PREFACE

With its grounding in the "guiding pillars of Access, Equity, Equality, Affordability and Accountability," the New Education Policy (NEP 2020) envisions flexible curricular structures and creative combinations for studies across disciplines. Accordingly, the UGC has revised the CBCS with a new Curriculum and Credit Framework for Undergraduate Programmes (CCFUP) to further empower the flexible choice based credit system with a multidisciplinary approach and multiple / lateral entry-exit options. It is held that this entire exercise shall leverage the potential of higher education in three-fold ways – learner's personal enlightenment; her / his constructive public engagement; productive social contribution. Cumulatively therefore, all academic endeavours taken up under the NEP 2020 framework are aimed at synergising individual attainments towards the enhancement of our national goals.

In this epochal moment of a paradigmatic transformation in the higher education scenario, the role of an Open University is crucial, not just in terms of improving the Gross Enrolment Ratio (GER) but also in upholding the qualitative parameters. It is time to acknowledge that the implementation of the National Higher Education Qualifications Framework (NHEQF), National Credit Framework (NCrF) and its syncing with the National Skills Qualification Framework (NSQF) are best optimised in the arena of Open and Distance Learning that is truly seamless in its horizons. As one of the largest Open Universities in Eastern India that has been accredited with 'A' grade by NAAC in 2021, has ranked second among Open Universities in the NIRF in 2024, and attained the much required UGC 12B status, Netaji Subhas Open University is committed to both quantity and quality in its mission to spread higher education. It was therefore imperative upon us to embrace NEP 2020, bring in dynamic revisions to our Undergraduate syllabi, and formulate these Self Learning Materials anew. Our new offering is synchronised with the CCFUP in integrating domain specific knowledge with multidisciplinary fields, honing of skills that are relevant to each domain, enhancement of abilities, and of course deep-diving into Indian Knowledge Systems.

Self Learning Materials (SLM's) are the mainstay of Student Support Services (SSS) of an Open University. It is with a futuristic thought that we now offer our learners the choice of print or e-slm's. From our mandate of offering quality higher education in the mother tongue, and from the logistic viewpoint of balancing scholastic needs, we strive to bring out learning materials in Bengali and English. All our faculty members are constantly engaged in this academic exercise that combines subject specific academic research with educational pedagogy. We are privileged in that the expertise of academics across institutions on a national level also comes together to augment our own faculty strength in developing these learning materials. We look forward to proactive feedback from all stakeholders whose participatory zeal in the teaching-learning process based on these study materials will enable us to only get better. On the whole it has been a very challenging task, and I congratulate everyone in the preparation of these SLM's.

I wish the venture all success.

Professor Indrajit Lahiri
Vice Chancellor

Netaji Subhas Open University

Four Year Undergraduate Degree Programme
Under National Higher Education Qualifications Framework (NHEQF)
& Curriculum and Credit Framework for Undergraduate Programmes
Course Type : Multi Disciplinary Course (MDC)
Course Title : Plant Diversity and Human Welfare
Course Code : NMD-BT-01

First Print : March, 2025
Memo No. SC/DTP/25/101
Date : 07.03.2025

Printed in accordance with the regulations of the University
Grant Commission–Distance Education Bureau

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: Course Writer :
Dr. Shymal Kumar Chakraborty
(Retd.) Associate Professor, WBES
Bidhannagar Govt. College

: Course Editor :
Prof. (Dr.) Samit Ray
Professor of ENVS
NSOU

: Format Editor :
Shri. Sandip Das
Assistant Professor of Botany
School of Sciences, NSOU

Notification

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Unit – 1 ❑ Plant Diversity and its Scope

Structure

1.0 Objectives

From this unit you should be able to :

- Have an idea about the extent of diversity that exists in the plant and microbial world;

- Define biodiversity;
- Understand genetic, species and ecosystem diversity in their diverse forms;
- Measure or assess biodiversity at each of these levels and the indices used for the purpose;
- Define biodiversity 'hotspots' and their importance.

1.1 Introduction

The plants sustain life and make our planet Earth green. They harvest sunlight and sustain all life-forms and constitute the primary producer in most ecosystems. They provide food and shelter to many animal species, protect watersheds, mitigate erosion and moderates climate. To humans, they are a source of food, medicine, pharmaceuticals, energy, timbers, paper pulp and oxygen to breathe free of cost. Fungi and bacteria too are a source of antimicrobials and a host of important compounds. Importantly, plants provide a host of ecosystem services that support human agriculture, pollination, nutrient cycling, pest control, soil development and maintenance. Their recreational value and aesthetic appeal is beyond question.

The first land plants appeared on Earth ~460 mya, in the Ordovician period, and that initiated greening of our planet. Today, there are 350386 vascular plants in the world (*State of the World's Plants and Fungi*, Royal Botanic Gardens, Kew, 2023), of which ~13 000 are threatened with extinction. In India, the total number of land plant species is ca. 22 000, which includes 74 gymnosperms and 18043 angiosperm species (http://bsienvis.nic.in. 2024).

Biological diversity, biodiversity in short, generally refers to all the living organisms present in an area. It is assessed at different levels: species, genus and ecosystems. Biodiversity is auto-sustainable and self-regulating, in the absence of human perturbations. It exists with the support of ecological processes and organic evolutions. However, such diversity is at a grave peril due to anthropogenic activities and/ or climate change. Plants sustain all forms of life and once this life-support is destroyed, planet Earth may gradually become uninhabitable. So, protection of biodiversity is one of our top priorities. Understanding the geographic patterns of the diversity of species used by people is also essential for the sustainable management of plant resources. The Convention on Biological Diversity (CBD) held in June 1992 at Rio de Janeiro, Brazil, was a watershed in international efforts to protect biodiversity. Lately, the Kunming–Montreal Global Biodiversity Framework, signed by nearly 200 parties and adopted in December 2022 (CBD, 2022), has set goals for the coming decades, to contain biodiversity loss while allowing threatened wild populations to recover. Our country has four biodiversity 'hot-spots' and it is important to protect them at all cost. There also exist countries with unexplored flora called biodiversity darkspots. The United Nations has decided to observe 22nd May each year as the International Day of Biodiversity. The value of accurate documentation, as a prelude to protection of biodiversity cannot be overstated. Unfortunately, there is no comprehensive detailed information on the location of every vascular plant species on Earth as yet. Finding mechanisms to preserve areas containing concentrations of utilized plants and traditional knowledge must become a priority. It is also a necessary ingredient for the implementation of the Kunming-Montreal Global Biodiversity Framework, hailed as a landmark deal for biodiversity and people.

