches, involving local people. The Govt. of Kerala has identified some of the areas to be protect-

ed as GPCAs and issued guidelines for identification and mapping of GPCAs in the State (KFD, 2005) (Table 7).

S. No.	State	No. of Sacred Groves
1	Andhra Pradesh	800
2	Arunachal Pradesh	58
3	Assam	40
4	Chhattisgarh	600
5	Gujarat	29
6	Haryana	248
7	Himachal Pradesh	5000
8	Jharkhand	21
9	Jammu & Kashmir	150
10	Karnataka	1424
11	Kerala	3500
12	Maharashtra	1600
13	Manipur	365
14	Meghalaya	79
15	Orissa	322
16	Pondicherry	108
17	Rajasthan	9
18	Sikkim	56
19	Tamil Nadu	499
20	Uttarakhand	1
21	Utter Pradesh	6
22	West Bengal	670
Total		**15585**

Table 7. Status of Sacred Groves in India harbouring original and pristine vegetation and biodiversity of area

3.8. Seed Production Areas (SPAs)

With an aim to improve the productivity and profitability of planting forest species and offering an attractive land use option, many SFDs have established Seed Production Areas, in collaboration with various research organizations, for different forest species. Such SPAs act as means of conservation of Forest Genetic Resources, especially of forest plantation species of high commercial value. Species wise list and total area under SPAs are given in Table 8.

Species (scientific name)	Purpose for establishing conservation unit	Number of populations or stands conserved	Total Area (Ha)
Abies pindrow	Seed production	1	13.25
Acacia catechu	Seed production	14	230.00
Acacia nilotica	Seed production	7	87.00
Acrocarpus fraxinifolius	Seed production	1	2.00
Haldinia cordifolia	Seed production	1	255.00
Aegle marmelos	Seed production	1	0.5
Ailanthus excelsa	Seed production	1	10.00
Ailanthus triphysa	Seed production	1	7.00
Albizia amara	Seed production	1	2.00
Amoora wallichii	Seed production	1	11.00
Anogeissus latifolia	Seed production	5	57.00
Artocarpus chaplasha	Seed production	1	2.00
Artocarpus heterophyllus	Seed production	2	5.00
Bombax cieba	Seed production	7	51.50
Borassus flabellifer	Seed production	1	30.00
Buchnania lanzan	Seed production	1	20.00
Calophyllum inophyllum	Seed production	1	315.00
Cedrus deodara	Seed production	6	86.8
Chloroxylon swietenia	Seed production	1	10.00
Chukrasia tabularis	Seed production	4	29.00
Cupressus torulosa	Seed production	1	5.00
Dalbergia latifolia	Seed production	5	37.30
Dalbergia sissoo	Seed production	19	197.00
Diospyros melanoxylon	Seed production	1	5.00
Dipterocarpus macrocarpus	Seed production	5	39.00
Dipterocarpus turbinatus	Seed production	1	2.00
Ficus spp.	Seed production	2	8.00
Garcinia indica	Seed production	1	78.00
Gmelina arborea	Seed production	7	59.50
Hardwickia binata	Seed production	7	80.40
Hopea parviflora	Seed production	4	50.70
Lagerstroemia lanceolata	Seed production	2	8.30
Limonia acidissima	Seed production	2	3.50
Madhuca longifolia var. latifolia	Seed production	1	10.00
Michelia champaca	Seed production	1	1.00
Mitragyna parvifolia	Seed production	1	5.00
Morinda tinctoria	Seed production	1	10.00
Morus laevigata	Seed production	1	1.00

