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Biodiversity in India: Status, Issues and Challenges

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Part I
Introduction

Chapter 1
Introduction

Ravinder Kumar Kohli, H. P. Singh, Amarpreet Kaur, D. R. Batish, and Shalinder Kaur

1.1 Introduction

"Biological diversity" means 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 (CBD 1992). The term *biodiversity* is a contraction of *biological diversity* and is credited to Edward O. Wilson who first used the term in 1986 during a conference (Wilson 1988). Human beings are substantially benefitted from these biodiverse ecosystems. Apart from provisional (food, fodder, fiber, timber, and medicines) and regulating (pollination, climate regulation, carbon sequestration and nutrient cycling) services, biodiversity also ensures non-material benefits and long-term flow of these ecosystem services by offering resistance and resilience against natural disturbances (Díaz et al. 2018). In fact, 13 of the 17 Sustainable Development Goals (SDGs) of United Nations are dependent on biodiversity. However, exploitation of these natural reserves in an unsustainable manner by the ever-growing human population has resulted in their loss at an unprecedented rate (Cardinale et al. 2012, IPBES 2019). As per the Global Assessment on Biodiversity and Ecosystem Services, about 75% of land environment and ¬ 66% of the marine environment have been altered by humans (IPBES 2019). Besides, other human-induced environmental and land-use changes have further exacerbated these losses, leading to the extinction of certain species (or their distinct subpopulations) and disruption of ecological processes (WWF 2020). Such irreversible changes even

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in the smallest of ecosystems can break down the entire functioning of a global biosphere, and therefore, biodiversity loss is a primary concern for ecologists and environmentalists.

1.2 Biodiversity in India

India, because of its location and diversity in climatic regions ranging from very cold to extremely hot, is one of the 17 mega-diverse countries in the world. It houses about 8% of the recorded species of the world with high endemism. India has a rich cultural diversity studded with a vast repository of traditional knowledge associated with biological resources. Over 97,642 species of animals (6.38% of the world; Venkataraman et al. 2020) in 10 biogeographic regions and 49,441 of plants (algae, fungi, bacteria, lichens, bryophytes, pteridophytes, gymnosperms, angiosperms; BSI 2019) accounting for 10.61% of global plant species recognized in 11 phytogeographic zones have been reported in India.

The fauna found in India includes 427 species of mammals, 1340 species of birds, 584 species of reptiles, and 407 species of amphibians (Table 1.2). On the other hand, among plant species, there are 18,666 flowering plants, over 1300 pteridophytes, more than 80 gymnosperms, and 17% of the world's bryophytes (Table 1.1).

There is a high level of endemism (~23%) in plant species found in India. A total of 11,554 plant species are endemic in India including 12 gymnosperms, 4303 angiosperms, 629 bryophytes, 66 pteridophytes, 1924 algae, 4100 fungi, and 520 lichens. All the endemic gymnosperms in India are threatened with one being critically endangered. Six angiosperms have been reported to be extinct, whereas two are extinct in wild (BSI 2019). India is one of the world's eight Vavilov's centers of origin of cultivated crop plants, with rice, red gram, chickpea, owpea, mung bean, eggplant, cucumber, sugarcane, black pepper, moth bean, rice bean, cotton, turmeric, indigo, millets, bread wheat, club wheat, sesame, linseed, muskmelon, carrot, onion, garlic, apricot, grape, hemp, cotton, etc. being originated in the country. Similarly, high endemism has been reported for various species of amphibians, lizards, insects, marine fauna, centipedes, mayflies, and freshwater sponges. About 12.6% of mammals, 46% of reptiles, and 56% of amphibians found in India are endemic. India hosts about 170 critically endangered animals. The level of diversity of biota in India

Table 1.2 A comparative position of species biodiversity in India among other mega-diverse countries of the world

Group	Rank among mega-diverse countries
Higher plants	IX
Mammals	VII
Birds	X
Reptiles	V
Amphibian	VII
Fishes	I

Source: https://www.cbd.int/countries/profile/?country=in

Table 1.1 An outline of the number of species in major groups of plants, microorganisms, and animals in India in comparison to the world

Taxonomic groups	Types in India	Types in world	% of world
Virus/bacteria	1223	11,813	10.35
Algae	7411	40,000	18.53
Fungi	15,396	98,998	15.55
Lichens	2581	17,000	15.18
Bryophytes	2780	16,236	17.12
Pteridophytes	1302	12,000	10.85
Gymnosperms	82	1021	8.03
Angiosperms	18,666	2,68,600	6.95
Mammals	427	5853	7.29
Bird	1340	10,357	12.9
Reptiles	584	10,450	5.58
Amphibians	407	7667	5.30
Fishes	3364	34,362	9.78

Source: BSI (2019), Venkataraman et al. (2020)

