Introduction

"*The most wonderful mystery of life may well be the means by which it created so much diversity from so little physical matter.*"

E.O. Wilson, 1992

"*Our National Food Security depends on our ability to conserve all our biological wealth.*"

M.S. Swaminathan, 1997

1.1. BIODIVERSITY

Biodiversity has been well known for its immense value for humankind in the present century, although it has been serving a lot for the mankind since the pre-historic era. Biological diversity, which Darwin (1859) called as '*Life's endless forms*' and Frankel (1970) as '*the essence of life*' is rooted deep into all the sphere of human life and activity (Krishnamurthy, 2003). During the last three decades, biodiversity, that forms the backbone of human sustenance, has drawn the attention of numerous scientists, policy makers and even the common people (Kumar & Asija, 2000). But the grand value of biodiversity is yet to be known. So far, only around 20 % of the existing species is discovered, named and classified. Whereas, till now, more than 80 % of those are unknown to us (Krishnamurthy, 2003) and the Biologists are in search of that yet unknown treasure of biological diversity. On the other hand, biological elements are facing severe threats of extinction due to some natural phenomena and/or man's self destructive activities, before they are discovered.

Different organizations, authorities and the nations in union are now realized the situation and are trying to sustain, preserve and to conserve biodiversity as well as to save the green earth that can sustain the endless form of the living world. It should be a fundamental duty of every individual man to protect and preserve biodiversity and our environment.

1.1.1. Definition

Biodiversity, the combined-abbreviated form for 'Biological Diversity', is very widely used by scientific communities, as well as the general public, environmental groups, conservationists, industrialists and economists. The term '*Biological Diversity*' was mentioned by Gerbilskii & Petrunkevitch (1955) in the context of intraspecific variation in behavior and life history (Magurran, 2004) and became popular around 1980 (Lovejoy, 1980a,b; Norse & McManus, 1980). Contraction of the term, '*Biological Diversity*' into '*Biodiversity*' was done during the first

planning meeting of the 'National Forum on Biodiversity' held at Washington DC in September 1986 (UNEP, 1995) and published in a book entitled '*Biodiversity*' (Wilson & Peters, 1998). Then it was further popularized by the United Nations Conference on Environment and Development (UNCED) held in 1992 at Rio de Janeiro (Krishnamurthy, 2003) which is popularly known as 'Rio Summit' or 'Earth Summit'. Scientific communities and social scientists defined biodiversity in various ways. Jutro (1993) identified about fourteen definitions and that indicates the complexity of the concept.

'Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystem to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes and their relative abundance' (OTA, 1987).

According to McNeely *et al*. (1990) Biodiversity '*encompasses all species of plants, animals and the micro-organisms and the ecosystems and ecological processes of which they are parts. It is an umbrella term for the degree of natures' variety, including both the number and frequency of ecosystem, species or genes in a given assemblage.*'

United Nations Environment Programme (UNEP) in 1992 defined Biodiversity as '*the variability among living organisms from all sources including, inter alia terrestrial, marine and other aquatic ecosystem and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems'*.

Definition sponsored jointly by WRI, IUCN and UNEP (1992) is '*the totality of genes, species and ecosystem in a region.*'

Biodiversity signifies variability of all the life forms of the nature and covers entire array of variation in and variability among the organisms and system at regional, landscape, ecosystem and habitat levels and at the organizational to gene levels (Ricklefs & Miller, 2000).

Biodiversity is considered in terms of gene, species and ecosystems which correspond with *genetic diversity*, *species diversity* and *ecosystem diversity*. *Genetic Diversity* also known as *intraspecific or infraspecific diversity* and means the diversity within and between populations of species. Genetic diversity of a species can exist at three different level — genetic diversity within individuals (heterozygosity), genetic diversity among individuals within a population and genetic diversity among population. Diversity or variability of species within a community is known as *species diversity* or *taxonomic* or *organismal diversity*. *Species diversity* is measured by different indices and methods — *species richness*

(indicated by total number of species in an area), *species abundance* (indicated by the total number of individuals of a species in an area) and *species evenness* (represented by equitability of species as given by their relative abundance). The diversity at the ecological or habitat level is called as *Ecological Diversity* or *Ecosystem Diversity* (Heywood, 1994; Norse, 1994). It is the intricate network of different species present in local ecosystem and dynamic interplay between them (Kumar & Asija, 2000). Many other scientists (Wilson, 1988; Szaro & Shapiro, 1990; Szaro & Salwasser, 1991) mentioned another form of biodiversity, known as *Landscape Diversity* (Krishnamurthy, 2003) which is defined as the diversity at landscape level (Noss, 1996). Scheiner (1992) called it as *Pattern Diversity* as the landscape has a pattern consisting of repeated habitat components.

Krishnamurthy (2003) stated that the definitions given by UNEP (1992) and jointly by WRI, IUCN and UNEP (1992) are mostly used, quoted and officialised. But Castri & Younes (1996) emphasized the interaction within, between and among the different levels of biodiversity, which is the essential mechanism to shape the features and functions of biodiversity and mentioned the lack of this interaction of these two definitions given by UNEP (1992) and jointly by WRI, IUCN and UNEP (1992).

Diversity at both the species and ecosystem levels consist of *alpha diversity (α), beta diversity (β) and gamma diversity (γ)* and were introduced by Whittaker (1960). Alpha-diversity is the species diversity within a community or habitat at a more local scale. Beta-diversity is the inter-community diversity expressing the rate of species turnover per unit change in habitat. Gamma diversity is overall diversity at landscape level and includes both alpha diversity (α) and beta diversity (β). Plant-diversity or Phyto-diversity means the variety and variability among the plants from all the sources. Phyto-diversity is essential for the sustenance of life on earth.

1.1.2. Significance of Biodiversity

Biodiversity is the part and parcel of our daily life and livelihood and forms the major resources upon which future generations in different communities and nations depend. The great classical Economist, Smith (1776) remarked that '*the origin of all wealth came from the bosom of earth*' that implies the immense value and significance of biodiversity.

Value of biodiversity may be of private and social. Private value of biodiversity needs to be understood to ascertain the driving force behind the loss of biodiversity whereas its social value is to understand for conserving it (Perrings, 1997; Krishnamurthy, 2003).

Biodiversity secures life sustaining goods and processes and is the foundation for human health. All animals including man are almost totally reliant on plants, directly or indirectly for their survival. It supports all, – food security, dietary

health and livelihood sustainability. Plant diversity forms the essential foundation of most of our terrestrial ecosystems.

The vast genetic variety available in terrestrial plants, animals and micro-organisms offers a wealth of possibilities for the betterment of mankind in the production of food, fodder and forage, medicine, horticultural and ornamental plants, timber, fiber, rattans and canes, dyes and other chemicals, fuel and renewable energy and a host of other products used in small and large scale industries and in domestic and international trade.

It provides important resources for traditional and modern medicines and for the research on medicine and about 25,000 species of plants have been recorded so far as traditional medicines (Heywood, 1992). There is wide variety of naturally derived drugs which still serve as important therapies in medicine today. Examples of drugs those are in use for many years and have importance even today include digitalin, aspirin, quinine, atropine, scopolamine, morphine, ergot alkaloids like ergotamine and ergonovine, ephedrine, reserpine, pilocarpine etc. Some more recent examples are the anti-cancer agents, vinblastine and vincristine from the common periwinkle, which is used to treat Hodgkin's disease, leukemia and testicular cancer; taxol which is obtained from yew (*Taxus baccata* and *T. wallichiana*) and used to treat ovarian and lung cancer (Young, 1999).

Biodiversity also plays a role in regulation of infectious diseases and its control and has social, cultural and spiritual importance. Intact ecosystem can reduce disaster risk and relief and recovery efforts.