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Species (scientific name)	Purpose for establishing conservation unit	Number of populations or stands conserved	Total Area (Ha)
Pinus caribaea	Seed production	2	6.00
Pinus kesiya	Seed production	1	15.00
Pinus patula	Seed production	1	1.50
Pinus roxburghii	Seed production	17	215.00
Pinus wallichiana	Seed production	5	87.00
Prosopis cineraria	Seed production	1	10.00
Pterocarpus dalbergioides	Seed production	1	29.11
Pterocarpus marsupium	Seed production	5	57.00
Pterocarpus santalinus	Seed production	2	32.40
Rhododendron arboreum	Seed production	1	0.50
Santalum album	Seed production	6	32.60
Schleichera oleosa	Seed production	1	5.00
Semicarpus anacardium	Seed production	1	186.00
Shorea robusta	Seed production	9	501.80
Sterculia villosa	Seed production	1	4.00
Swietenia mahogany	Seed production	1	10.00
Tamarindus indica	Seed production	1	5.00
Tectona grandis	Seed production	223	6014.34
Terminalia alata	Seed production	6	51.74
Terminalia bellirica	Seed production	1	67.00
Terminalia chebula	Seed production	1	5.00
Vateria indica	Seed production	1	4.00
Xylia xylocarpa	Seed production	1	33.00
Ziziphus mauritiana	Seed production	2	14.50
Taxus baccata	Conservation of threatened species	16	89
Tachycarpus takil	Conservation of rare palm species endemic to Kumaon hills	1	10
Shorea robusta	To preserve high quality sal crop.	6	75
Haldinia cordifolia, Albizzia procera, Shorea robusta, Diospyros embroptria, Terminalia belerica	To preserve an area of primeval fresh water swamp forest.	4	57
Dalbergia sissoo	To study natural succession.	2	2
Pterospermum acerifolium	To maintain this interesting group of kanakchampa trees in perpetuity and study the natural succession in this type of forest.	1	3.7

Table 8. Target forest species as Forest Genetic Resources in *in situ* conservation programmes/ units.

3.9. Preservation plots

The Silvicultural conference held in 1929 recommended laying out of preservation plots in India, by selecting representative areas of major forest types and exceptional trees to be selected for permanent protection. Subsequently, 309 preservation plots were laid out throughout the country, 187 in natural forests and 122 in plantations covering a total area of about 8, 500 ha (Table 9.) In addition to this, 537 trees in various States were protected (Khullar, 1992).

State	Number of preservation plots		
	Natural Forests	Plantations	Total
Andhra Pradesh	11	-	11
Arunachal Pradesh	1	-	1
Assam	9	1	10
Bihar	9	-	9
Gujarat	18	-	18
Haryana	-	-	0
Himachal Pradesh	6	6	12
Jammu & Kashmir	3	-	3
Karnataka	11	-	11
Kerala	8	43	51
Madhya Pradesh	28	-	28
Maharashtra	11	-	11
Manipur	-	-	0
Meghalaya	2	-	2
Nagaland	-	-	0
Orissa	6	-	6
Punjab	-	-	0
Rajasthan	3	-	3
Tamil Nadu	2	67	69
Union Territories	-	-	0
Uttar Pradesh	32	-	32
West Bengal	27	5	32
Total	**187**	**122**	**309**

Table 9. *In-situ* conservation and Status of preservation plots in India (1991) for observing and preserving the original vegetation and natural animals

Rodgers (1991) opined that, a network of forest preservation plots within a larger extent of natural forests, which covers the entire range of forest types in India could play a major role in national efforts to protect biodiversity. He pointed out the virtual lack of co-ordination of management efforts in maintaining the network of plots. He therefore advocated that there is need for extending the network of preservation plots to ensure that, it covers (a) the "Vegetation Series" of vegetation mapping studies carried out by the French Institute, Puducherry (b)

biogeographic classification of India prepared for conservation and planning purposes and (c) Project Tiger areas, established in different parts of India. He concluded that such a network would complement the conservation zone of Biosphere Reserves and their conservation capability into a much wider variety of forest types.

3.10. Plus trees

Plus tree selection is one of the methods to conserve diversity at species level. Plus tree is a phenotypically superior tree. Most of the tropical forest trees are out crossers and therefore, there is wide variability among individual trees of a particular species in terms of growth, form and wood characters. In some cases much of the variations may be genetic and in others environmental. It is the utilization part of gene conservation where individual selection and breeding within locally adapted provenance will provide additional improvement in selected characteristics. A list of superior phenotypes of different species (Emmanual *et al*. 1990) selected in different States is given in Table 10.