Table 1.3 An overview of biodiversity hotspots in India

Vital status	Western Ghats (and Sri Lanka)	Indo-Burma	Himalayas	Sundaland
Hotspot original extent (km^2)	189,611	2,373,057	741,706	1,501,063
Hotspot vegetation remaining (km^2)	43,611	118,653	185,427	100,571
Loss in vegetation (%)	77%	95%	75%	93.3%
Endemic plant species	3049	7000	3160	15,000
Endemic threatened birds	10	18	8	43
Endemic threatened mammals	14	25	4	60
Endemic threatened amphibians	87	35	4	59
Extinct species	20	1	0	4
Human population (people/km^2)	261	134	123	153
Protected area (km^2)	26,130	235,758	112,578	179,723

Source: https://www.bsienvis.nic.in/files/biodiversity%20Hotspots%20in%20India.pdf

and ranking among the mega-diverse countries are very encouraging (Table 1.2). According to Conservation International, India is ranked as the most mega-diverse country in terms of different species of fishes recorded from its marine and freshwater habitats (Table 1.2).

Of the 36 biodiversity hotspots recognized world over, four (Himalayas, Indo-Burma, Western Ghats and Sri Lanka, and Nicobar Islands in Sundaland hotspot) are present in India (Table 1.3).

1.3 Cultural Linkage to Biodiversity

Indian culture and literature teach respect for biotic and abiotic components of biodiversity. It has been suggested that for the first time in the world, laws for the protection of wildlife were enacted in the third century in India by Emperor Ashoka. Protection of plants and animals has always been a part and parcel of the rich culture of India. India is perhaps the only country where the protection of living beings is associated with religion and the plants and animals are worshiped in relation to different gods and goddesses.

Several deities have been associated with different wild and domestic animals. Animals such as deer have consistently been associated with *Lord Brahma* (Hindu deity), whereas *garud* (a mythological creature mix of eagle and human), lion, and sheshnag (mystical five-headed snake) are often seen with *Lord Vishnu* (Hindu deity) (Table 1.4). *Nandi* (the bull) is the vehicle of Lord *Shiva* (Hindu deity) and reflects his legendary virility. Shiva is also described holding snake as a garland around his neck, signifying his status as *nageshwar*, Lord of the Snakes (Table 1.4). *Ganesha* is another Hindu deity, represented as a human with an elephant head, and travels using *mushak* (mouse). Similarly, deities like Lord Hanuman and Lord Krishna are associated with monkey and cow, respectively.

Medicinal plant species such as neem (*Azadirachta indica*), Bel (*Aegle marmelos*), and Tulsi (*Ocimum sanctum*) are associated with Hindu gods and goddesses and often planted and worshipped in households. It is believed that these plants not only cure common diseases but wipe away the negative energy and fill the surroundings with positivity, good health, and prosperity. Gautam Buddha, the spiritual teacher associated with Buddhism, is said to have attained enlightenment under *Ficus religiosa*, and hence, the tree is considered sacred and worshipped by the people. Kadamb (*Neolamarckia cadamba)* is considered favorite tree of Lord Krishna (Hindu deity), and mango (*Mangifera indica*). Tulsi is considered incarnation of Goddess Laxmi and revered and used for worship of Lord Vishnu and Krishna. *Saraca asoca* (Ashoka tree) is considered sacred and worshipped in

Table 1.4 Cultural linkage to wildlife: Indian culture and literature teach non-violence and respect for biota wildlife which has enjoyed linkage with religious ideals and sentiments

Gods associated with animals		Gods associated with trees	
Brahma	Deer	Neem	Sitla
Vishnu	Garud, lion, cobra	Banyan	Sheshnag
Shiva	Bull Nandi, snake	Tulsi	Lakshmi, Vishnu
Ganesha	Elephant, Mushak	Bel	Shiva
Durga	Lion	Ficus	Buddha
Krishna	Cow	Ashoka	Indra
Saraswati	Swan	Kadamb	Krishna
Hanuman	Monkey	Mango	Lakshmi
Guru Gobind Singh	Bagh	Pipal	Vishnu and Krishna
		Lotus	Saraswati

Hinduism and Buddhism. The tree has been mentioned widely in Indian ancient books and in Ramayana, and Goddess Sita was kept in *vatika* (garden*)* having this tree in Sri Lanka. Lord Buddha is believed to be born under Ashoka tree in Lumbini Garden.