Agricultural biodiversity plays a crucial role in sustaining and strengthening food, nutrition, health and livelihood security throughout the globe and provide crucial raw materials for improving productivity and quality of crops, livestock and fish and confers multiple benefits — ecological, economic, nutritional and cultural (MSSRF, IPGRI and GFU, 2005) and not only that, thousands of species is used as ornamentals in parks and gardens – both public and private, as street or avenue trees and for shade and shelter.

1.1.3. Biodiversity in danger

Depletion of biodiversity is one of the major threats to the existence not only for humankind but for the entire biosphere (Anonynous, 1996). Though Charles Darwin (1859) predicted that in the natural conditions the unfit species become extinct but threats to biodiversity arise when the rate of extinction exceeds the rate of speciation. Natural extinction of species due to geological and meteorological catastrophe is not uncommon (Anonynous, 1996) and now the anthropogenic activities have been the major threats to biodiversity (Leemans, 2001) and became the major cause of extinction (Wilson, 1988). The day when early man learnt to tame fire (Das, 2011) and started exploiting various forest products, from that

moment the loss of biodiversity was initiated and since then the process is going on at a very high rate, both on local and global scale (Given, 1996).

As a result we are losing about 5.2 million hectares of forest cover around the world (FAO, 2010) and 3 species being extinct in every hour (Stearns *et al*, 2000). The situation is much severe in tropical zone (FAO, 1991). In Tropical Asia 65% of the total natural forests has been destroyed so far. Though India has recorded increase in net forest cover in recent past but natural forests have decreased and in the post independent period India has lost 4696 Million hectares of forest (MoEF, 1999) and the existing forests are under severe threats particularly in the Himalayas, uplands of Central India and Western Ghats (WWF & ICIMOD, 2001; Dhar, 2002; Ninan, 2007).

Kumar & Asija (2000) identified a variety of factors which are responsible for the loss of biodiversity and its depletion. These are:

1. **Developmental pressure**: developmental pressure includes construction, forest based industries, hydrel and irrigation projects, mining, drilling for oil, pollution, resource extraction, road construction and transport, extension of settlement areas and industries, etc.

2. **Encroachment:** it covers agriculture, expansion of forest villages, fishery, grazing, habitat depletion or change, horticulture, monoculture forestry, new settlements, shifting cultivation, siltation of river bed, teak and rubber cultivation, etc.

3. **Exploitation**: Large scale exploitation by local authorities as revenue resources, firewood or MFP collection, food gathering and food hunting by meat loving population, poaching and illegal hunting, smuggling of timber and other forest produces, unregulated collection of medicinal plants and orchids, etc. and those are mostly work under the influence of uncontrolled market forces. Collection made by scientific/educational institutions and trophies or specimen collection as hobbies are also blamed for biodiversity loss but the impact of such activities is insignificant.

4. **Human induced disasters**: Floods, major oil spills, wildlife depredation, epidemic pests, natural and man-made forest fire including jhumming are some such factors.

5. **Managements of natural resources**: Diseases, fire and management tool, genetic uniformity, hybridization, inadequate water and food for wildlife, increased competition, introduction of exotic species, lack of patronage for local/native species, lack of pollinator and dispersal agents, low population/ restricted range of distribution, predation, etc.

6. **Management of human resources**: Change in people's lifestyle, conflicting/increasing demand, dilution of traditional values, erosion of indigenous knowledge, generation gap, human harassment, ignorance and lack of awareness, inadequate trained human resources, inappropriate land use, lack of effective management, negative attitude, tourism development, influence of valueless costly education, thirst for property, etc.

7. **Political and policy issues**: Civil unrest and political movement, armed conflict, intercommunity conflict, intervention failure, lack of clear policy, effective implementation of concerned rules and regulations, lack of interdepartmental coordination, lack of intervention, military activities, refugees, reduction in size of migratory corridors both for plants and animals.

Threatened Plants Committee of International Union for Conservation of Nature and Natural Resources (IUCN, 2006) has demarked about twenty factors which are considered as the main threats to the plants and are:

1. Grazing
2. Forestry
3. Ploughing of old grassland
4. Regeneration of Scrub
5. Changes in arable farming
6. Flooding
7. Drainage
8. Water pollution
9. Air pollution
10. Industrialization and urbanization
11. Road construction
12. Traditional rural practices
13. Dam construction
14. Mining and quarrying
15. Pressure from introduced plants
16. Tourism and infrastructural facility development in coastal/inland area
17. Collection of horticultural purposes/ academic purpose
18. Critically low population
19. Natural causes
20. Lack of pollinators

In Indian subcontinent the scenario of loss of biodiversity is almost same and the extremely rich and diversified flora faces lots of threats. Karthikeyan (2000) has summarized the major threats affecting biodiversity in India. These are population pressure and encroachment of the forested area, large scale removal of natural resources, habitat destruction and exotic weeds.

1.1.4. Conservation of Biodiversity

Conservation of Biological diversity along with its exploitation has been practicing for centuries (Meffe & Carroll, 1994) and that traditional conservation efforts were based on an economic and utilitarian philosophy (Krishnamurthy, 2003). India also has a long and glorious history of conservation of nature in the form of worshipping trees, forests, rivers, ponds, mountains and different animals which are believed to be abode of different Gods and Goddesses. Importance of sacred groves in traditional conservation is now well-known especially in Asiatic countries. The Convention on Biological Diversity held in Rio de Jeneiro in 1992 strongly emphasized the need for conservation of biological diversity of this planet and in recent years its conservation along with sustainable utilization has become the most important and burning topic for the survival of human beings on this earth (Singh & Chowdhery, 2002). Conservation of biodiversity can be attempted at three levels – genetic level, species level and ecosystem level which constitute different level of biological organization and are interconnected (Krishnamurthy, 2003). Though the conservation of biodiversity is achieved through *in-situ* and *ex-situ* modes, in the modern era both of these modes of conservation are practiced together for better result. *Ex-situ* conservation means the conservation of a species outside of its natural habitat like Zoological parks and Gardens and Botanical Gardens. In India there is a chain of Botanical Gardens, of which Indian Botanic Garden (BSI), Howrah is the most important one. Therefore, *in-situ* conservation receives high preference over *ex-situ* mode and is achieved through the establishment of Protected Area Networks. Under the Wildlife Protection Act and Indian Forest Act different types of Protected Areas have been recognized in India including National Park, Wildlife Sanctuary, Game Reserve, Closed Area, Reserved Forest and Protected Forest.

1.1.4.1. Role of IUCN in conservation activities

IUCN that stands for International Union for Conservation of Nature and Natural Resources, is a federative membership organization, composed essentially of governments or governmental agencies, scientific, professional and conservation organizations and now is also known as the World Conservation Union (Krishnamurthy, 2003). In co-operation with the United Nations and other intergovernmental agencies as well as its sister organizations – the WWF, it aims to influence, encourage and assist societies throughout the world to conserve nature and to ensure that any use of natural resources is equitable and ecologically sustainable. (http://fur.ca/conservation/iucn/).

IUCN works through its six Commissions, namely (i) Commission on Education and Communication (CEC), (ii) Commission on Environmental, Economic and Social Policy (CEESP), (iii) World Commission on Environmental Law (WCEL), (iv) Commission on Ecosystem Management (CEM), (v) Species Survival Commission (SSC) and (vi) World Commission on Protected Areas (WCPA), which all promotes different aspects of conservational activities directly and/or indirectly. IUCN runs field projects for habitat and species conservation around the world and the organization is best known for compiling and publishing

the IUCN Red List, which assesses the conservation status of species worldwide and thus play crucial role in conservation of biodiversity. The IUCN Red List of Ecosystems is of global standard to assess the conservation status of ecosystems and is applicable at local, national, regional and global levels. It also organizes and supports several conferences and workshops on biodiversity.