1.2 Plant Diversity and its scope

We all know what 'plants' are, but technically speaking, its definition underwent several changes over the last few decades. Research in phylogenomics and cladistics has ultimately settled on calling all green plants **'Viridiplantae'**, i.e. all photosynthetic organisms with cellulose cell walls and plastids bound by only two membranes with chlorophylls a and b and starch as the primary storage product. If we include within 'green plants' thus defined, photoautotrophic red algae and the minor group of glaucophyte algae which store Floridean starch in the cytoplasm, the clade will be called **'Archaeplastida'**. It includes members which had acquired their primary chloroplasts directly, by engulfing cyanobacteria. Plants in their strictest sense to include liverworts, hornworts, mosses and vascular plants, are termed **'Embryophyta'**. Of course, in the broadest sense, we may usethe term 'plants' to embrace the unrelated groups of algae, fungi and bacteria (sensu 'Plantae') of Linnaeus, Haeckel and Whittaker, but the term is no longer used except in a very general sense. Plants are the products of a long evolutionary history and have amassed tremendous variation over the ages. They constitute ~80% of the global biomass, at about 450

[for *endnote*: The Kunming-Montreal Global Biodiversity Framework aims to halt and reverse biodiversity loss by 2030. It was adopted in December 2022 at the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity].

gigatonnes of carbon. In scale, they range from unicellular desmids 10 μm across to 120 m tall giant conifer *Sequoia sempervirens*.

In India, there are different estimates of the status of flora of diverse taxa. Given below is one such estimate (http://bsienvis.nic.in, accessed June 13, 2024). According to a more recent estimate, the total number of plants in India is recorded as 49 003, of which ~ 18532 are angiosperm species (Singh P 2020).

Table 1.1

	No. of species known		**P.C.in India**	**No. of endemic spp.**	**No. of threatened spp.**
	World	**India**			
I. *Seed plants*					
Gymnosperms	1021	74	7.35	8	7
Angiosperms	268600	18043	6.72	~ 4036	~ 1700
II. *Non-seed plants*					
Bryophytes	16236	2523	15.54	~ 629	~ 80
Pteridophytes	12000	1267	10.57	~ 47	~ 414
III. *Others*					
Virus & Bacteria	11813	986	8.77	-	-
Algae	40000	7284	18.21	1924	-
Fungi	98998	14883	15.09	~ 4100	~ 580
Lichens	17000	2401	14.12	~ 520	-
TOTAL	465668	47461	-	11264	2781

But we may ask: why plant diversity and their distribution pattern really matters. To address this issue, Antonelli *et al* (2023) indicates the direction of research and poses a set of related questions. Thus, in order to investigate the drivers of plant diversity and life forms they suggest that we need to ask (i) what determines diversity patterns;(ii) when the major clades evolved and (iii) how plants adapt to changing environments.Further, to quantify plant extinction risks and the resulting impact, we may inquire : (i) which all species are at risk; (ii) where are the plant 'hot-spots' and 'dark-spots' located? Undertaking such investigations would entail a close look into the plant traits to be considered, genomic data, extinction risk assessments, citizen's observations, digitization of species occurrences and to bring out a World Checklist of Vascular Plants.

Understanding which and where different plant species occur across space could help address many fundamental and applied questions in ecology, evolution and conservation biology. Species distribution data can then be linked to various other data resources, depending on the questions posed, or for practical purposes, such as the identification of priority areas for protection. Let us begin by definitions of biodiversity.

1.3 Biodiversity defined

The term "biodiversity" was introduced to the scientific community in 1988 by the renowned evolutionary biologist E. O. Wilson. It represents all life forms present on Earth, be it plants, animals, microbes, aquatic life or even coral reefs. It embraces diversity at the species, genus, organism and ecosystem level. Biodiversity is a resource repository – a source of food, medicine, industrial products and the germ-plasm of all life forms diversified through 3.5 billion years of evolution.etc. But its decline has started long back, a process which has accelerated by anthropogenic activities -- rapid population growth, urbanization, war, encroachment of habitat and clearing of forests, mining, etc. Many people believe we are on the brink of a Great Sixth Extinction.

The Convention on Biological Diversity (CBD) in June 1992, defines Biological Diversity in its Article 2 as: *"the variability among living organisms from all sources including inter-alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems."* It includes all life forms in earth and its life support system, which is essential for the normal functioning of ecosystems and biosphere as a whole. In simple terms, biological diversity is *"the totality of genes, species and ecosystems in a region"* as summed up in the 'Global Biodiversity Strategy' of the United Nations Environment Programme in 1992.

[for endnote: CBD, known informally as the Biodiversity Convention, is an international legally binding treaty that was adopted at the Earth Summit in Rio de Janeiro in June 1992 and ratified by 196 nations. The Convention has three main goals: "the conservation of biological diversity (or biodiversity), the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilization of genetic resources."]

1.4 Levels of Biodiversity

Biological diversity is examined broadly at three levels: *genetic diversity* – which is the diversity of gene pool in a species, *species diversity*— the variety of species in a region, and *Ecosystem or Community diversity*—the variety of habitats that occur within a region – the collective response of species to different environmental conditions. One may also add 'molecular diversity' to the list. But of course, without diversity at the molecular level, there could be no evolution of life forms, leave alone their survival or extinction. *Agrobiodiversity*, a subset of overall biodiversity, is the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. We shall deal with it separately in the next unit.