State	Species with number of trees
Andhra Pradesh	*Tectona grandis*-75.
Arunachal pradesh	*Acrocarpus fraxinifolius*-16, *Ailanthus grandis-18, Altangia excelsa 27, Neolamarkia cadamba-08, Bombax ceiba-21, Canarium resiniferum-7, Cinnamomum cecidodaphne-4, Chukrasia tabularis-5, Dipterocarpus macrocarpus-39, Mesua ferrea-8, Michelia champaca-30, Phoebe goalparensis-21, Shorea assamica-27, Terminalia myriocarpa-28, Tectona grandis-2, Pinus roxburghii-4, Gmelina arborea-20.*
Himachal Pradesh	*Pinus roxburghii*-47 high resin yielder and 59 for timber production.
Karnataka	*Tectona grandis-50, Artocarpus heterophyllus-31, Phyllanthus emblica -11, Limonia acidissima-40, Ziziphus mauritiana-3, Syzygium cumini*-1
Kerala	*Tectona grandis-29, Bombax ceiba-11, Santalum album*-3, *Azadirachta indica*-300
Madhya Pradesh	*Tectona grandis-360, Albizia procera-55, Azadirachta indica-200*
Maharashtra	*Tectona grandis-33, Dalbergia sissoo-12, Bombax ceiba-1, Acacia catechu*-23.
Manipur	*Tectona grandis-25.*
Tamil Nadu	*Tectona grandis*-24.
Tripura	*Gmelina arborea-50, Shorea robusta-50, Tectona grandis-50.*
Uttar Pradesh & Uttarakhand	*Pinus roxburghii- 54* for tree form and *39* for high resin yield*, D. sissoo 302,*
Rajasthan	*Dalbergia sissoo-50, Azadirachta indica –350*
Gujrat	*Tectona grandis -63*
North eastern states	*Gmelina arborea-119,Tectona grandis-46,Dipterocarps-93*

Table 10. Plus trees selected in different States for *in situ* conservation

3.11. Conservation of Bamboo Genetic Resources

India is the 2nd richest country in bamboo genetic resources. Large forest areas have been declared as National Bamboo Reserve and maintained. Considering the limitation in seed supply, vegetative methods for *ex situ* conservation and tissue culture work have been started in Asian countries. National Bamboo Mission has been launched by the Ministry of Agriculture for bringing more areas under bamboos. National Mission on Bamboo Applications (NMBA), focuses on Wood substitutes and composites, construction & structural applications, agro-processing, machinery & process technologies, propagation & cultivation, industrial products and product applications in bamboos. A National Mission on Bamboo Technology and Trade Development was established, considering its role in rural economy and poverty alleviation and potential use in handicrafts and industrial development. A Bamboo Information Centre established at KFRI, Peechi disseminates information on 137 species of Indian bamboos (Table 10). To deal with the gregarious flowering of Muli bamboos (*Melocanna baccifera*) in N. E. States, 3 task forces on 'regeneration', 'harvesting and marketing' and 'rodent control' have been constituted.

3.12. Mangrove Conservation Program

Mangrove forests in India covers an area of 6,000 km^2 and they shelter 59 plant species coming under 41 genera and 29 families. Taking into consideration the ecological and economic significance of Mangroves, the Ministry of Environment and Forests had launched a Scheme for Conservation and Management of Mangroves and Coral Reefs in 1986 with following objectives:-

- Conservation and protection from further degradation of the Mangrove Ecosystem;
- Afforestation of degraded Mangrove areas
- Restoration of degraded Coral Reef areas
- Maintenance of genetic diversity especially of the threatened and endemic species
- Creation of awareness among the people on importance of Mangrove/ Coral Reef Ecosystem and the need for their conservation.

This was launched in 1987 and 35 mangrove areas were identified for intensive conservation and management (Table 11). Financial support is given under Management Action Plans for raising mangrove plantations, protection, catchment area treatment, siltation control, pollution abatement, biodiversity conservation, sustainable resource utilization and creating awareness. A National Mangrove Genetic Resource Centre was established in Orissa, in the east coast of India, for conservation, afforestation and regeneration of mangrove species.

3.13. Medicinal Plants Conservation Program

India has probably the oldest, richest and most diverse cultural traditions in the use of medicinal plants. The total number of medicinal plant species recorded from India is about 7500 and still the health care system based on herbal medicine is very much prevalent in the

SN	State/ UT	Mangrove Area
1.	West Bengal	Sunderbans
2.	Orissa	Bhitarkanika, Mahanadi, Subernarekha, Devi and Dhamra
3.	Andhra Pradesh	Coringa, East Godavari and Krishna
4.	Tamil Nadu	Pichavaram, Muthupet and Ramnad
5.	Andaman & Nicobar	North Andamans and Nicobar
6.	Kerala	Vembanad
7.	Karnataka	Coondapur and Dakshin Kannada
8.	Goa	Goa
9.	Maharashtra	Achra-Ratnagiri, Devgarh-Vijay Durg, Veldur, Kundalika- Revdanda, Mumbra-Diva, Vikroli, Shreevardhan, Vaitarna, Malvan and Vasai- Manori
10.	Gujarat	Gulf of Kutchh and Gulf of Khambat