The IUCN Program on Protected Areas (PPA), a Secretariat Program based in IUCN HQ and the IUCN World Commission on Protected Areas (WCPA), the world's leading network of protected areas, are two important programs that work together as to deliver IUCN's work in relation to protected areas (www.iucn.org/westasia). About 10 types of protected areas have been recognized by IUCN, of which World Heritage Sites and Biosphere Reserves have international standard and recognition (WRI, 1992). It recognizes Biodiversity Hotspots of Conservation also. IUCN plays vital role in recognition of Biodiversity Hotspots and has modified the concept and criterion of hotspots stating that it must hold at least 1500 endemic plant species and have lost 70 % of its original habitat is lost (Mittermeier *et al*. 2011).

I. Biodiversity Hotspots: The Himalaya Biodiversity Hotspot

The concept of '*Biodiversity Hotspot'* was brought in by Myers (1988) on the basis of total endemics and the rate of natural habitat loss. Biodiversity hotspots or simply Hotspots are nothing but the concentration of unique biodiversity. Hotspots support a number of threatened taxa and ecosystems and they deserve conservational attention. Uniqueness of biodiversity, amount of habitat lost and protected and magnitude of endemism along with some other factors are regarded as important criteria for recognition of Hotspots. Biodiversity hotspot must have lost at least 70 % of its original native vegetation.

Initially, 13 biodiversity hotspots were documented worldwide and then further 12 more hotspots were added (Myers *et al.* 2000). After that IUCN added 9 more regions to already existed list of biodiversity hotspots amounting total 34 numbers of hotspots all over the globe (CI, 2005).

Planet earth is unique in its capacity to support lives on it, and is the only habitat for over 40 millions of living organisms that form the basic level of biodiversity. Although the living organisms spread all over the globe but they are not uniformly distributed. Somewhere they are concentrated in number and variety while in other places their number and variation is too less. Depending on the distributional patterns, variations and concentration of floral elements different phyto-geographer divided the planet into different Kingdoms and Subkingdoms. Indian region or Indian sub-continent falls under Indo-Malayan subkingdom of Paleotropical Kindgom (Good, 1974) and is divided into a number of botanical provinces.

The Himalayas is recognized for its ecosystem services to the Asian region as well as to the world as it maintain slope stability, regulate hydrological integrity,

sustain high levels of biodiversity and human wellbeing also. It is exclusive and inimitable in respect of biodiversity, and is receiving topmost priority for biodiversity conservation in global agendas since last few decades (Sharma *et al*. 2010).

Among the Hotspots Himalaya is the most important one from the view points of phytodiversity, endemism and occurrences of threatened taxa and it covers northern Pakistan, Nepal, Bhutan and the northwestern and northeastern states of India. It spreads over around 750,000 km² areas and includes the world's highest mountain, Mt. Everest and several of the world's deepest river gorges. The diversity in landforms results in diverse ecosystems to from alluvial grasslands and subtropical broadleaf forests to alpine meadows above the tree line (Anonymous, 1996).

The Himalaya hotspots is divided into two regions: the Eastern Himalaya, which covers parts of Nepal, Bhutan, the northeast Indian states of West Bengal, Sikkim, Assam, and Arunachal Pradesh, southeast Tibet and northern Myanmar; and the Western Himalaya covering the Kumaon-Garhwal, northwest Kashmir, and northern Pakistan (http://www.cepf.net/resources/hotspots/Asia-Pacific/Pages/Himaaya.aspx on 19.5.16).

Vegetation cover of the Himalaya Hotspot is 185,427 km², which is the home for around 10,000 species of plants of which 3,160 Species is endemic to this region. Not only that, it nurtures important populations of numerous large birds and mammals, including vultures, tigers, elephants, rhinos and wild water buffaloes.

Table 1.1. Species diversity and endemism in Himalaya Hotspot (http://tech-organic.blogspot.in/2011/09/himalayan-biodiversity-hotspot.html on 19.05.2016)

Taxonomic Group	Species	Endemic Species	Endemism (%)
Plants	10,000	3,160	31.6
Mammals	300	12	4
Birds	977	15	1.5
Reptiles	176	48	27.3
Amphibians	105	42	40
Freshwater Fishes	269	33	12.3

Biodiversity of the Himalayas also subject to face different type of threats due to over exploitation of natural resources, population explosion, extensive clearing of forests and grasslands for cultivation and settlement development, overgrazing by domestic livestock, widespread logging, manmade fire, accidental spread out of fire that convert the forests and grasslands into denuded land and habitat (www.conservation.org). Not only that, illegal poaching, overexploited for traditional medicinal plants, fuel wood collection and too much extraction of non-timber forest produces, both for domestic consumption and export, unplanned and poorly managed tourism has led to environmental deterioration in the Himalayan belt (Das, 2011).

At the beginning, McNeely (1990) recognized 12 Mega-diversity countries globally, which harbour 70 % of the total flora of the world (Groombridge, 1992). India is one of the seventeen megadiversity countries of the world and is the home to 17500 species of flowering plants (Sing & Choudhery, 2002). However, at present 17 Megadiversity countries are recognized by Conservation International (http://www.biodiversitya-z.org/content/megadiverse-countries on 11/05/2017)

1.1.4.2. Plant diversity of Eastern Himalaya

Eastern Himalaya, one of the twelve phyto-geographic regions recognized in India, covers Eastern Nepal in the West to Arunachal Pradesh in the East and passes through Darjeeling district of West Bengal, and the states like Sikkim and Arunachal Pradesh (Clarke, 1898; Hooker, 1904; Chatterjee, 1940). Though extends over a small area, covering only 850 km stretch (Gansser, 1964), Eastern Himalayas is regarded as the heaven for countless plant species and exhibits the richest flora in Indian sub-continent (Rao & Murti, 1990). Though too much of anthropogenic activities started degrading the greenery, still there are many patches of vegetation in the Eastern Himalaya those remain untouched and virgin.

Several plant explorers, botanists, researchers and plant-hunters from round the world (Das 1995, 2004) have worked on the vegetation of Eastern Himalaya and categorized it in different ways (Rao, 1994). East Himalayan flora consists of (i) Tropical evergreen forests, (ii) Subtropical forests, (iii) Temperate forests, (iv) Subalpine and (v) Alpine forests (Sahni, 1981). But, Mehra *et al,* (1985) grouped East Himalayan vegetation under three major types along with some sub-types.

Based on the previous workers including Griffith (1847), Hooker (1849), Hara (1966, 1971), Rao (1974), Ohashi (1975) and Rao & Hazra (1986), later on in 1994 Rao classified vegetation of Eastern Himalaya into following altitudinal types with numerous sub-types:

1. Tropical Forest
(i). Tropical evergreen forests
(ii). Tropical grasslands
(iii). The Sub-tropical forests
2. Temperate Forest
(i). Cool broad leaved forests of Eastern Himalaya wet temperate forests.
(ii). Evergreen Oak forest and
(iii). Temperate Rhododendron-Conifer forests
3. Sub-alpine Forest
4. Alpine Forest

The Eastern Himalayan zone is extremely diverse and rich in floristic elements and several factors have been recognized for this. Those include topographic variation, different altitudinal zones – from plateaus and valleys to ice

capped mountains; climatic variables in different climatic zones; high to moderate to low precipitation zones; horse-shoe shaped alignment of folds; lesser height than Central and Western Himalayas; confronting of monsoon winds coming from Bay of Bengal containing heavy load of moisture that causes heavy rainfall and moist and warmer environment (Anonymous, 1996).