1.5 Genetic Diversity

Diversity within a species is genetic diversity – the variation of genes within a species, as opposed to geneticvariability – the tendency of genetic characteristics to vary. Genetic diversity includes each and every difference in inherited biological information, among individuals within a species. Now, each member of any plant or animal species differs widely from other individuals in its genetic makeup. This is due to the huge number of possible combinations in the genes that provide every individual their characteristic traits. The amount of genetic variation is the basis of speciation -- the evolutionary process by which new biological species arise. Genetic diversity within a species is often associated with increased environmental variability. Such diversity is crucial to the survival and adaptability of a species because when a species' environment changes, even slight gene variations become necessary to initiate changes in the organism to enable it to adapt and survive. A species that has a large degree of genetic diversity among its population will naturally have more variations from which to choose the best fit alleles. Species that have very little genetic variation are vulnerable to pathogens. As examples of such threats arising from reduced genetic variability, one may recall the case of Gros Michel Banana, a prime variety grown in commercial plantations till 1960s. Panama disease (a fungal disease) caused by Fusarium oxysporum, nearly wiped out the variety. As these plants are propagated essentially by cuttings and suckers, there was minimal genetic variability among them, which led to the disaster. Of late, the Black Sigatoka disease caused by the fungus *Pseudocercosporafijiensis* poses the same threat to Cavendish bananas (*Musa acuminata*).

Genetic variability is indispensable to a healthy breeding population of any species. With very little gene variation within the species, healthy reproduction becomes increasingly difficult, and offspring often deal with problems similar to those of inbreeding. Eventually, this can lead to the extinction of the species. The diversity of wild species constitutes the 'gene pool' from which our crops and domestic animals have developed over thousands of years. The gene pool is enriched by 'gene flow'–the transfer of alleles and genetic recombinants, when mating occurs between members of different populations of a species. Genetic diversity is also referred to as *within-species diversity* or *intra- or infraspecific diversity*. A number of infra-specific categories have often been recognized, most of them with taxonomic implications without necessarily being defined in genetic terms (UNEP 1995): subspecies, varieties, land races, clines, cultivars, ecotypes, chemotypes, cytotypes, hybrids, polytypes, polyploid complexes, aggregated species, and so on. The recognition of these 'taxonomic' categories often poses problems in defining and conceptualizing genetic diversity. It should thus be emphasised that there is no single definition of genetic diversity that can be used for all purposes.

1.6 Species Diversity

The group of organisms which can interbreed freely under natural conditions to produce viable offspring is called a species. The biological species concept (Mayr 1942) defines species as "groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups". Species diversity is the variety of species within a region is, i.e., the number of different species found in a particular area. It is often treated as synonymous with biological diversity. Species diversity has different geographical distribution patterns. Ecosystems like tropical rainforests and corals are considered to be one of the most species diverse ecosystems. Whereas ecosystems like alpine tundra and boreal forests are comparatively less diverse. The species diversity tends to increase from poles towards the equator. It tends to decrease from sea-level to higher altitudes.

Species are distinct units of diversity, each playing a specific role in the ecosystem. Their diversity represents the entire range of evolutionary and ecological adaptations of species to particular environments. There are different ways of measuring species biodiversity, but most of them use two parameters: species richness and species evenness. *Species richness* refers to the total number of species in a defined region, usually estimated through sampling. An area with a greater number of species will have greater species richness. For example, a tropical rain forest has a very high number of different species, so it would be described as being a *species-rich* area. However, species richness alone can be a misleading indicator of diversity, as it does not take into account the number of individuals of each species. For that we invoke a separate parameter that measures the *relative abundance* of the different species in the given area. It is called *species evenness*, which tells us how evenly the species are distributed in that region. An area in which all the species have similar abundances will have greater species evenness, and therefore higher overall species diversity. To obtain a clear picture of species biodiversity, both of these parameters need to be taken into account.

Thus, if we consider species numbers alone, life on earth would appear to consist mostly of insects and microorganisms, because of their relative abundance. For a truer picture of species diversity, species richness, species evenness together with *species composition* (which particular species are present) should all be taken into account.

The 'species' is generally the obvious choice for the level to examine whole-organism diversity. This is because species are the primary focus of evolution; origin and extinction of species being the principal drivers of biological diversity. However, species cannot be recognized and enumerated by systematists with absolute precision. Opinions often vary about the boundaries of a species in different taxa. It is for this reason, among others, that species diversity alone is not a satisfactory basis on which to define biodiversity.

Ecologists, in particular those interested in functional aspects of ecosystems, more often use a number of diversity indices. Such diversity index is a quantitative tool which helps us measure the distribution of various species present in a community, along with their richness, evenness and dominance. Some of the popular indices include the Shannon-Wiener diversity index or Shannon-Weaver index, Simpson's index of dominance, Pielou's index of species evenness, and Margalef's index of species richness—all of which take into account species richness and relative species abundance. Each index has its own relative advantages and disadvantages. Some of these terms are given in Box 1.

Species diversity tends to increase with habitat heterogeneity. Communities that have increased habitat variation have an increased number of ways to divide up the available niches. The number or variation of available niches varies by organism-type. However, plant niches tend to be defined by different variables than animal niches.

Box 1. MEASURING SPECIES DIVERSITY

Species Richness (S): *Variety of species or the number of different species (or genera, families, etc.). It is an index based on the number of species.*

Simpson Index (D) *- a measurement that accounts for the richness and the percent of each subspecies from a biodiversity sample within a zone. The index assumes that the proportion of individuals in an area indicate their importance to diversity.*

Shannon-Wiener index (H) *- Similar to the Simpson's index, this measurement takes into account subspecies richness and proportion of each subspecies within a zone. The index comes from information science. It has also been called the Shannon index and the Shannon-Weaver index in the ecological literature.*

Species Density: *Number of species per unit area*

Species evenness: *Relative abundance – the proportion of each species in the ecosystem.* ***Pielou's evennessindex (J)*** *is a common measure which indicates how close each species are in numbers. The value of J ranges from 0: higher the values of J, the more even species are, in numbers; at maximum evenness J = 1.Low J indicates that 1 or few species dominate the community.*

Margalef's index of species richness*—it adjusts species richness (S) according to the total abundance per sample (N). A higher Margalef index value indicates greater species richness or diversity, considering the total number of individuals observed. This index is widely used in ecological studies and biodiversity assessments as it provides a simple and informative measure of species richness, accounting for the size of the dataset while allowing forcomparisons of biodiversity between different communities or over time.*

Plant species richness may vary with variation in local soil properties. Animal species richness may vary with the complexity of the habitat form, for example vegetation structure. Thus habitat heterogeneity is both context and species dependent.