Kusha or Darbha or Doorbha grass (*Desmostachya bipinnata*) is widely used in Hindu, Jain, and Buddhist religions for sacred ceremonies including Puja, etc. Its use has been mentioned in Rigveda, Vishnupuram, and Bhagavad Gita. The flower of lotus (*Nelumbo nucifera*) is used during worshipping of Goddess Lakshmi and considered a symbol of purity in Buddhism. In fact, it is the most important flower and strongly associated with religious ceremonies and is the national flower of India. Several flowers have been used for offerings and worshipping (puja) deities. For example, lotus is used as offering to Goddess Lakshmi, Palash or parrot tree (*Butea monosperma*) to Goddess Saraswati, Jamine (Chameli) to Lord Hanuman, Prajita or Indian Magnolia to Lord Vishnu, Red Hibiscus to Goddess Kali, *Calotropis* and Datura flower to Lord Shiva, and *Nerium oleander* to Maa Durga. The sacredness and religious importance of many flowers have been manifested in their adoption as state flower, for example, Brahma Kamal in Uttarakhand and Palash in Bihar and Madhya Pradesh.

Several plants found in remote and pristine areas in high mountains have been mentioned in ancient Hindu texts and mythology for their offerings to deities and Gods. For example, flowers of Brahma Kamal (*Saussurea obvallata*; Lotus of Brahma), found at high altitude (3000–4800 m) in Himalayas, has been linked to Brahma (The Creator God), is linked to Lord Shiva and Lord Brahma, and even finds reference in epics like Ramayana and Mahabharata. Moreover, several wildflowers and fruits are used by local communities and tribes in remote areas during local festivals and worship of deities as a part of their culture and tradition. The use of traditions, rules, and religious beliefs is strongly linked to the cultural identity of tribal communities and the use of native plants for various ceremonies. These cultural and religious beliefs teach the importance of biodiversity and encourage conservation of the plants and wildlife. However, good traditions and reverence for biodiversity are declining at a fast pace.

1.4 Protected Area Networks in India

Due to anthropogenic reasons, many epiphytic and herbaceous plants have disappeared from their endemic regions in India, and several orchids, ferns, cycads, and medicinal herbs are categorized as endangered. Among the faunal diversity, many mammals, birds, reptiles, corals, and fishes have been assigned a threatened status in the country. As per the Living Planet Report of 2020, in India around *3%* of bird species face extinction; *19%* of amphibians are threatened or critically endangered, and over *12%* of wild mammals are threatened with extinction (WWF 2020). To protect its biodiversity, several protected areas and conservation sites have been declared in India, and nearly 5% of its total area is formally classified as protected

Table 1.5 An overview of protected area networks in India (as of December 28, 2020)

Protected areas	Number
National parks	106
Wildlife sanctuaries	564
Conservation reserves	99
Community reserves	218
Tiger reserves	52
Elephant reserves	30
Biodiversity heritage sites	18
Key biodiversity areas	531

Adapted from WIIENVIS, https://wiienvis.nic.in

(WIIENVIS 2020). As of 8 February 2022, India has a network of 987 protected areas including 106 national parks, 564 wildlife sanctuaries, 99 conservation reserves, and 218 community reserves covering a total of 173,053.69 km^2 of the geographical area of the country which is approximately 5.26% (Table 1.5). In addition, 131 marine protected areas have been recognized in peninsular areas and islands of India to protect and conserve marine species. The International Union for Conservation of Nature (IUCN) has recognized 531 sites in Key Biodiversity Areas in India. Likewise, 18 sites have been identified as Biodiversity Heritage Sites by National Biodiversity Authority, India, to protect and conserve the unique biodiversity and fragile ecosystem of these areas (NBA India, http://nbaindia.org/content/106/29/1/bhs.html). The Government of India under the aegis of the Ministry of Environment, Forests and Climate Change has instituted sites of conservation importance to protect species such as tiger, elephants, crocodile, bird, etc. Project Tiger, which was started in the year 1972, now comprising 52 Tiger reserves, is a major effort to conserve tiger and their habitats in the country. Similarly, Project Elephant was started in 1992, and at present 30 such reserves have been established for the protection of elephants. Many such programs have been undertaken for the conservation of crocodiles, rhinos, and birds. To protect and conserve the rich biodiversity of wetlands, 41 sites have been included under Ramsar Convention as Ramsar Wetlands of International Importance. These conservation practices have yielded variable success rate, but many more efforts are required to conserve the mega-diversity of the country.

1.5 Way Forward

According to the World Bank, India is categorized under lower middle economies, and in developing countries like India, there are additional hindrances in the application of conservation approaches such as lack of adequate finances, insufficient scientific capacities, and minimal participation of the government in environmental issues (Adenle et al. 2015). It requires a whole government effort including excellent planning, creating mass awareness, and meticulous execution of strategies

for conservation. The efforts to reduce anthropogenic repercussions on biodiversity have been widely amplified since the first United Nations Convention on Biological Diversity (CBD) was held in 1992. Until now, a total of 196 countries have ratified the legal treaty and devoted themselves to "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" (https://www.cnd.int). Strategies, frameworks, policies, and action plans have also been developed at international, national, and regional levels by various government and nongovernment organizations to tackle the loss of biodiversity. Developing countries although behind, yet their participation in conservation practices has been continuously increasing. Several conservationists are also adopting cultural and indigenous management practices to protect natural ecosystems from present and future catastrophes (Adenle et al. 2015). Such efforts gain prominence in view of the greater biodiversity in developing countries rather than in developed nations. Despite these many endeavors, biodiversity (especially the wild floral and faunal populations) continues to decline, and the risk of species extinction continues to intensify, thereby threatening all the biotic components of the environment interconnected through a complex food web (IPBES 2019).