About 63% of flowering plant families in India are represented in this region. Some families like Coriariaceae, Nepenthaceae, Turneraceae, Illiciaceae, Ruppiaceae, etc. which are represented in India by one or two species of a solitary genus are found here (Rao, 1994). About 9000 species of flowering plants have been recorded from this floristic zone (Myer, 1988; Wilson, 1992) which shares highest forest cover in Indian phytochorion (FSI, 2003). The Eastern Himalaya is very wealthy having a great number of orchids, tree-ferns, primulas and blue poppies. Eastern Himalaya hosts about 650, 70, 34 and 58 species of orchids, *Rhododendron*, *Hedychium* and bamboo respectively against the Indian representative numbers are 1200, 82, 60 and 100 respectively (Rao, 1994; Rai, 2006; Mao, 2012). A large number (ca 82) of wild relatives of cultivated plants have been recorded from this zone like *Houttuynia cordata* Thunb., *Myrica esculenta* Buch.-Ham. *ex* D. Don, *Betula alnoides* Buch.-Ham. *ex* D. Don, *Alnus nepalensis* D.Don and others. This is a natural store house of numerous lifesaving drug plants like *Coptis teeta* Wall., *Paederia foetida* L., *Sinopodophyllum hexandrum* (Royle) T.S. Ying, *Nardostachys grandiflora* DC., *Panax pseudo-ginseng* Wall., *Cheilocostus speciosus* (J.Koenig) C.D. Specht, *Acorus calamus* L., etc. Diversity of primitive flowering plants in Eastern Himalaya, like *Magnolia griffithii* Hook.f. & Thomson, *Magnolia pterocarpa* Roxb., *Houttuynia cordata* Thunb., *Myrica esculenta* Buch.-Ham. *ex* D. Don, *Betula alnoides* Buch.-Ham. *ex* D. Don, *Alnus nepalensis* D.Don, *Schisandra neglecta* A.C.Sm., etc. are also remarkable. Not only for flowering plants, Eastern Himalaya is also well known for its diversified non-flowering plants like ferns and fern allies, liverworts and mosses, algae, fungi and lichens. About 500 species of ferns occur in this phytogeographical region and this accounts almost 50 % of the total Indian fern species (Rao, 1994).

I. Endemism in Eastern Himalaya

This phytogeographic zone exhibits a great extent of confinement of flora in correspondence with the Indian sub-continent. About 39 % of recorded flora from Eastern Himalaya is endemic (Wilson, 1992) and this is further supported by the estimation of endemic plants by Nayar (1996), that shows occurrence of 1808 endemic species in Eastern Himalaya out of total 5725 species found in India. Recent workers like Das (1995, 2004), Bhujel & Das (2002), Ghosh & Das (2009) has contributed to the endemism of Eastern Himalaya. The region is home for several interesting and rare plants as well as the primitive angiosperms that led to the consideration of Eastern Himalaya as '*Sanctuaries of Ancient Flora*' (Rao, 1994). Takhtajan (1969) treated this zone as '*Cradle of Flowering Plants*'. Recent workers (Shrestha, 1982; Das, 1986, 1995, 2004; Lama, 2004; Rai, 2006) believe that the

Eastern Himalaya have been playing as the meeting ground for diverse floral elements from adjoining areas and is an important centre for speciation.

Some plant species endemic in this zone are *Uvaria lurida* Hook.f. & Thomson, *Magnolia griffithii* Hook.f. & Thomson, *Ardisia quinquangularis* A.DC., *Eria barbata* (Lindl.) Rchb. f., *Paphiopedilum insigne* (Wall.) Pfitz., *Hedychium calcaratum* Rao & Verma, *Nepenthes khasiana* Hook. f., *Magnolia lanuginosa* (Wall.) Figlar & Noot., *Coptis teeta* Wall. etc.

1.1.4.3. Plant diversity in India

Indian region, the most distinct biogeographic regions of the world extends over 3,280,383 sq km and is diverse in its climatic, altitudinal and ecological habitats. Its climate ranges from almost rainless areas to the highest rainfall areas in the world; altitude varies from sea level to highest mountain and the habitat type from humid to hot desert, cold desert to icy mountain ranges (Rao, 1994). These extreme variety and variability of habitats, climates and altitudes are the main reasons for the richness of Biodiversity in India (Das, 1995, 2002, 2004, 2011; Rai, 2006) and its richness of the vegetation cover is well known and the region is considered to be one of the twelve megadiversity countries recognized first by McNeely in 1990 (Groombridge, 1992). It now covers three '*Conservational Hotspots of Biodiversity'* out of 34 recognized world-wide by IUCN (CI, 2005). N.I. Vavilov (1926) considered the Indian region as '*the Hindustan Centre of Origin of Cultivated Plants'*. Not only that, Sir J.D. Hooker (1904) mentioned that the Indian flora is more varied than that of any other country of equal area in the eastern hemisphere, if not in the world.

This sub-continent possesses scrub forest, tropical evergreen rain forest, costal mangrove, temperate forests, alpine flora, xerophytic vegetation etc (Rao, 1994; Rai, 2006). Well mixing of floristic components from the surrounding countries is the main feature of the Indian flora which posses African, Arabian, Middle Asian, Mediterranean, European, Siberian, Tibetan, Chinese, Japanese, South-East Asian, Malaysian, Australian, Sri Lankan floral elements (Anonymous, 1996). Based on this observation, Sir J.D. Hooker (1904) concluded that India has no flora as a separate entity but an admixture of the floras from the neighbouring countries. But, the phytogeographers after critical analysis came to the conclusion that India has its own distinct flora (Rao, 1994).

Champion & Seth (1968) recognized 16 major forest types in India along with several minor types. Major forest types of India as proposed by them are as follows:

1. Tropical Wet evergreen Forest
2. Tropical Semi-evergreen Forest
3. Tropical Moist-deciduous Forest

4. Littoral and Swamp Forest
5. Tropical Dry-deciduous Forest
6. Tropical Thorn Forest
7. Tropical Dry Evergreen Forest
8. Sub-Tropical Broad-Leaved Hill Forest
9. Sub-Tropical Pine Forest
10. Sub-Tropical Dry Evergreen Forest
11. Montane Wet Temperate Forest
12. Himalayan Moist Temperate Forest
13. Himalayan Dry Temperate Forest
14. Sub-Alpine Forest
15. Moist Alpine Forest, and
16. Dry Alpine Scrub.

Udvardy (1975) recognized 10 biogeographic regions in India that represent 3 basic Biomes and 2 natural realms within the territory of the Indian Republic. Several phytogeographers (Hooker, 1854, 1904; Clarke, 1898; Chatterjee, 1940, 1962; Razi, 1955; Puri, 1960; Rao, 1974; Rodges & Panwar, 1988) have worked on phytogeography of Indian region and divided it variously. Major phyto-geographic regions of India are;

1. Trans-Himalaya
2. West Himalaya
3. East Himalaya
4. North-East India
5. The Indian Desert
6. Semi-arid zone
7. Gangetic plain
8. Western Ghats
9. Deccan peninsula
10. Indian coasts
11. Andaman and Nicobar Islands; and
12. Lakshadweep Islands

India covers only 2.4 % of the global geographic area and over 45000 species of plants have been reported from the Indian region that represent 11 % of the known plants species from the world (Rao, 1994; Singh & Chowdhery, 2002). So far 17500 species of flowering plants reported from India (Singh & Chowdhery, 2002). Approximately half of the world's aquatic plants occur in India and a large number of primitive flowering plants (at least 131 species) are found in India (Rao, 1994). India has remarkable record in agro-biodiversity with 167 crop species and their wild relatives and is regarded as 'the Centre of Origin' of 30,000 – 50,000 varieties of crop plants that made the nation to rank 7th in the world for contributing to the world agriculture (Kumar & Asija, 2000). Not only the angiosperms but plenty of Algae, Fungi, Bacteria, Lichens, Bryophytes and Pteridophytes have been

enumerated (Anonymous, 1996). Flora of India is renowned for its high degree of endemism (Chatterjee, 1940, 1962; Nayer, 1980; Rao, 1994; Ahmedulla, 2000; Sharma, 2000; Mao *et al.* 2001; Bhujel & Das, 2002); about 33 % of recorded floras are endemic in the North East, Western Ghats, North-West Himalaya and the Andaman and Nicobar Islands. Number of endemic species of Indian Flora is about 6000 (Chatterjee, 1940). About 2500, 2600, 800 and 200 species are endemic in North-Eastern Region, Western Ghats and Peninsular region, North Western Himalaya and Andaman-Nicobar Islands respectively (Chatterjee, 1940, 1962; Nayar, 1980). Separation of Indian flora from neighboring countries by the great Himalayas in the North and different oceans in peninsular region led to high degree of endemism of Indian floras. Considering this high degree of endemism Takhtajan (1969) recognized this region as '*Cradle of Flowering plants'*.