1.6.1 Species Inventory

An inventory is the totality of defined elements of biodiversity such as genes, individuals, populations, species, habitats, ecosystems and landscapes at a particular point of time in a defined geographical unit (spatial scales may range from nanometres to countries or even continents). The inventory is built on surveys, sorting, cataloguing, quantifying and mapping of these elements.

Here we are concerned with the inventory of species. Several considerations influence a good inventory: (i) The existing knowledge base on which the proposed inventory is to be constructed; the wider the knowledge base, the better the inventory. (ii) The level of expertise of personnel and technical capabilities available. (iii) The level of funding; the larger the funding, the better the inventory. (iv) The purpose and richness of the inventory. (v) The presence of multiple performers 'contributing to a common network of data administration and analysis' will promote greater success in the inventory.(vi) Lastly, the level of enthusiasm, dedication and commitment of the personnel and institutions involved in the inventory significantly determine its coverage.

Based on species inventory, one can study biodiversity at the global or national / regional levels for the whole plant kingdom or specific groups of plants. Possible approaches for creating an inventory are :

(i) Survey of major elements;

(ii) Identification of keystone species and indicator elements;

(iii) Identification of targeted elements, such as threatened species;

(iv) A comprehensive assessment of other important elements, such as exotic or alien invasives, flagship species, and other economically useful taxa.

1.6.2 Species Diversity of Microbes and Plants

Discussion of global biodiversity is typically presented in terms of global numbers of species in different taxonomic groups. An estimated 1.8 million species are supposed to be present today in the world of which only ~ 1.2 million have been identified so far (Larsen *et al* 2017). However, the real number can be anything from 5 million to nearly 100 million. A conservative working estimate puts the figure to around 12.5 million (Swingland, 2001). Insects, with a little over a million species described so far, easily outnumbers any other taxa.

There are an estimated 3 50 386 vascular plants in the world today of which > 13 000 species are threatened. (Antonelli et al 2023). A current checklist of all organisms prepared by the IUCN is given below (Tab 1.2).

The total number of microbes on Earth could be as high as 1 trillion (Locey & Lennon 2016). It is very difficult to estimate the total number of viruses in the biosphere. A figure of 10 nonillion (10^{31}) is often quoted, which would exceed the total number of stars in the universe (Hendrix *et al* 1999). As on 2022, the total number of named viral species is only 11, 273, including satellite viruses and viroids (ICVCN), of which only 219 viral species are known human pathogens. The total biomass of all prokaryotes on Earth is estimated as 77 billion tonnes of carbon (Bar-On YM *et al* 2018) though identified prokaryotes number only about 6200. The species of fungi, lichens, algae and vascular plants known today can be found in Table 1.1.

Table 1.2. A checklist of the number of identified and named species in each taxonomic group. Since many species have not yet been described, this is a large underestimate of the total number of species in the world.

All groups	2,161,755
Amphibians	8,536
Arachnids	110,615
Birds	11,188
Brown algae	4,541
Corals	5,574
Crustaceans	80,122
Ferns and Allies	11,800
Fishes	36,367
Flowering plants	369,000
Fungi and Protists	141,541
Green algae	12,929
Gymnosperms	1,113
Horseshoe crabs	4

Insects	1,053,578
Invertebrates	1,521,459
Lichens	17,000
Mammals	6,596
Molluscs	113,813
Mosses	21,925
Mushrooms	120,000
Other invertebrates	157,543
Plants	424,335
Red algae	7,568
Reptiles	11,733
Velvet worms	210
Vertebrates	74,420

Data source: International Union for Conservation of Nature (IUCN) Red List (2022)

1.6.3 Spatial Patterns of Species Diversity

Complex spatial patterns of species biodiversity have often been recognised by dividing species richness into three major components, to characterise diversity on different scales: alpha richness, beta richness and gamma richness (more popular as *alpha diversity, beta diversity* and *gamma diversity* respectively).

Alpha (α) or point richness refers to the number of species in an area, i.e., within-area diversity comprising all the species of organisms in that area. Here we count the number of species using only their presence (and not abundance) in a given area of a given size. *Beta* (β) richness or between-area richness refers to the changes in number of species between sites at local, small and homogeneous areas. Beta richness cannot be expressed in species numbers. It can only be represented in terms of the similarity index between species diversity, or of the species turnover rates between the selected sites of the study region. Biodiversity is not evenly distributed around the world. Therefore, quantifying the differences among biological communities by measuring beta diversity is often a first step towards understanding how biodiversity is distributed. *Gamma* (γ) richness is the overall species richness within a large region at the level of landscape, which is a means to characterise biodiversity at a regional scale. Gamma diversity, therefore, does not have an upper limit. The ratio of gamma diversity of a region to the average alpha diversity of local areas within that region ($\beta = \gamma / \alpha$) is also considered as beta diversity (UNEP 1995). However, various authors have given different definitions for beta diversity. Therefore, alpha diversity includes the diversity withina region; beta diversity compares the diversity between the sites, while gamma diversity gives the overalldiversity of a large area, which may include many ecosystems.