Several factors affect the biotic components and natural processes, and unfortunately, most of these are human-driven. Biodiversity loss is usually an unintentional aftereffect of policy verdicts undertaken for economic growth and development. Urbanization, agricultural and infrastructural expansions, increasing domestic and industrial demands, tourism, and illegal trade are the major forces imposing undue pressures on biodiversity (Cardinale et al. 2012, IPBES 2019). The key pressures include habitat loss/fragmentation, invasive alien species, overexploitation of resources, pollution, and climate change (IPBES 2019). New technologies developed to mitigate environmental issues may further affect biodiversity if they do not offer sustainable and integrated solutions. On top of these popular threats, there are several other issues that are not yet well understood such as microplastic pollution, artificial life, etc.

Although abundant information has been collected on the natural/anthropogenic disturbances which affect different life forms, issues and challenges associated with biodiversity are dynamic and so is its ever-changing status. Research in this direction, therefore, needed to be levelled up at every step, and conservation managers are required to stay up to date. Knowledge gaps pertaining to the distribution, population trends, conservation status, and ecological roles of several microbial, invertebrate, and wild plant species need to be filled. In addition, more deep-seated changes, policies, and decision frameworks are required for the conservation of biodiversity, along with an assurance of their effective implementation. Both the traditional and modern conservation approaches—such as ecological restoration, ecotourism, targeted habitat management, habitat creation/re-establishment, trans-boundary conservation, check on invasive species, captive breeding, and reintroduction of species—are needed to be adopted to contain the rate of biodiversity loss (ref). These approaches should also take into consideration the apparently intractable economic and political concerns. Furthermore, it is important to note that biodiversity

conservation needs to be holistic in approach with a participatory framework and inclusive of every developed and emerging economy of the world, as global biosphere functions as a whole and any harm to an ecosystem is generally separated on temporal and spatial scales from the ones experiencing its repercussions (Matarrita-Cascante et al. 2019, Smith et al. 2021).

Since conservation of biodiversity and maintenance of ecosystem processes are fundamental for the continued existence of human beings, an improved understanding of factors and processes responsible for declining biodiversity is essential. The present book offers a platform to discuss the status, issues, and challenges associated with biodiversity in the present scenario, particularly in the Indian context. We tried to review major factors that drive biodiversity loss in marine, freshwater, and terrestrial ecosystems and outlined the key efforts put forward by the Government of India to conserve biodiversity. The discussion draws a broad range of individual perspectives across natural sciences from researchers, ecologists, wildlife biologists, and conservation practitioners.

The book comprises 23 chapters, with the first 5 chapters focusing on the biodiversity of lower and higher plants and the next 4 chapters devoted to the biodiversity of invertebrates, herpetofauna, birds, and wild fauna. Similarly, status, issues, and challenges to the freshwater and marine biota, diatoms, are discussed separately in three chapters. A special focus on agricultural crops and livestock, non-agricultural insects, and insects of agricultural importance has been provided in another four chapters. Thereafter, the next two chapters emphasized the rising global issue of biological invasions in terrestrial and aquatic ecosystems. The last few chapters shed a light on specific reasons for biodiversity loss in India and conservation efforts put forward by the Government of India, and the relevant laws for the protection of biodiversity in India have been suitably dealt with. Overall, the book attempts to illustrate the present and potential threats to biodiversity in India across different ecosystems and taxonomic groups.

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Part II
Plant Diversity

Chapter 2
Status, Issues and Challenges of Biodiversity: Lower Plants (Non-vascular)

D. K. Upreti and Rajesh Bajpai

2.1 Introduction

India has a total geographical area of about 329 million hectares with a coastline of over 7500 km. The ecological diversity of the country ranges from sea level to the highest mountainous ranges together with hot and arid conditions in the northwest to cold arid conditions in the trans-Himalayan region, tropical wet evergreen forest in north-eastern India and the Western Ghats, mangroves of Sundarbans and freshwater aquatic to marine ecosystems.