Table 11. State-wise list of Mangrove areas identified by MoEF, Govt. of India for Conservation and Management for *in situ* conservation of costal vegetation

country. A National Medicinal Plants Board (NMPB) was established for co-ordination and implementation of policies relating to conservation, harvesting, cultivation, research and marketing of medicinal plants through 32 State Medicinal Plant Boards. At the national level 32 medicinal plant species have been selected for research and development. A network of 54 Medicinal Plant Conservation Areas (MPCAs)-"as forest gene bank sites" have been established by the State Forest Departments of Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Maharashtra (Ravikumar, 2010) in consultation with the Foundation for Revitalization of Local Health Traditions (FRLHT) and with the support of DANIDA, which harbour 45 percent of recorded populations of flowering medicinal plants of Peninsular India, including 70 percent of the red-listed species. To conserve wild germplasm, revitalize the indigenous health care and livelihood security, a UNDP-CCF-II project has been implemented in 9 states. A list of MPCAs in Karnataka, Kerala and Tamilnadu is provided below in Table 12.

3.14. Biodiversity Hotspots in India

Certain tropical forest areas rich in diverse endemic species, which are on the verge of destruction, have been designated as 'Hot Spots'. The conservation of these areas is indispensable for the survival of these species. About 34 'Hot Spots' of biodiversity have been identified around the world. Among them four are in India-Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaland located in Nicobar Islands. These 'Hot Spots' together have about 5330 endemic species including flowering plants, mammals, reptiles, amphibians and butterflies (Ramakrishna, 2010).

1	Agumbe	Karnataka
2	BRT hills	Karnataka
3	Charmadi	Karnataka
4	Devimane	Karnataka
5	Devrayandurga	Karnataka
6	Karpakapalli	Karnataka
7	Kemmanagundi	Karnataka
8	Kollur	Karnataka
9	Kudremukh	Karnataka
10	Sandur	Karnataka
11	Savanadurga	Karnataka
12	Subramanya	Karnataka
13	Talacauvery	Karnataka
14	Athirapally	Kerala
15	Eravikulam	Kerala
16	Kulamavu	Kerala
17	Peechi	Kerala
18	Silent Valley	Kerala
19	Triveni	Kerala
20	Waynad	Kerala
21	Agasthiarmalai	Tamilnadu
22	Alagarkovil	Tamilnadu
23	Kodaikanal	Tamilnadu
24	Kodikaria	Tamilnadu
25	Kollihills	Tamilnadu
26	Kurumburam	Tamilnadu
27	Kutrallum	Tamilnadu
28	Mundanthurai	Tamilnadu
29	Petchiparai	Tamilnadu
30	Thaniparia	Tamilnadu
31	Thenmalai	Tamilnadu
32	Topslip	Tamilnadu

Table 12. Medicinal Plants Conservation Programme for *in situ* conservation of medicinal plants in Karnataka, Kerala and Tamilnadu

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The following are some of general criteria for identification of *in-situ g*enetic conservation units:-

- Hot spot areas of biodiversity and endemism
- Representative and unique forest types
- Representative forest plantations of valuable timber species
- Areas with high concentration of medicinal plants of conservation concern

Generally, it is true that *in-situ* conservation measures are preferred over *ex-situ* means, because of habitat specificity of constituent species; maintenance of diversity and providing opportunities for evolutionary process to continue; endemic and threatened nature of some of the species; high cost factor and technological need involved in *ex-situ* conservation measures.

Constraints and problems for in-situ conservation

- The greatest constraints to improving *in situ* conservation in the country are lack of scientific know-how, anthropogenic and biotic pressures like fire, grazing, encroachment and illicit felling, to mention a few.
- Certain areas in the country are still unexplored, which need intensive exploratory survey.
- Conservation of FGR across the forest, including production forests and agro-forests, have not been developed for most of the species nor applied in India
- Research is needed to identify the best combination of approaches (*in situ*, *ex situ* and *circa situ*) for species that are important for livelihoods and subsistence in areas of high diversity and/or high poverty.