1.6.4 Species Diversity in India

India is one of the mega-diverse countries among 17 mega-diversity regions of the world with ~ 12 % of the world's recorded species spread over its ten bio-geographic regions. It has four of the world's 34 global biodiversity hotspots (Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaland) and the country is one of the seven mega-diverse regions of the world. Globally, out of 12,44,360 species, India ranks twelfth with a total of 1,50,170 catalogued species, of which 1,01,167 are animals and 49,003 are the plants and fungi (Dar et al 2022). India's contribution to the global biodiversity is around 8% species. In terms of *floral diversity*, India ranks tenth in the world and fourth in Asia. It has over 40 sites, which are known for their high endemism and genetic diversity. In fact, our flora is more varied than any other country of equal area in the eastern hemisphere, if not on the globe. As elsewhere however, many organisms in the lower groups, such as the bacteria, fungi, algae, lichens and bryophytes are yet to be comprehensively explored and described, from remote geographical terrains of the country. Importantly, India is one of the eight Vaviloviancentres of origin and diversity of crop plants, with > 300 wild ancestors and close relatives of cultivated plants. Known for its rich heritage of biological diversity, India is also a vast repository of Traditional Knowledge (TK) associated with biological resources. The varied edaphic, climatic and topographic conditions with years of geological stasis have resulted in a wide range of ecosystems and habitats in the country. Despite having 2.2% of the world's geographical area, over the years, the country has built up a dense web of protected areas of national parks, wildlife sanctuaries, conservation and community reserves which totals 1,71, 921 km^2 (https://indiabiodiversity.org/). It is a matter of grave concern however, that > 90% of the area under India's biodiversity hot spots appears to have been lost and at least 25 species have gone extinct. The Indo-Burma hotspot having lost 90% of its vegetation cover, has suffered the most (State of India's Environment 2021, CSE).

1.7 Plant diversity at the Community or Ecosystem level

Diversity of the biological communities in which different species exist is referred to as *community diversity* or *ecosystem diversity*. A *biological community* is defined by the populations of various species that occupy a particular area and the interactions between these species. A biological community together with the physical environment associated with it, is called an *ecosystem*. Ecosystems comprise living (biotic) and non-living (abiotic) components. The organisms which comprise the biotic component are collectively called the community. The organisms that belong to an ecosystem are connected to each other in a complex web. *Biomes* are ecosystems where several habitats interact. While the earth is one large biome, deserts, tundra, grasslands and rainforests are examples of smaller biomes.

Measuring biodiversity on a large scale involves measuring **ecosystem diversity**, the number of different ecosystems on Earth or in a geographical area as well as their relative abundances. Ecosystem diversity can be described for a specific geographical region, a *taluka*, a state, or even a political entity such as a country. The presence of both abiotic and biotic components in the ecosystem renders assessment of their biodiversity difficult. The problem is compounded by the lack of unanimity on the definition of an ecosystem and their classification at the global or regional level. Global ecosystem classification has become 'highly subjective like the classification of plants themselves'. Another stumbling block is that ecosystems are essentially dimensionless and lack sharp boundaries. There are a large variety of different ecosystems on earth, which have their own complement of distinctive interlinked species based on the differences in the habitat. The loss of an ecosystem means the loss of the interactions between species and the loss of biological productivity that an ecosystem is able to create. Many ecosystems are now all but gone, being replaced by crop fields, pasture lands and suburban sprawl. Many of the species manage to survive, but the hugely productive ecosystem that was responsible for creating our most productive agricultural soils is now gone. As a consequence, their soils are now being depleted unless they are maintained artificially at great expense.

Earth harbours a wide variety of ecosystems which can be divided into terrestrial and aquatic. Aquatic ecosystems can be further be categorised into marine, freshwater and wetlands. Various types of terrestrial ecosystems include forests, grasslands, deserts, mountains and tundra. Each region also has man-modified areas such as farmland or grazing pastures. The foregoing difficulties notwithstanding, the main advantage of assessing biodiversity at the ecosystem level is that it is much easier to record and to monitor changes, trends and the effects of human activities than on individual populations of species. At the ecosystem level, biodiversity is considered within areas (alpha diversity) and between areas.

The composition of communities is often strongly affected by competition and predation. Predators often dramatically reduce the numbers of populations of prey species and may eliminate some prey species from certain habitats. Predators may indirectly increase biological diversity in a community by keeping the densities of other species so low that competition for resources does not occur. *The number of individuals of a particular species that the resources of an environment can support is known as the* ***carrying capacity***. A population's numbers are often well below the carrying capacity when it is held in check by a predator population. If the predator is removed, the population may increase to the extent that it reaches the carrying capacity or may even exceed to the point at which the environment is damaged.

1.7.1 Major Ecosystem Types of the World

As already stated, it is very difficult to design a classification of the world's ecosystems acceptable to all. For the sake of convenience, a few major ecosystems are discussed here in terms of their diversity.

Tropical moist forest ecosystems are often treated as *rain forests*. These forests occur between the Tropic of Cancer and the Tropic of Capricorn, 23.5 degrees north and south of the equator. In India, they are found on the southern slopes of the Eastern Himalayas, in south-west India (Western Ghats). The total land area of Earth occupied by such ecosystem is 9,350,000 km^2 (but 72,007,990 km^2 according to FAO/UNEP). These forests contain a closed community of essentially, but not exclusively, broadleaf, evergreen trees. These trees occur in two or more strata ('Forests piled upon forests'). Ground vegetation is extensive and vines, lianas and epiphytes abound. A great variety of microbial populations (viruses, bacteria, fungi and microalgae) as well as of Bryophytes and Pteridophytes is common. Tropical moist forests account for 50% to 90% of all known plant species. These forests are also rich in endemics. ln fact, in 14 of the originally proposed 18 areas of the Earth with an unusually high degree of plant endemism (hot spots), tropical moist forests constitute the major vegetation. An estimated 37,000 endemic plant species, i.e., 15% of all the plant species, are present in < 30,000 km^2 or ~ 0.2%

of the Earth's land surface, in such ecosystems. Life-form classes are also extremely diverse here.

Temperate forests (*or Woodlands*), unlike Tropical forests, occur mainly in the Northern Hemisphere – in Europe, eastern Asia, eastern North America, as a narrow band along the Pacific coasts of North and South America, and in the islands of New Zealand and Tasmania. Temperate forests are dominated by deciduous hardwood trees and to a lesser extent, by evergreen broadleaf hardwood trees and conifers. More than 1200 species of trees are reported in such forests. Eastern Asia is the most diverse in this respect, with the greatest number of species.