India has 12 biogeographical provinces, 5 biomes and 3 bioregion domains (Cox and Moore 1993). Being a mega-diversity country, India exhibits an exceptional concentration of endemic species in four biodiversity hotspots, namely, eastern Himalayas, Western Ghats (Sri Lanka), North-east India and Andaman Island (Indo-Burma). Forest, grassland, wetlands, coastal, marine and desert are the major ecosystems in India. The forest cover of the country contributes about 21.05% (692,027 km^2) with 16 major forest types comprising 221 subtypes (Champion and Seth 1968). India has about 4.1 million hectares of wetlands, about 6700 km^2, i.e. 7%, of mangroves of the world. Coral reef, a unique marine ecosystem, occurs in Andaman Islands, Lakshadweep Islands, Gulf of Kutch and Gulf of Mannar. The states of Rajasthan, Gujarat, Punjab and Haryana cover about 2% of the total land mass of desert ecosystem, characterized by low precipitation and largely barren arid lands. The Ladakh (Jammu and Kashmir) and Lahaul-Spiti of Himachal Pradesh covers an area of about 109,990 km^2 as cold deserts.

India harbours a total of 45,500 species of plants and ranks among the top ten species-rich nations with high endemism. Among the vascular plants, Angiosperm and Gymnosperms are represented by 18,043 and 74 species, respectively. Among

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the lower group of plants (non-vascular) Bryophytes and Pteridophytes are represented by 2562 and 1267 species, respectively, while Algae, Fungi and Lichens are represented by 7310, 14,883 and 2900 species respectively. Apart from the vascular and non-vascular plants, India is also known for 98 virus and bacteria species. Since the non-vascular plants exhibit a wide variation in their diversity and distribution in India, the issues and challenges regarding their threats and conservation are described separately for each group in the following sections.

2.2 Status of Fungi

Fungi lack photosynthetic capacities and thus obtain their food as saprophytes. Fungi range from single-celled yeasts to mushrooms and moulds to larger slabs of bracket fungus growing up on the treetrunks and branches. Many fungi live properly in soil and water, and many more engage in parasitic or symbiotic relationships with other plants and animals. Most species of fungi are composed of strands of cells called hyphae that combine to form a fungal body or mass known as mycelium. Around 96,000 species of fungi have been described from the world of which about 14,883 species under 45 classes, 120 orders, 345 families and 2660 genera are known from India.

2.3 Status of Algae

Algae are single- or many-celled organisms that have varied size and shape. Algae occur on both land and water and have ability to adopt harsh environmental condition. Algae occur in fresh water of river, pond wetland and lakes together with marine water of salt marshes, salt pans, estuaries and the ocean. Apart from water, algae also grow on stones, rocks, snow surface, thermal springs, acid bogs, alkaline as well as fertile and desert soil in sub-aerial habitats such as tree trunk as epiphytes. Algae play a vital role in the world's ecosystem as a primary producer and also as a source of natural products such as bio-fertilizers and biochemicals. Algae are classified into 11 classes pertaining to Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonadineae, Euglenophyceae, Phaeophyceae, Rhodophyceae and Cyanophyceae. India is represented by the occurrence of 7310 species of algae under 10 classes and 95 orders and 2529 genera.

2.4 Status of Lichens

Lichen may resemble a single plant-like organism, but it is really a colony of algae embedded in a matrix formed by the filaments of a fungus and thus is a good example of symbiosis. The algae in lichens make food through photosynthesis, while the fungi absorb food and water from their environment. Owing to its symbiotic nature, lichens can survive in challenging harsh environments of Arctic and Antarctic or dry arid regions. There are about 20,000 species of lichens known so far from the whole world of which India is represented by more than 2900 species belonging to 79 families and 407 genera. Lichens produce a major fodder source for reindeer and caribou and are used commercially as food, spices, dyes and medicines.

2.5 Bryophytes

Bryophytes, commonly called "amphibians of plant kingdom", are widely spread in almost all the phytogeographical regions of the country. There are three distinct lineages of bryophytes: thalloid/liverworts (Marchantiophyta), hornworts (Anthocerotophyta) or mosses (Bryophyta). In India, the bryophytes are represented by 2562 taxa with 1636 species of mosses, 887 liverworts and 39 hornworts exhibiting their rich diversity in the Himalayas, northeast and peninsular India and Andaman & Nicobar Islands as they prefer to grow in damp and shady sites of these areas.

Bryophytes provide important environment services as they together with lichens help in soil formation and stabilization. Similar to lichens, bryophytes are also an excellent organism for biomonitoring environmental condition of an area.

2.6 Pteridophytes

The land plants evolved 430 million years ago from predominately freshwater green algae. Living members of these groups of plants seem more evolved today. These plants reproduce by means of spores and alternating generations. The reproduction process of ferns is different from the flowering plants. The fern frond or leaf under them bears rows of small brown dots-like structure called the sporangia which inside bear the spores that develop and release into the air. The fallen spore sprout out into tiny heart-shaped plants that anchor themselves in the ground with root-like structure called rhizoid. The heart-shaped plant (gametophytes) bears eggs and develops sperm. The structure bearing sperm swells and bursts due to rain water and releases flagellated sperm that travel to the egg in water and fertilized the egg, thus resulting in an embryo that develops into a new plant (sporophyte).