1.2. FORESTS AND PLANTATIONS

1.2.1. Forests

Forests make up about 30% of the total land cover on earth and are of incredible value to life. These are stores of carbon and play large variety of important roles including climate control and watershed functioning and are the sources of innumerable raw materials that humans depend on.

1.2.1.1 Etymology

The term '*forest'* is derived from Middle English '*Foreign'* that means outside. In English it was first introduced as the word for wild land set aside for hunting. Some authorities claim that Through several stages of modification it is derived via Old French, from the late Latin phrase *forestis silva* (= outside wood) which is further derived the Latin *foris* (meaning outside). Generally, it means a growth of trees and other plants covering a large area (American Heritage Dictionary of the English Language.2011).

1.2.1.2. Definition

'Forest' has been defined in many ways and the fact reflects the diversity of forests and forest ecosystems in the world and of the diversity of human approaches to forests. So many useful definitions of "forest" exist in published form but the definition put forward by the FAO (1998) is considered as the basic one. Accordingly 'a forest is a land area of more than 0.5 ha, with a tree canopy cover of more than 10%, which is not primarily under agricultural or other specific non-forest land use' (FAO, 1998; FRA, 2000). In the case of young forests or regions where tree growth is climatically suppressed, the trees should be capable of reaching a height of 5 m *in-situ*, and of meeting the canopy cover requirement (more than 10%).

1.2.1.3. Type of forests

Different types of forests have been recognized around the world on the basis of different parameters including geography, climate, dominant vegetation, gross appearance or physiognomy and species composition. Depending on biomes forests are broadly classified into three major types - tropical forests, temperate forests and boreal forests.

Tropical forests are the ecologically most rich, occur near the equator and are most threatened due to logging and clearance for agriculture and settlement. Salient features of this forest biome are - multi-layered continuous Canopy that allow little light to penetrate, highly diversified flora, about 100 different tree species per square km, 25 – 35 m tall trees with buttressed trunks and shallow roots and mostly evergreen and presence of epiphytes (including orchids and bromeliads), vines, ferns, mosses and palms. This type of forests is further classified into different sub types like tropical rainforests, dry coastal forests, montane cloud forests and semi-arid savannah woodlands. (http://www.fs.fed.us/global/ lzone/student/ tropical.htm).

Temperate forests occur in eastern North America, north eastern Asia, and western and central Europe. Well-defined seasons with a distinct cold winter characterize this forest biome. Due to the shorter growing season temperate forests regenerate more slowly than tropical forests thus only scattered remnants of original temperate forests remain.

This type of forest biome is characterized by evenly distributed precipitation (75 – 150 cm) throughout the year, about 10°C average temperature, mild Summer (21°C) and sub zero winter temperature, litter rich fertile soil, moderately dense canopy that allows light to penetrate, well-developed and richly diversified under storey vegetation and occurrences of only 3 – 4 tree species per sq km. Moist conifer and evergreen broad-leaved forests, Dry conifer forests, Mediterranean forests, Temperate coniferous and Temperate broad-leaved rainforests are the major type of Temperate forests determined mainly by seasonal distribution of rainfall (www.eco-portal.com/ Forests/ Forest_Types/ Temperate_Forests/ welcome. asp).

Boreal forests, alternatively also known as taiga, represent the largest terrestrial biome and found in northern areas with shorter, warm summers and long winters. These are mostly found in Europe, Asia, Siberia, and North America. Plant life in the boreal forest is sturdy due to stunted growth in low temperature, consisting mainly of evergreen and other resilient vegetation. Generally the Boreal forests occur between latitudes of 50 and 60 degrees north and thus named so as boreal means northern. The forests consist of mostly evergreen conifers – pine, fir and spruce and some deciduous genera such as birch and poplar (http://www.ucmp.berkeley.edu/glossary/gloss5/biome/forests.html #boreal).

Depending on logging, forests are classified as primary and secondary forests. *A primary forest* is a type of forest that has never been logged and has developed following natural disturbances and under natural processes, regardless of its age. Whereas, *secondary forests* are vegetation that have been logged and recovered naturally or artificially into a forested structure. In Europe, both primary and secondary forests has different connotation and refers to an area of forest land which has probably been continuously wooded at least throughout the historical times and it has not been completely cleared or converted to another land use type for any period of time. While a forest land which has come across a period of complete clearance by humans with or without a period of conversion to another land use is regarded as secondary forest.

1.2.2. Natural Forests

Forests are either directly affected by human activities such as cutting, planting and drainage, or indirectly by manipulation of the grazing regime, air pollution and other factors and very little untouched forest is left in the world. This is happening almost in every corner of the planet and is directly or indirectly influenced by human activities.

In the Temperate and Boreal Forest Resources Assessment (TBFRA)-2000, UN-Economic Commission for Europe and FAO on the basis of human intervention characterized forests and other wooded land as *natural forests* (undisturbed by man), *semi-natural forests* (under some degree of management, past human intervention) and *plantation forests* [forests under active management] (Kirby *et al.* 1984).

Natural forest is a forest which has spontaneously generated itself on the location and which consists of naturally immigrant tree species. This type of forest can be more or less influenced by culture, e.g. by logging or regeneration techniques, but the forests must not have been subject to regeneration by sowing or planting (The National Forest and Nature Agency, 1994 & http://www.geus.dk/ departments/environ-hist-climate).

The World Resources Institute (WRI) coined the term "frontier forests" to describe forested areas that are relatively undisturbed by human activity and are large enough to maintain their biodiversity, including viable populations of wide-ranging species. Frontier forests constitute about 40% of total forest area (WRI, 1997; http://www.wri.org/wri/ffi/).

Land that has either a crown cover of 5 to10 percent of trees which are able to reach a height of 5 m at maturity; or a crown cover of more than 10 percent of trees not able to reach a height of 5 m at maturity; or with shrub or bush cover of more than 10 percent is called *Other Wooded Land*.

Another type of forest is *social forests* what is defined in Ninth Commonwealth Forestry Congresses as forest which aims at producing flow of protection and recreation benefits for community (Tiwari, 1983). Social forestry program is recommended by the National Commission on Agriculture (NCA, 1976) and the main task assigned to it is to meet the community requirements.

1.2.3. Plantation or Plantation Forests

Generally the term plantation is used as an abbreviation for Plantation forest (i.e. Planted forest) and/or Forest Plantation. Plantations cover 5 % of global forests and supply about 35 % of the world's round-wood (FAO, 2010a). They may also play an important role in alleviating pressure on natural forests for timber and fuel wood production.

1.2.3.1. Definition

The term, *plantation* is informal and not defined precisely. Generally it means a long artificially established forest, farm or estate, where crops are grown. According to Collins English Dictionary (1991) plantation means '*an estate, especially in tropical countries, where cash crops such as rubber, oil palm, etc. are grown on a large scale'*.