3.15. Ex-situ conservation

Ex-situ conservation is the conservation of components of biological diversity outside their natural habitats (CBD, 1992). Plant species and varieties can be preserved under artificial conditions away from the places where they naturally grow. Ex-situ plant collections have a number of uses for conservation and development, including for the re-vitalization of plant populations and associated economies and cultures (Hamilton and Hamilton, 2006). The following are the techniques generally employed for ex-situ conservation (Table 13 & 14).

The storage of seeds in seed banks has advantages for preserving species, but can only be used for species with seeds capable of remaining viable after long term storage (known as 'Orthodox' seeds). The typical techniques used for seed storage is to lower the moisture content of seeds to 2-6 percent or less and reduce temperature to around 0^0 C or lower.

Technique	Definition
Seed storage	The collection of seed sample at one location and their transfer to a gene bank for storage. The samples are usually dried to a suitable low moisture content and then kept at sub-zero temperatures.
Field gene bank	The collecting of seed or living material from one location and its transfer and planting at a second site. Large number of accessions of a few species are usually conserved.
Botanic garden/ arboretum	The collecting of seed or living material from one location and its transfer and maintenance at second location as living plant collections of species in an arboretum. Small numbers of accessions of a large number of species are usually conserved.
In-vitro storage	The collection and maintenance of ex-plants (tissue samples) in a sterile, pathogen free environment).
DNA/ Pollen storage	The collecting of DNA or pollen and storage in appropriate, usually refrigerated condition.

Table 13. Techniques of *ex-situ* conservation (Hawkes *et al.* 2000)

Technique	Definition
Seed storage	The collection of seed sample at one location and their transfer to a gene bank for storage. The samples are usually dried to a suitable low moisture content and then kept at sub-zero temperatures.
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Table 14. Techniques of *ex-situ* conservation (Hawkes *et al.* 2000)

4. Identification of research needs gaps and constraints

4.1. Identification of Research and Development Gaps

i. Identification of research needs:

a. Biodiversity documentation

b. Global Net-Working in identification and monitoring forest biodiversity

c. Strategies and Actions for Wild biodiversity

d. Involvement of stakeholders in biodiversity conservation through participatory forest management and yield sustainable benefits to people

e. Critical trends such as degradation/ fragmentation of habitat, extinction of species and destruction of unique habitats and its need for monitoring

f. A possible REDD-mechanism (financial incentives for reducing emission from deforestation and forest degradation) under the post-2012 framework of the Kyoto Protocol should consider effects on local communities and poor people, and survive to ensure a fair sharing of benefits.

g. Extent of invasion of Weeds and Invasive species in different Forest Types of India

h. Identification of indicator species for understanding ecosystem health so as to evaluate the efficiency of management interventions

i. Socio-economic variables and their interaction with biological component of various ecosystems with special attention to ethnology, tribal livelihood and dependence on forests

ii. **Gaps and Constraints:** There are numerous gaps and constraints, which hamper in undertaking research activities. These gaps and constraints are there in the forms of lack of knowledge, lack of technologies in developing countries, unavailability of finance, non-availability of relevant data, data non-accessibility, data organization constraints, lack of well framed and effective policy work etc. The details of these gaps and constraints are summarized below

a. *Knowledge Gaps:* Knowledge and information gaps on biodiversity-related issues and solutions at local levels. There is international and regional cooperation in areas of knowledge gap.

b. *Financial Gaps :* There is an urgent need for action and investment planning for the research activities of forestry sector. It is important to make simple and easy approachable rules and regulation for funding the project work related to biodiversity conservation and ecological securities

c. *Research Gaps*: There is a considerable gap in our knowledge of the natural resources of India. There are three broad areas, related to knowledge and data gaps that need to be addressed:

- First, there is much to learn about the potential magnitude and rate of extinction of plant biodiversity at the regional and local levels, and subsequent impacts on the full range of biodiversity endpoints and ecosystems.
- Second, there is no consolidated handbook of proven biodiversity conservation techniques, covering all the eco-regions of India.
- Third, detailed analysis need to be developed for each of the priority climate change threats to biodiversity and other resources.