The fern species thrived on earth from 359 to 299 million years ago during the carboniferous period, which is well-known as age of ferns since they were the dominant vegetation on earth in that period. The ferns that grew during the carboniferous period are now extinct, but some of them likely evolved into the ferns we know today. As many as 12,000 species of ferns have been identified worldwide of which India is represented by 1267 species.

2.7 Challenges to Biodiversity

At present throughout the world, there are a number of factors responsible for the loss of biodiversity, which is occurring at a very alarming rate. A number of conservation programmes are there, but the problem lies in their implementation; thus, there is a great need of public awareness, and changes in the attitude of the people are required. Among the different areas of the earth, the biological diversity in the urban areas is affected greatly and implementation of conservation programmes in these areas is most difficult. The urban areas lack open spaces in inner cities, or they are small and isolated and difficult to maintain as natural ecosystem for earlier resident species of the area.

Human interventions including development activities and rampant poverty are leading to change in land use patterns, habitat loss and fragmentation in the Indian Himalayan regions. In Western Ghats selective logging and conservation to agricultural and cash crop plantations and many river valley projects contributed to the decline of biodiversity. Mass tourism, unsustainable land-use practices and extensive subsistence dependence on the forest are major challenges for loss of both of a large number of faunal and floral elements including lower group of plants.

In India, the implementation of the United Nations Convention to Combat Desertification (UNCCD) indicates that most of Indian arid, semi-arid and dry sub-humid areas are either subject to desertification, identified as drought-prone or considered wastelands. India has 115 wetlands, identified under the National Wetland Conservation Programme (NWCP).

2.8 Reasons of Worry

The fast pace of urbanization together with industrial development in the country affected severely different groups of plants together with a number of lower group (non-vascular) plant species moving towards extinction. Thus, to maintain ecological balance, conservation of non-vascular plant diversity in the country is a prerequisite.

Most of the lower groups of plants excluding fungi and algae are slow-growing organisms. Lichens which are commercially exploited frequently for spices and dyes have growth rates from 5 mm/year to about 2 cm/year. Sometimes the attempts to

reintroduce and transplant the species are difficult as certain plant species have their phytogeographical limitation and host specificity. Commercial use of flora by the ethnic people in remote areas is a good source of income for them; however, unscientific exploitation of flora for its commercial use sometimes resulted in the extinction of a number of taxa.

Various developmental activities lead to human influx accompanied by destruction of a number of ecosystems such as habitat loss, fragmentation and degradation through conversion of land use through agriculture, urbanization and industrial development, invasive alien species, and over-exploitation of natural resources including plants and animals which are among the major threats faced globally and in our country. More than 1.17 million hectares of forest land is estimated to have been diverted for more than 23,000 developmental projects since the enactment of the Forest Conservation Act in the year 1980 (MoEF 2008 report). The pressure of livestock grazing forest and grassland together with increasing incidence of forest fires is also a great threat in the dry deciduous forest.

2.9 Conservation Efforts and Strategies

Almost all the lower groups of the plant have insufficient information regarding their status in the IUCN red list categories in the world and also in India. It has been estimated that 15–20% of all plant species would become extinct and 25–30% of the genetic diversity would possibly be lost over the years leading up to the year 2025. The threat of extinction may increase depending upon the increase in human interferences. Protected areas (PAs) are an important element of conservation strategies to preserve tropical forests (Geldmann et al. 2013). India has about 5% of the total geographical area as PA with 448 Wildlife Sanctuaries, 102 National Parks and 18 Biosphere reserves (MoEF 2011).

In the year 2001, the conservation of lower plants was given further importance of the Global Strategy for Plant Conservation (GSPC) as a part of CBD provide a useful structure within which plant conservation work of lower plants and fungi in Scotland was initiated.

The initiation of conservation efforts in a country requires understanding and documentation of the plant diversity of the country/area. A meagre information about the Red data Books (CPCB) regarding the lower group of plants in India is available. The conservation efforts by the Central Government, State Government and local administration and the role of society in maintaining the forest, ecological balance and socio-economic development were realized by National Forest Policy (NFP), and a minimum 33% of country's geographical area under forest and trace cover was maintained. At present, the country has 137 protected areas (PAs) in Indian Himalayan regions and Western Ghats.