Boreal Forest ecosystems are circumpolar biomes covering approximately 13×10^6 km^2 as upland entities and 2.6×10^6 km^2 in peatland, in North America and Eurasia. Boreal forests are generally poor in terms of species richness, but the functional diversity of component species is very high.

Arid and Semiarid ecosystems have poor biological diversity being influenced by water availability. Precipitation here is extremely unpredictable and scarce in time and space. Such ecosystems comprise mostly drought-evading, drought-enduring and drought-resisting taxa.

Arctic and Alpine ecosystems are extremely cold regions which are largely devoid of trees. They occupy ~ 8% of Earth's land surface – 5% in the arctic region and 3% in the alpine. Such ecosystems support only ~ 4% of Earth's flora, with 1500 species in the arctic zone and 10,000 in the alpine regions.

Grassland ecosystems are the most common form of natural vegetation on Earth's land surface. It is dominated by grass and grass-like species, although in some areas shrubby and herbaceous elements (often called 'forbs') as well as trees, may be present. Trees, however, are no more than 10-15 per hectare.

A wetland ecosystem is difficult to define, because it covers a wide range of inland, coastal and marine habitats. The all-inclusive definition of wetlands is perhaps the one provided by the Ramsar Convention: areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceed six metres. Wetlands support waterbird, fish, amphibian, reptile and plant species during important life-stages, by providing roosting, nesting and feeding habitat as well as refuge during extreme weather conditions.

Knowledge about the biodiversity of the *marine environment* in general and of *marine sediments* in particular, is very poor. This is true of both species richness and distribution along latitudinal and depth gradients, as well as of the ecological and evolutionary processes regulating them. Such ignorance or lack of interest in marine benthos in the coastal system and in pelagic or deep-sea communities of open seas is surprising, given that marine environment covers 71% of the Earth's surface, of which ~ 51% is covered by oceans > 3000 m in depth. However, 49 large marine ecosystems have been recognised in the world, accounting for 20,000 marine plant species and a number of marine viruses and microbes.

Mangroves are intertidal forested wetlands characteristically located in littoral, sheltered and low-lying tropical and subtropical coast. They dominate river deltas, lagoons and estuarine complexes developed from terrigenous sediments (derived from continental sources transported by rivers, wind, ocean currents, and glaciers. It is dominated by quartz, feldspar, clay minerals, iron oxides, and terrestrial organic matter). Mangroves are also found on islands. They are highly salt-tolerant and exhibit various structural and physiological adaptive features. Although mangroves have a diverse collection of trees and shrubs, some of them are *exclusive* species while others are other *non-exclusive* species. The former are confined to mangrove habitats while the latter are not restricted to mangrove areas. About 60 species in 22 genera are exclusive, while 23 species in 16 genera are nonexclusive. Some 54 species of mangroves are trees. In addition, the mangrove habitat promotes the growth and establishment of a wide variety of other organisms. Mangroves do not have a uniform appearance. They may vary from extremely closed forests of trees reaching 40-50 m of height in parts of South America and the Bangladesh part of Sundarbans, to open forests with sparsely distributed trees and stunted shrubs of less than 1 m in height. In the world, mangroves cover an area of 240×103 km^2 along the coastal belt (Krishnamurthy, 2003).

SAQ I

1. What is genetic diversity and why is it important?
2. Define species diversity and name two indices used to measure it.
3. What is 'carrying capacity'?
4. Match the following types of diversity with their correct description:

Column A (Type of Diversity)	**Column B** (Description)
(a) Genetic diversity	(i) Variation among species in an ecosystem
(b) Species diversity	(ii) Variety of ecosystems in a region
(c) Ecosystem diversity	(iii) Genetic variation within a species

5. Select the correct answer :

(a) As per the most recent estimates, approximately how many vascular plant species exist worldwide?

(i) 150,000 (ii) 250,000

(iii) 350,000 (iv) 390,000

(b) Which of the following is NOT a measure of genetic diversity?

(i) Allelic diversity (ii) Species richness

(iii) Heterozygosity (iv) Genetic distance

(c) Which of these biodiversity indices considers both species richness and species evenness?

(i) Simpson's Index (ii) Shannon-Wiener Index

(iii) Both a and b (iv) None of the above

(d) Which ecosystem is characterized by permafrost and low-growing vegetation such as mosses and lichens?

(i) Desert (ii) Tundra

(iii) Tropical rainforest (iv) Grassland

(e) Which of the following is NOT a reason for preserving biodiversity?

(i) Economic benefits (ii) Climate regulation

(iii) Control of forest fires (iv) Genetic reservoir for future crops

1.8 Biodiversity 'hot-spots'

Biodiversity conservation effort is closely linked up with the concept and 'hotspots'. To qualify as a biodiversity hotspot, a region must meet two strict criteria: First, it must have at least 1,500 vascular plants as endemics—which means, it must have a high percentage of plant life found nowhere else on the planet. Second, it must have retained 30% or less of its original natural vegetation. A loss of 70% or more natural vegetation would mean that the region must be threatened. Based on floristic richness, the environmentalist Norman Myers was the first to propose the concept of hot-spots in 1988. He had originally recognized 18 hotspots throughout the world. Later, Myers et al. (2000) identified 25 biodiversity hotspots throughout the world. As of 2022, 36 areas qualify as hotspots, which represent 2.5% of the Earth's land surface. But they support more than half of the world's endemic plant species—and nearly 43% of bird, mammal, reptile and amphibian species as endemics.

The leading hot spots are richer in endemics than other hot spots. Hottest hotspots can be recognised depending on five key factors: numbers of endemics and endemic species/area ratios for both plants and vertebrates, and habitat loss. Some of them are Madagascar and Indian Ocean Islands, Philippines, Sundaland, Brazil's Atlantic Forest, Carribbean, Indo-Burma, Western Ghats and Sri Lanka, Eastern Arc Mountains and Coastal Forests of Tanzania and Kenya (Myers et al., 2000). As mentioned earlier, India is is one of the 17 megadiverse nations in the world and is home to four biodiversity hot-spots, viz., the Western Ghats, The Himalayas, Indo-Burma and Sundaland.