A *plantation forest* or *forest plantations* are afforested land or a secondary forest established by planting or direct seeding. A gradient exists among plantation forests from even-aged, single species monocultures of exotic species with a fiber production objective to mixed species, native to the site with both fiber and biodiversity objectives. These gradients also reflect the capability of the plantation forest to maintain "normal" local biological diversity. ASFR (2003) has defined the term plantation as 'intensively managed stands of trees of either native or exotic species created by the regular placement of seedlings or seeds (http://worldforestry.blogspot.in/2008/06/australias-state-of-forests-report-2003.html)'. Plantation forest is usually easily distinguished from natural forests by the trees planted in straight lines. It is can be monoculture or polyculture over a large area and does not include extensive naturally occurring stands of plants that have economic value. But another different view is there, regarding the use of these two terms, which distinguished them on the basis of the existing stand and the degree of planting.

Food and Agricultural Organization of United Nations has recently revisited the definition of "planted forests" and "plantation forests" (FAO, 2005). Accordingly Planted forest means *'forest stand in which trees have predominantly been established by planting, deliberate seeding or coppicing, where the coppicing is of previously planted trees (this includes all stands established by planting or seeding of both native and non native species)'* and '*Forest Plantation'* means the Forest stand in which trees have been established by planting or/and deliberate seeding or coppicing (where the coppicing is of previously planted trees) with either native

species or non-native species that meet all the following criteria: (i) one or two or a few species, (ii) even-aged, and (iii) regular spacing (FAO, 2005; Kanowski *et al.* 2005). Plantation forests or planted forests are even-aged stands of a single or a mixture of tree species established primarily for wood production, land restoration, fuel-wood or amenity or other purposes.

1.2.3.2. Objectives of Plantation

Plantations are established for a variety of reasons. Primary objectives of almost all plantations are the production of large quantities of wood and fiber like timber and paper production (Lindenmayer *et al.* 2003). Social and environmental objectives are considered as secondary objectives, especially in the projects funded by Govt. or other developmental agencies (FAO, 1992; Evans, 1992). Now-a-days, plantation and forest management are increasingly becoming an integral part of biodiversity conservation (Eyecott *et al.* 2006) along with its role in delivering a range of products and benefits like sawn timber production, wood fiber and other wood based products, shelterbelts for animals and crops, the provision of multiple environmental benefits through addressing land degradation, salinity and soil erosion, generation of biomass, storage of carbon etc (http://www.ffic.com.au/plantations). Some industrial plantation are grown for non-timber forests products such as gum, resins, oils, etc. Community forests are raised for extraction of fuel-wood, fodder, fruit and other non-forest products as well as protection to water, soil resources and for restoration benefits (Parrota *et al.* 1997).

Sawyer (1993) has mentioned following reasons for establishing plantations:

1. Compensation for lack of resources from natural forests due to deforestation
2. Fulfilling demands for lumber, pulp, and paper products
3. To meet demand for high quality species
4. To develop export market
5. To restore degraded sites and protect watersheds
6. To provide domestic uses like firewood, posts and home fences
7. To protect the genetic diversity of forests species *ex situ*
8. To produce desired species that fails to regenerate naturally
9. To supply potential markets for carbon sequestration and
10. To provide forests uses on previously unproductive sites when natural forests are not accessible.

The purpose of fast-wood plantation differs from that of plantation and is to produce large volume of small diameter logs at competitive prices as quick as possible as raw material for pulping and paper industries (Huy, 2004).

In 2000, plantations which covers 5 % of global forest, supplied about 35 % of the world's round-wood (FAO, 2010). Pine, spruce, eucalyptus, poplar, teak, Sal etc. are widely planted far beyond their natural range because of their fast growth rate, tolerance of rich or degraded agricultural land and potential to produce large volumes of raw material for industrial use. Though in ecological terms, plantations are always young forests and lack the type of growth, soil or wildlife typical of old-growth natural forest ecosystems, some crucial component of natural forest ecosystems like decaying dead wood etc. are missing. However, they can be managed in different ways to enhance their role in biodiversity protection and may provide some kind of ecosystem services like maintenance of nutrient capital, protection of watersheds and soil structure as well as storage of carbon. They may also play an important role in alleviating pressure on natural forests for timber and fuel wood production.

1.2.3.3. Type of plantation

The *Global Forest Resource Assessment, 2000* by Food and Agricultural Organization of United Nations recognizes three broad categories of plantations: (i) ***Industrial plantations***, which produce wood or fiber to supply wood-processing industries and charcoal for industrial use; (ii) ***Non-industrial plantations***, which produce fuel-wood for domestic use, or are established to protect soil and water resources; and (iii) **Plantations whose purpose and end products are unspecified**. Fast-wood plantations are industrial plantations (FAO, 2001). However, FAO's figures make no distinction between fast-wood and other types of industrial plantations. Generally, the Industrial plantations are fast-wood plantations and found in Brazil, Indonesia, China, India, South Africa, Thailand, Vietnam, Malaysia, Venezuela, Swaziland, Chile, Portugal, Spain, Argentina, Uruguay, South Africa and Australia (Evans, 1992).

Sometimes plantations may be divided into some other types: Industrial plantations, farm or home plantations, environmental plantations, high value food crops, fishing plantations etc. *Industrial plantations* which are usually even-aged and often consist of just one or two species are established to produce a high volume of wood in a short period of time. Plantations which are grown by state forestry authorities and/or the paper and wood industries and other private landowners, have replaced the natural forest in southern and southeastern Asia (Cossalter & Pye-Smith, 2003). These species can be exotic or indigenous. The plants used for the plantation are often genetically altered for desired traits such as growth and resistance to pests and diseases in general and some other desired specific traits. Wood production on a tree plantation is generally higher than that of natural forests.

Farm or *Home Plantations* are typically established for the production of timber and fire wood for domestic use and sometimes for sale and the management may be less. But it is difficult to distinguish the farm plantation from naturally regenerated forest.

Environmental plantations are established for environmental protection such as watershed or soil protection, erosion control, landslide stabilization and windbreaks etc. They are raised to foster native species and promote forest regeneration on degraded lands as a tool of environmental restoration.

High-yield, intensively managed, short rotation plantations are called *fast-wood plantations* or fiber farms and often managed on a short-rotation basis and are becoming more widespread in South America, Asia and other areas.

Depending upon the tree species used for planting, plantation forests are of two types – *Exotic species plantation* and *Native species plantation.* Exotic species plantations are Intensively managed forests with > 30% canopy cover, which have been planted by people with species not naturally occurring in that country. Native species plantations are Intensively managed forests with > 30% canopy cover, which have been planted by people with species that occur naturally in that country.

Again on the basis of number(s) of plant species used plantation may be of *Monoculture* and *Polyculture* or *mixed plantation*. In case of monoculture plantation only one species is selected to be planted whereas a number of plant species are used in ploycutlural or mixed plantations which is now preferred over the single species plantation forests.

Plantation which are intensively managed for commercial purpose, set in blocks of a single species, which produce industrial round wood at high growth rate (mean annual increment of no less than $15m^3$/ha) and which are harvested in less than 20 year rotation is known as Fast-wood plantation (Cossalter & Pye-Smith, 2003). This type of plantation is nothing but a type of monocultural and industrial plantation.

A large number of species are used for raising plantation and their selection is based on the locality, objectives and type of plantations. These are *Tectona grandis, Casuarina equisetifolia, Dalbergia sissoo, Gmelina arborea, Swietenia macrophylla, Terminalia* spp*., Eucalyptus* spp*., Pinus* spp*., Acacia* spp. and others. Among these some widely used ones in tropical countries are *Eucalyptus* spp*.,* some species of *Pinus, Tectona grandis, Acacia* spp. etc.

1.2.3.4. History of plantation

The practice of planting trees goes back to ancient times (Cossalter & Pye-Smith, 2003) but planting tree as a means of regenerating forests and afforesting bare land is relatively recent. The nineteenth century witnessed a little bit of plantation establishments but tree planting began in earnest in the first half of the 20th century in Western Europe, the United States, Australia, New Zealand, South Africa and a small number of developing countries such as India, Chile, Indonesia and Brazil (Evans, 1992).