- A further strategic approach is needed for detailed research on different ecosystem services and functions to estimate the potential impacts of climate change

d. *Technological and Capacity Building Gaps*: Today, science and technology is growing very fast. But it is not hard to see that the forestry sector of India has not been able to tap into the advances in technology to the optimal and uniform level. On the one hand, we have high and technical devices and on the other forestry sector lacks well equipped technical devices needed to research activity. Perhaps, one of the reasons why the status of forestry statistics has become a cause of concern because there is a vast gap in the current technology applications and their adaptation to the day-today working of forest research.

The local capacity to collect data at regional level is weak. Before implementing technological advances in statistical data reporting work, it is necessary to build adequate capacity for collection of data from primary sources. The primary data collector should be well versed not only in the terminology of the database, but also with the importance of such a database to ensure sincerity in the work. The capacity-building programmes should have a sustainable structure aiming at timely upgrading in tandem with the technology. Use of local and wide area networks is essential to ensure on-time data availability.

e. *Capacity strengthening:* The capacity to identify, collect and share data, use information and methods and build knowledge relevant for biodiversity conservation and ecological security is critical because of rapidly changing climatic, environmental and socio-economic conditions. Extension services and mechanisms have been weakened greatly over the last two decades. Extension will need to be strengthened substantially in order to address biodiversity conservation for providing an efficient interface between policy-makers and the forest community.

5. Road map for future research

The following research areas are suggested for conservation and sustainable utilization of forest biodiversity:-

- Species recovery research
- Establishing of new permanent preservation plots of representative forest types
- Locating of old permanent preservation plots, data collection & maintenance
- Establishing of Gene Pool Conservation Areas (GPCAs) outside protected areas, where there is concentration of endemic and RET species.
- Studies on plant-animal interactions/ associations
- Diversity of soil microflora and fauna

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- Establishing of Gene Sanctuaries of endemic & RET species
- Preparation of Biodiversity Registers in a collaborative mode with the State Biodiversity Boards.
- Biodiversity assessment and updating for Forest Working Plans.
- Monitoring biodiversity of Sacred Groves and provide inputs for conservation.
- Studies on regeneration status of important primary and secondary timber species.
- Studies on reproductive biology and breeding systems of important tree species.
- Awareness creation on biodiversity, benefit sharing and other legal issues.
- Phenological studies on important tree species vis-à-vis climate change.
- Studies on intra-specific variations in important timber species.
- Monitoring the structural composition of different forest types vis-à-vis climatic factors.
- Studies on species yielding natural dyes, wild fruits, tubers and fodder.
- Identification, documentation and domestication of wild plant species of aesthetic value for Urban Forestry.
- Studies on usage of plants and animals in lesser known ethnic communities and validation of information.
- Studies on sustainability of over-exploited bioresources among forest dwelling communities.
- Eco-restoration of degraded forest areas.
- Studies on factors contributing towards forest degradation.
- Impact of natural calamities on forests and developing technologies for re-vegetating the affected areas.
- Studies on plant successions.
- Environment Impact Assessment Studies.
- Studies on reclamation of lands subjected to pollution and mining.
- Microfloral and faunal dynamics of forest litter vis-à-vis climate change
- Eco-restoration of degraded riparian and swamp ecosystems.
- Studies on aquatic biodiversity in hill streams and rivers.
- Studies on the impact of invasive weeds in forest ecosystem.

Abbreviations

FSI	---	Forest Survey of India
SG	---	Sacred Groves
CBD	---	Convention on Biological Diversity
SCBD	---	Secretariat of the Convention on Biological Diversity
DANIDA	---	Danish International Development Agency
MoEF	---	Ministry of Environment and Forest
IUCN	---	International Union for Conservation of Nature
TEEB	---	The Economics of Ecosystems and Biodiversity
IPCC	---	The Intergovernmental Panel on Climate Change
EIA	---	Environmental Impact Assessment
SEZ	---	Special Economic Zone
UNCED	---	The United Nations Conference on Environment and Development
PA's	---	Protected Ares (for Wildlife)
UT	---	Union Territory
SFD	---	State Forest Department
KFD	---	Kyasanur forest disease
KFRI	---	Kerala Forest Research Institute
REDD	---	Reducing emission of carbon from deforestation and forest degradation
FGR	---	Forest Genetic Resources

Author details

Vivek Khandekar* and Anita Srivastava*

*Address all correspondence to: vykhandekar@hotmail.com

Biodiversity Conservation, Indian Council of Forestry Research and Education, Ministry of Environment and Forests, Government of India, India

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