1. The Himalaya — entire Indian Himalayan region (and the part that comes under Pakistan, Tibet, Nepal, Bhutan, China and Myanmar).
2. Indo-Burma — entire North-Eastern India, except Assam (and Myanmar, Thailand, Vietnam, Laos, Cambodia and southern China).
3. Sundaland — covers Nicobar group of Islands (and Indonesia, Malaysia, Singapore, Brunei, Philippines).
4. Western Ghats and Sri Lanka: the entire Western Ghats (and Sri Lanka).

(For endnote at the end of the page) To be classified as megadiverse, a nation must have at least 5,000 plants that occur naturally only within its borders, as well as a marine ecosystem. The 17 megadiverse countries comprise approximately 70% of the world's biodiversity. Australia, Brazil, China, Colombia, DRC, Ecuador, India, Indonesia, Madagascar, Malaysia, Mexico, PNG, Peru, Philippines, South Africa, USA, Venezuela are the 17 megadiverse countries.

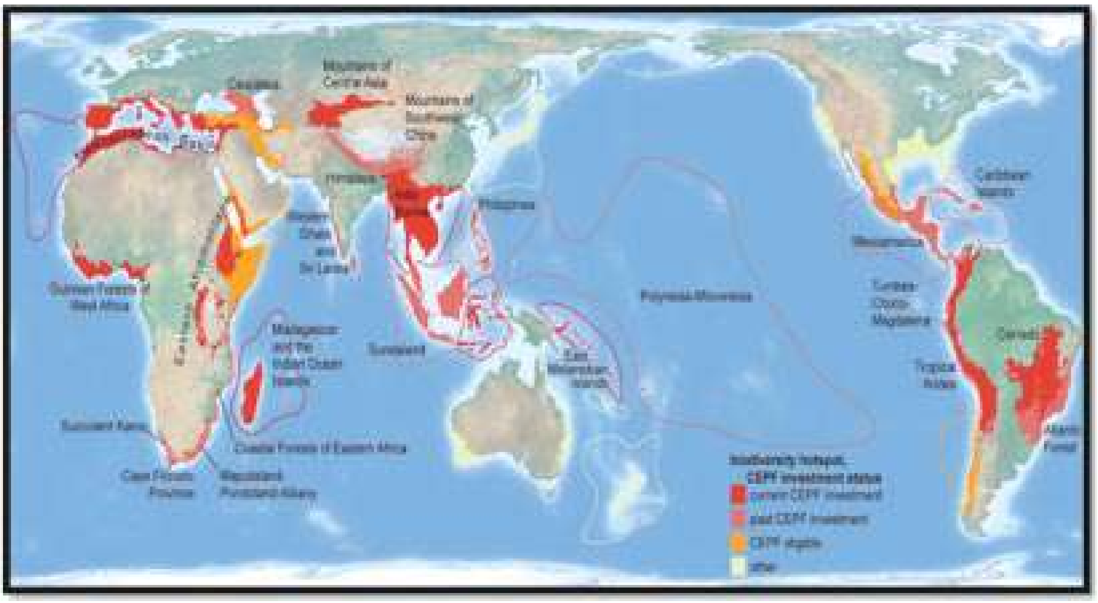

Figure 1.1 The World's 36 Biodiversity Hot-spots.

[Image: European Commission]

The areas they cover are as follows: [Source: Conservation International: www.conservation.org; www.cepf.net]

1. THE HIMALAYAS — This hotspot is home to the world's highest mountains, including Mt. Everest as well as several of the world's deepest river gorges. The mountains rise abruptly, resulting in a diversity of ecosystems that range from alluvial grasslands and subtropical broadleaf forests to alpine meadows above the tree line. Vascular plants have even been recorded at more than 6,000 m. The hotspot is also home to important populations of numerous large birds and mammals, including vultures, tigers, elephants, rhinos and wild water buffalo.

Table 1.3 The Himalayan hotspot — vital features

Hotspot Original Extent (km²)	741,706
Hotspot Vegetation Remaining (km²)	185,427
Endemic Threatened Birds	8
Endemic Threatened Mammals	4
Endemic Threatened Amphibians	4

Extinct Species†	0
Human Population Density (people/km²)	123
Area Protected (km²)	112,578
Area Protected (km²) in Categories I-IV*	77,739

†Recorded extinctions since 1500. *Categories I–IV affords higher levels of protection.

Biogeographically, the Himalayan Mountain Range straddles a transition zone between the Palearctic and Indo-Malayan realms. Species from both realms are represented in the hotspot. In addition, geological, climatic and altitudinal variations in the hotspot, as well as topographic complexity, contribute to the biological diversity of the mountains along their east-west and north-south axes.

Table 1.4.Species Diversity and Endemism in the Himalayas

Taxonomic group	Species	Endemic Species	Endemism (%)
Plants	10,000	3,160	31.6
Mammals	300	12	4.0
Birds	977	15	1.5
Reptiles	176	48	27.3
Amphibians	105	42	40.0
Freshwater Fishes	269	33	12.3

FLORA : Of the estimated 10,000 species of plants in the Himalaya hotspot, ~ 3,160 species, 71 genera and five families are endemic. The endemic families are: the Tetracentraceae, Hamamelidaceae, Circaesteraceae, Butomaceae and Stachyuraceae. The largest family of angiosperm in the hotspot is the Orchidaceae, with 750 species; a large number of orchids, many representing rather young endemic species, have recently been reported from the hotspot, indicating that further exploration could reveal a much higher degree of plant endemism. The Eastern Himalaya is also a center of diversity for several widely distributed plant taxa, such as Rhododendron, Primula, and Pedicularis. A zone of permanent rock and ice begins at about 5,500–6,000 m; despite such harsh conditions, there are records of vascular plants occurring at some of the highest elevations on Earth. Six species of vascular (cushion) plants recorded at an altitude of 6,150 m. *viz*., *Drabaalshehbazii, Drabaaltaica, Ladakiellaklimesii, Poa attenuata*, *Saussureagnaphalodes and Waldheimiatridactylites* (Angel 2016). On the slopes of Mt. Kamet in the northwestern Himalayas, a high-altitude scree plant of family Brassicaceae, *Ermaniahimalayensis*, was found at an altitude of 6,300 m.