Since 1950s establishment of plantations attained an ever increasing extent in the tropics and subtropics and during this period Japan, Korea and China embarked on massive reforestation programs. The 1960s witnessed the launching of large-scale plantation programs in many tropical and subtropical countries, and between 1965 and 1980 the area devoted to tropical plantations became triple (Cossalter & Pye-Smith, 2003).

According to the *Global Forest Resource Assessment 2002*, conducted by FAO, the global Plantation estate increased from 17.8 million hectares in 1980 to 43.6 million hectares in 1990 and 187 million hectares in 2000 (FAO, 2001). A third of today's plantations are found in the tropics and two thirds in temperate and boreal zones. China, United States, the Russian Federation, India and Japan each possessing over 10 million hectares of plantations and are accounts for 65 % of the world's plantations. The FAO assessment estimates the global rate of new planting at 4.5 million hectares a year, with Asia accounting for 79 % and South America 11 %. However, there is significant increase of plantations established for industrial purposes between 1991 and 2000.

Since its initiation, plantations are replacing natural forests very fast. According to FAO (2001) about 7 % of the natural dense forests getting lost in the tropics due to the conversion of land into plantations and the remaining 93% of the land is being converted to agriculture and other human settlements. There are more than one million hectares of recently established eucalypt plantations in southern China (Xu *et al.* 2000).

1.2.3.5. Present scenario of Plantation

Plantations cover wide parts of the earth's surface and in 2000 it was about 187 million hectares (FAO, 2000), which is now greatly exceeds that of the native natural forests and the process is progressing at high rate all over the globe. This is much more prominent in some European countries (French *et al.* 2008) and about 70 % of the total forest area in United Kingdom is Plantation (FAO, 2006).

At the beginning of the twenty-first century forest plantation amounted to about 5% of global forest cover. Fast-wood plantations are high-yielding, intensively managed, rotate in short duration and are becoming widely popular in South America, Asia and other areas.

Teak is a widely planted hardwood species in warm areas having extremely high commercial demand and some other important and potential species include *Eucalyptus* spp., *Acacia* spp., *Casuarina equisetifolia*, *Dalbergia sissoo, Gmelina arborea, Swietenia macrophylla, Terminalia* spp., etc.

Table 1.2. Different sub-regions of Teak plantation all over the globe in Million Hectare [mha]

Sub-region	Net area of teak plantation [mha]		Sub-region	Net area of teak plantation [mha]
West Sahelian Africa	4.02		Insular Southeast Asia	706.01
East Sahelian Africa	14.85		Tropical Asia	2,107.89
Moist West Africa	87.88		Tropical Oceania	3.03
Southern Africa	2.8		Central America	22.29
Tropical Africa	109.55		Caribbean	8.06
South Asia	1,099.60		Tropical South America	2.72
Continental Southeast Asia	302.28		Tropical America	33.07

1.2.3.6. Plantation in Indian sub-continent

India is one of the ten most forest-rich countries of the World along with the Russian Federation, Brazil, Canada, USA, China, Democratic Republic of the Congo, Australia, Indonesia and Sudan. India's forest cover grew at 0.22% annually during 1990 – 2000 and at 0.46 % per year during 2000 – 2010 (www.en.wikipedia. org/wiki/forestry _in_india). India's forest cover has increased from 68 mha (24% of the total area of the country) to 69.8 mha in 2012 (FSI, 2013).

Booth & Nambiar (2000) traced the scenario in Kerala, where there were rich forests and abundant supply of tropical timber, and which supported a major inter-state timber trade. But, deforestation has brought this to an arrest. Though the uses of timber for house construction have decreased due prohibitive price and scarcity, current use is estimated to be 2.6 to 3.0 million m^3 for a population of more than 29 million.

Table 1.3. Estimated net plantation area of major plantation species in 1995

Plantation Species	Area in Hectare	Tropical Plantations (%)
Eucalyptus spp.	9,949,588	17.7
Acacia spp.	3,904,307	7
Tectona grandis	2,246,559	4
Casuarina spp.	787,200	1.4
Dalbergia sissoo	626,020	1.1
Gmelina arborea	418,050	0.7
Swietenia macrophylla	151,214	0.3
Terminalia spp.	303,957	0.5

India is the world's largest grower of *Eucalyptus* spp. They occupy 4.8 million ha (Davidson, 1995) and represent about 25 % of the country's plantation estates. Because natural forests cannot be harvested in India, plantations of various tree species are becoming increasingly important for the supply of forest products including industrial timber and domestic firewood.

1.3. IMPACT OF PLANTATION FORESTS ON BIODIVERSITY: MYTHS AND THE REALITY

Biodiversity refers to the variety and variability of all the biological organisms at their species, genetic and ecosystem levels and plantations or plantation forests, irrespective of their types and objectives, are an important part of the ecosystem and environment of that particular area where they are established. Thus plantation forests become a component of biodiversity of that area as the natural forests are. In other words biodiversity include plantations raised at the same locality, if any, and there must be a relationship between them. The inter relationship of plantation forests and biodiversity is quite complex and that become more complex when the issue of the effects of plantation forests over the biodiversity is considered.

Plantation affects biodiversity and environment both ways, direct and indirect. Rapidly growing interest in developing plantation forests is one of the most important reasons of replacing and clearing of environment friendly natural forests, which positively impacts physical and biological environment as well as the biodiversity of the area.

Rapidly growing plantation forests have been accompanied by increased concerns about the potential environmental impacts. The concern also focus on the potential loss of soil fertility and productivity in case of short harvest rotations, risks associated with introducing exotic elements and catastrophic pest infestations. Developing monoculture plantations and the implications of replacing natural forests and associated flora and fauna lead to the formation of vegetation which became biologically very less diverse (Bowyer, 2006).

In question of impact of plantations on biodiversity, all the environmentalists, sponsors and others who are concern with the plantation forests, biodiversity and its conservation, get separated into two groups. One group holds the opinion that plantation forests enhances or favours biodiversity whereas the second lot opposes the first group of thinkers.

Questions have been raised over the environmental effects of plantation forests as significant difference has been found between the plantations and natural forest regarding tree species composition, stand structure and rotation length etc. (French *et al.* 2008.) and some large environmental organizations are running serious anti-plantation campaign, like the *Rainforest Action Network* and *Greenpeace*.

Generally exotic species are used for raising plantation as they return superior yield, are tolerant to native pests, better adapted over native trees for their wider ecological amplitude and capacity to access the resources easily (Harrison *et al.* 2000). There is a common belief that the managed forests negatively influence the biodiversity. Some argue that monocultures prevent understorey vegetation growth thereby resulting decreased biodiversity and soil fertility (Poore & Fries, 1985; Abbasi & Vinithan, 1997).

The widely held view among the ecologists is that plantation forests are on average, less favourable as habitat for a wide range of taxa, particularly in case of even aged single species stands involving exotic species (Hunter, 1999; Hartley, 2002) and are harmful to the environment and have a reputation for being "Biological deserts" (Allen *et al.* 1995; Dyck, 1997; Hartman *et al.* 2010).

The replacement of natural forest with tree plantations has caused several social problems along with environmental hazards and that made them controversial. Plantations which are established for the production of fiber provide much narrower range of services for the local forest-dependent people. Many ecologists raised objections on exotic plantation as they generally consume native species, infect native species with diseases and drastically change the functioning of ecosystem (Vitousek *et al.* 1997; Wilcove *et al.* 1998) and are thought to be one of the serious causes of species declines and habitat degradation (Antonio & Meyerson, 2002). Much of the opposition to *fast wood plantations* is based on the belief that they have high damaging impact on the environment. They are seen as threats to Biodiversity, to water resources and to soil fertility. Many environmental groups also fear that genetically modified tree plantation will lead to many other serious problems in future and will be responsible for spreading of pests and diseases (Huy, 2004).