The National Biodiversity Action Plan (NBAP) involves the Ministry of Environment Forest and Climate Change (MoEF&CC) and 23 ministries/Government of India Departments, State Forest Department, state planning boards, local-level

institutions such as village eco-development committees (VEDCs), joint forest management committees (JFMCs) and Gram sabha (Village assemblies) for implementation of different conservation strategies for conservation of the biodiversity of the country. National Biodiversity targets and Millennium Development Goals (NBT&MDGs) are other efforts toward achieving targets for conservation and human development in the country.

The country is taking significant steps in achieving the 20 Aichi Biodiversity targets which deal with the demands of a growing human population for food, medicine, fibre, shelter and fuel, along with the need for economic development that is increasing the pressure on biodiversity and ecosystem throughout the country.

Under India's fifth report on convention on Biological diversity, the following 12 National Biodiversity targets are proposed:

1. Indicators and monitoring framework: By 2020 a significant proportion of the country's population, especially the youth, are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.
2. By 2020, values of biodiversity are integrated in national and state planning processes, development programme and poverty alleviation strategies.
3. Strategies for reducing rate of degradation, fragmentation and loss of all natural habitats are finalized and actions put in place by 2020 for environmental amelioration and human well-being.
4. By 2020 invasive alien species and pathways are identified and strategies to manage them developed so that population of prioritized invasive alien species are managed.
5. By 2020 measures are adopted for sustainable management of agriculture, forestry and fisheries.
6. Ecologically representative areas on land and in inland waters, as well as coastal and marine zones, especially those of particular importance for species, biodiversity and ecosystem services, are conserved effectively on the bases of Protected Area (PA) designation and other areas based on conservation measures.
7. By 2020 genetic diversity of cultivated plants, farm livestock and their wild relatives including the socio-economically or agriculturally valuable species is maintained.
8. By 2020 ecosystem services especially those relating to water, human health livelihoods and well-being are enumerated.
9. Access to genetic resources and the fair and equitable sharing of benefits.
10. By 2020 an effective participatory and updated national biodiversity action plan will be made.
11. By 2020 national initiatives using communities and traditional knowledge relating to biodiversity are strengthened, with a view to protecting this knowledge in accordance with national legislation and international obligations.
12. By 2020 opportunities to increase the availability of finance, human and technical resources to facilitate effective implantation of the strategic plan for

biodiversity 2011–2020 and the national targets are identified and the strategy for resource mobilization is adopted.

2.10 Conservation of Fungi

The fungi are the largest group of organisms on the earth next to insects. Fungi are different from animals and plants and belong to a separate biological kingdom. Fungi are also threatened by climate change, habitat destruction, invasive species, pollution and over-exploitation; therefore, the conservation of fungi is also important similar to another organism. Following the IUCN protocol for conservation of fungi, the Agharkar Research Institute (ARI), Pune Department of Science and Technology (DST), set up in the year 2008 the National Facility of Culture Collection of Fungi (NFCCF) with the aim to conserve the germplasm of indigenous fungi in a repository. NFCCF is holding over 2800 strains of fungi together with 9000 herbarium samples.

2.11 Conservation of Lichens

The Indian Himalayan regions and Western Ghats in south India together with Andaman Island exhibit occurrence of most of the endemic lichen taxa in India. The central Indian region particularly the region of Amarkantak-Achanakmar Biosphere also represents occurrence of some unique lichen taxa being a meeting place of elements coming from Indian Himalayan regions and south India.

Upreti and Nayaka (2008) suggested creation of lichen gardens and lichen sanctuaries in the country for conservation of lichens. Most of such sanctuaries proposed are already protected in a number of protected areas of the country in wildlife sanctuaries, national parks and biosphere reserves.

2.12 Conservation of Algae

According to IUCN (2003), a single marine red alga *Vanvoorstia bennettiana* (Delesseriaceae, Ceramiales) was assessed as extinct in the red list. The red list of algae in Japan includes 5 extinct species (single species extinct in wild) and 35 critically endangered.

For algae, in situ conservation involves the maintenance of genetic variation at the locations where it is conducted either in the wild or in traditional farming systems. The establishments and scientific management of nature reserves in different part of the country especially restoration of degraded habitats would be helpful in this purpose. Under the ex situ conservation, the algal samples are conserved either

as living collections (e.g. culture collections) or as spores, and DNA are maintained under special artificial conditions. Cryopreservation allows living algae to be maintained indefinitely in an assessed state.

The culture collection methods for algal conservation have several advantages as they are efficient and reproducible and feasible for short-, medium- and long-term storage.

Cryopreservation is storage of living organism or a portion thereof at an ultra-low temperature, and it remains capable of survival upon thawing. Hundreds of species of cyanobacteria and eukaryotic microalgae have been successfully cryopreserved.

2.13 Conservation of Bryophytes

Bryophytes are the second largest group of land plants after angiosperms. Bryophytes have not been figured as largely as flowering plants in conservation initiatives. Recently the importance of ex situ conservation and the value of in vitro biotechnology have been endorsed in the conservation of biological diversity and in the subsequent global strategy for plant conservation. The bryophyte flora is continually being impoverished in many countries today. The red list that has already been published shows that the rate of confirmed extinction among bryophytes ranges, in most cases, from 2 to 4% and that a substantial proportion of the bryoflora worldwide is threatened in the short term. However, the level of legal bryophyte protection and interest varies from region to region. Interest in bryophyte conservation has increased significantly in the last two decades especially in developed countries. The ex situ conservation of bryophytes consists of several equally important steps: collection of material, propagation and storage, cryopreservation and reintroduction. The availability of material of threatened species is limited by rarity and legislation. The collection of plant material should respect natural populations and avoid potentially adverse impacts on them due to harvesting in situ. However, in propagation phase it is normal to use axenic cultures. In bryophytes, developing in vitro and ex situ propagation and cryopreservation techniques for both vegetative tissue and spores provides additional security against the permanent loss of bryophyte diversity. The focus on rapidly declining and extremely rare species must be a top priority. Once we lose the species, we lose them forever.

2.14 Conservation of Pteridophytes

Pteridophytes prefer moist tropical to temperate habitats and thus are known to occur from sea level to the highest mountains. India having its diversified topography, variable climatic conditions and unique geographical position exhibits the presence of several migrant species. The pteridophytes prefer to grow in moist shady places and are dependent on the microclimatic condition of the region. The disturbance or

any change in the microclimate influence the population of these plants up to a great extent. The population of pteridophyte species in a particular area is greatly influenced by deforestation, thinning out of forests and reduction of moisture and shade, increasing urbanization, industrialization encroachment of forest lanes, unplanned development activities and climate change.

The unplanned felling of trees in the forest is responsible for the reduction in the epiphytic pteridophytic species. Large-scale collection of ferns from the forest area for ornamental purposes together with for use as medicine or food (vegetable) also poses a threat to the fern and fern allies.

The conservation of flowering plants has been achieved up to a greater extent in the country; however, regarding the conservation of Pteridophytes, few fern conservatories or fern gardens are established in the country at CSIR-National Botanical Research Institute, Lucknow, and CSIR-Institute of Himalayan Bioresource Technology, Palampur. For conservation of RET species of pteridophytes, the tissue culture is a useful technique for mass multiplication of the species within a short time and a number of such species and regenerated in vitro in the country. Apart from in-vitro propagation, localities rich in pteridophytic species must be declared as "Pteridophytic biosphere reserve" such as Pachmarhi, Madhya Pradesh.

Apart from Botanical Survey of India and few other governmental organizations, CSIR-National Botanical Research Institute, Lucknow, Uttar Pradesh, is one of the well-known scientific organizations playing vital roles in the conservation of Algae, Lichens, Bryophytes and Pteridophytes in the country. The institute has excellent repositories of all the non-vascular plants represented by more than 150,000 specimens of lichens, 15,500 of Bryophytes, 2500 of algae and 6500 of Pteridophytes of herbarium specimens.

Apart from rich and widely represented herbarium specimens from different parts of the country, the institute has more than 20 living threatened specimens of bryophytes in the moss garden of the institute together with more than 65 species of ferns and fern allies in the fern house.

2.15 Recommendations

The most urgent task for the conservation initiative regarding lower group of plants in the country needs understanding and documenting diversity of different non-vascular plants. Through red list species that is selection of species in need of conservation (RET species) and to target the preparation of distribution database and identify data gap, continue further field survey. Importance should be given to identification of species of principal importance for conservation, based on the grouping of habitat-specific species: general habitats (natural, woodlands, wayside, trees, park, etc.). Specific habitats different forest/Montage lime stone/mangrove/boulders. Sub littoral water/fresh water pond/snow beads for Bryophytes/Lichens/Pteridophytes. It is also recommended that there should be the promotion of the survey of habitat of high nature conservation interest for their lower plants. Sites

that currently lack statutory protection should be recognized as important for their lower group of plants' interest.

There are a number of sites that should urgently be designated for their lower group of plants that they can receive adequate protection and funding support for monitoring and appropriate management. Some of such sites are core zones of most of the biosphere reserves, different forest types, coastal sites for mangrove lichens and other palmate trees and specified freshwater lake in different phytogeographical regions.

Sustainable use of biodiversity is one of the three pillars of successful conservation. Different lower group of plants collected majority for seaweed collection for algination/food/biofuel/biofertilizer (Algae), spices/dyeing material/medicinal (Lichens), horticulture trade (Bryophytes), food/medicinal (Fungi) and ornamentals/medicinal (Pteridophytes) and the sustainable harvesting of the lower group of plants can be maintained/regulated by code of conduct to inform the local collectors.

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