Some argue that monoculture exhaust soil water and nutrient resources, prevent under-storey growth, decrease biodiversity, causes soil erosion and loss of fertility (Shiva *et al.* 1982), hamper nutrient cycle of the surface soil, breaks out diseases and pathogens and lead to ecological imbalances.

Comparison of vegetation of ground layer in plantation with that of natural vegetation reveals that the former one is more even than the later. Overall richness and density of plants at ground layer in the natural forests is higher compared to plantations (Das & Lahiri, 1997; Tripathi & Singh, 2009) and that may be an indication of reducing biodiversity by plantation.

Plantation of exotic species may cause catastrophic outbreak of pests and diseases leading to huge loss (Nair, 2001). Plantations, particularly monocultures, are at much greater risk of catastrophic losses than natural forests. The introduction of exotics tends to alter natural balances that serve to keep pathogenic organisms in check in ecosystems (Nair, 2001). Pure Teak plantations are susceptible to defoliating pests, particularly when under storey growth is suppressed and site

conditions are suboptimal (Chaiglom, 1990). The dhupi (*Cryptomeria japonica*) plantations in Darjiling Hills caused serious damage to local biodiversity as the dark forest floor is completely unsuitable for the growth and survival of local species of plants, animals and microbes (Das & Lahiri, 1997).

Concerns about the impact of plantations on soil moisture and water yield are mostly related to the depletion of soil moisture that reduces the stream flow. Establishment of plantation on grassland sometimes diminishes flow of local streams with the formation of close canopy, particularly during dry seasons, due to the interception and re-evaporation of rainfall at the crown level. Certain species like eucalyptus which account for as much as 25 % of the plantation area worldwide – may use far more water than species that occur in natural forests, drawing down the water table in some localities. In the Pampas grasslands of Argentina the brackish groundwater lies under shallow freshwater lenses that provide drinking water and when grasslands had been converted to forest plantations the freshwater lenses were eliminated (Werth & Avissar, 2005).

Intensively managed plantation led to soil compaction, erosion, and degradation of physical, chemical and nutritional properties of soil (Wigley & Roberts, 1997). Plantations tend to be kept in an early successional stage, with maximum removal of biomass from the site at harvest and are said to be less efficient for trapping released nutrients, as fewer roots exists near the surface. The ultimate result is significant nutrient loss over the harvested areas.

The result of the increased deforestation directly and indirectly caused by the banana plantation has impacted the physical and biological environments in Costa Rica. About 75 % of all diversity is held within the tropical forests (Panayotou & Ashton, 1992). The destruction of tropical rainforest habitat results in the loss of numerous species of plants and animals. In the Sarapiqui Valley of Costa Rica, expansion of banana plantation has resulted in the near extinction of 18 known tree species (Mara, 1998). Sometimes maintenance of high yields requires frequent and intense applications of agrochemicals- fertilizers, herbicides, nematicides, etc. The intensive use of chemicals the local environment has been heavily contaminated (Astorga, 1998). In different parts of the world, aquifers that supply water to that region is heavily contaminated by different pesticides; many of those are used in nearby plantations (Wheat, 1996).

Plantations necessarily have vastly lower biodiversity than surrounding native forests and other type of vegetation due to high stocking density and lack of structural diversity. Being wide in species diversity and more heterogeneous in composition of species natural forest in comparison to plantations provides suitable habitat and forage for the large herbivores. On the other side plantations are unable to provide suitable habitat and forage for the local wild animals (Tripathi & Singh, 2009). Some plantation trees, such as pines and eucalyptus, can be at high risk of

fire damage because their leaf oils and bark resins which are highly flammable and become explosive under some conditions.

Contrary to this, some studies have found that fast growing tree plantation favours regeneration of under growth plants from surrounding forests, increases fertility, and biodiversity and help in artificial regeneration and rehabilitation (Harrington & Ewel, 1997; Loumeto & Huttel, 1997; Thapa *et al.* 2011)

Recent studies (Parrotta, 1995; Otsoma, 2000; Viisteensari *et al.* 2000) have shown that they can help in enhancing the recruitment, establishment and succession of native woody species by functioning as foster ecosystem, as they stabilizes the soil and create conditions favourable for native animals and plants to re-colonize (Yirdaw, 2002; Rawat *et al.* 2009). Some considered that exotics too have some beneficial effects on biodiversity (Lugo, 1997; Hartmann *et al*. 2010).

Plantations protect vegetation against soil erosion and man-made fires and also may serve to rehabilitate ecosystem properties when natives are not capable of recolonizing immediately. Their high growth rate and productivity is likely to replenish environmental condition that can improve the conditions for re-establishment of native flora (Martinez, 2007). In some semi arid zones where anthropogenic disturbances have destroyed almost all the natural forests, plantation forests can be very fruitful in reviving the biodiversity of indigenous flora (Rawat *et al.* 2009).

Using of small number of fast-growing short-lived tree species which are equivalent to early successional pioneer species, which will create a canopy that shade out grasses and other weeds, and diminish the fire hazard. Not only has that it facilitated colonization of the site by a wider range of species from nearby intact forests (ITTO, 2002; Elliott et al. 2003; Lamb et al. 2005).

The tree species used in a plantation is an important factor while detecting the impact of plantation forests. Where non-native varieties or species are grown, few of the native fauna are adapted to exploit these that lead to further loss of biodiversity. However, even non-native tree species may serve as corridors for wildlife and act as buffer for native forests, reducing edge effect.

Plantations may be used successfully to keep saline groundwater below crop rooting zones and in many countries plantations are being used to dry waterlogged soils and alleviate flooding (Werth & Avissar, 2005).

In the Kyoto Protocol, there are proposals encouraging the use of plantations to reduce carbon dioxide levels but this idea is being challenged by some groups on the grounds that the sequestered CO_2 is eventually released after harvest.

Managed forests sometimes favours regeneration of native species e.g. *Ficus benghalensis, Ficus semicordata, Madhuca longifolia, Toona ciliata* and *Ziziphus*

rugosa seemed to have regenerated well in managed forests in Katerniaghat Wildlife Sanctuary in Northern India which were not found in natural forest. In commercial plantations species of early successional stages could be promoted and enhances the overall biodiversity at landscape level (Tripathi & Singh, 2009).

If a plantation is established on abandoned agricultural land, or highly degraded land, it can result in the improvement of both habitat and biodiversity. A planted forest can be profitably established on lands that will not support agriculture or suffer from lack of natural regeneration.

Many have suggested that plantation development will take pressure off natural forests by reducing or eliminating the need for harvesting within them. In principle this is true because due to the high productivity of plantations less land is needed. Many point to the example of New Zealand, where 19 % of the forest area provides 99 % of the supply of industrial round wood. It has been estimated that the world needs for fiber could be met by just 5 % of the plantation forest (Sedjo & Botkin, 1997). However, there is considerable disagreement on this point.

An afflicted plantation can in some cases be cleared of pest species cheaply through the use of a prescribed burn, which kills all lesser plants but does not significantly harm the mature trees (Lamb *et al.* 2005).

But, another group of researchers have noted that exotics face lower risks than native species, since introduction of a species into a region that is outside of its natural range separates that species from its natural pests and can thus improve health and performance, at least in the short term.

Though there are large number of environmental concerns and problems associated with the establishment and management of some forest plantations, the benefits of plantations of rapidly growing trees are so significant that further development of forest plantations is virtually assured (FAO, 2007). Ecological impact of plantation forest is very much specific to the site where the plantation is to be established or already established. If planted forests replace natural forest a reduction in biodiversity and loss of habitat will likely result (Hartmann *et al.* 2010). A group of workers assures that forest plantations operate sustainably in every sense of the word, and they provide the greatest possible array of benefits. It is necessary to take steps to address known problem areas and concerns, and international forest policy needs to be developed to counter current efforts to leave vast areas of natural forests in a non-managed state (Hunter, 1999).