2. INDO-BURMA — Covering > 2 million km² of tropical Asia, this region has lately been found to be home to six large mammal species: the large-antlered muntjac, the Annamite muntjac, the grey-shanked douc langurs, the Annamite striped rabbit, the leaf deer, and the saola. This hotspot also records endemism in freshwater turtle species, most of which are threatened with extinction, due to over-harvesting and extensive habitat loss. Bird life in Indo-Burma is also incredibly diverse, with ~ 1,300 species, including the threatened white-eared night-heron, the grey-crowned crocias, and the orange-necked partridge. The hot-spot covers the Andaman Islands in the Andaman Sea. The transition to the Sundaland Hotspot in the south occurs on the Thai-Malay Peninsula. The boundary between the two hotspots occurs along the Kangar-Pattani Line, which cuts across the Thailand-Malaysia border, though some analyses indicate that the phytogeographical and zoogeographical transition between the Sundaland and Indo-Burma biotas may lie just to the north of the Isthmus of Kra, associated with a gradual change from wet seasonal evergreen dipterocarp rainforest to mixed moist deciduous forest.

Much of Indo-Burma is characterized by distinct seasonal weather patterns. A wide diversity of ecosystems is present in this hotspot, including mixed wet evergreen, dry evergreen, deciduous, and montane forests. Patches of shrublands and woodlands on karst limestone outcrops and, in some coastal areas, scattered heath forests, are also seen. Moreover, a number of distinctive, localized vegetation formations occur, including lowland floodplain swamps, mangroves, and seasonally inundated grasslands. The patterns of biological diversity in Indo-Burma have resulted from the interaction of topography, past climate changes, soil characteristics, and the hotspot's patterns of seasonal rainfall. The hotspot contains many localized centers of endemism, particularly montane isolates, but also areas of lowland wet evergreen forest that were isolated at some stage, plus river basins.

Table 1.5 The Indo-Burma hotspot–the vital features

Hotspot Original Extent (km^2)	2,373,057
Hotspot Vegetation Remaining (km^2)	118,653
Endemic Plant Species	7,000
Endemic Threatened Birds	18
Endemic Threatened Mammals	25
Endemic Threatened Amphibians	35
Extinct Species†	1
Human Population Density (people/km^2)	134
Area Protected (km^2)	235,758
Area Protected (km^2) in Categories I-IV*	132,283

†Recorded extinctions since 1500. *Categories I-IV affords higher levels of protection.

FLORA. Knowledge of plant species in the Indo-Burma hotspot is uneven, and is influenced by sociopolitical divisions and taxonomic considerations. A conservative estimate of total plant diversity in the hotspot reveals ~13,500 vascular plant species, of which about 7,000 (52%) are endemic. Among the flora of the Indo-Burma Hotspot are a wide array of orchid and ginger species (> 1,000 orchid species in Thailand alone) and many tropical hardwood trees, including commercially valuable dipterocarp species and teak (Tectona grandis).

Table 1.6 Species Diversity and endemism in Indo-Burma

Taxonomic Group	Species	Endemic Species	Endemism (%)
Vascular Plants	13,500	7,000	51.9
Mammals	433	73	16.9
Birds	1,266	64	5.1
Reptiles	522	204	39.1
Amphibians	286	154	53.8
Freshwater Fishes	1,262	553	43.8

3. SUNDALAND — The Sundaland hotspot covers the western half of the Indo-Malayan archipelago, an arc of some 17,000 equatorial islands, and is dominated by two of the largest islands in the world : Borneo (725,000 km²) and Sumatra (427,300 km²). More than a million years ago, the islands of Sundaland were connected to mainland Asia. As sea levels changed during the Pleistocene, this connection periodically disappeared, eventually leading to the current isolation of the islands. The Nicobar Islands, which are under Indian jurisdiction, falls under Sundaland. Outside India's borders, Sundaland covers a small portion of southern Thailand (provinces of Pattani, Yala, and Narathiwat); nearly all of Malaysia (nearly all of Peninsular Malaysia and the East Malaysian states of Sarawak and Sabah in northern Borneo); Singapore at the tip of the Malay Peninsula; all of Brunei Darussalam; and all of the western half of the megadiversity country of Indonesia, including Kalimantan (the Indonesian portion of Borneo, Sumatra, Java, and Bali). Sundaland is bordered by three hotspots. The boundary between the Sundaland Hotspot and the Indo-Burma Hotspot to the northwest is here taken as the Kangar-Pattani Line, which crosses the Thailand-Malaysia border. Wallacea lies immediately to the east of the Sundaland Hotspot, separated by the famous Wallace's Line, while the 7,100 islands of the Philippines Hotspot lie immediately to the northeast.

Here, lowland rainforests are dominated by the towering trees of the family Dipterocarpaceae. Sandy and rocky coastlines harbor stands of beach forest, while muddy shores are lined with mangrove forests, replaced inland by large peat swamp forests. In some places the ancient uplifted coral reefs support specialized forests tolerant of the high levels of calcium and magnesium in the soils. Infertile tertiary sandstone ridges support heath forest. Higher elevations boast montane forests thick with moss, lichens, and orchids, while further up, scrubby subalpine forests are dominated by rhododendrons. At the very tops of the highest mountain peaks, the land is mostly rocky and without much vegetation.

Table 1.7 Sundaland hotspot–the vital features

Hotspot Original Extent (km²)	1,501,063
Hotspot Vegetation Remaining (km²)	100,571
Endemic Plant Species	15,000
Endemic Threatened Birds	43
Endemic Threatened Mammals	60

Endemic Threatened Amphibians	59
Extinct Species†	4
Human Population Density (people/km²)	153
Area Protected (km²)	179,723
Area Protected (km²) in Categories I-IV*	77,408

†Recorded extinctions since 1500. *Categories I–IV affords higher levels of protection.

The spectacular flora and fauna of the Sundaland Hotspot are succumbing to the explosive growth of industrial forestry in these islands and to the international animal trade that claims tigers, monkeys, and turtle species for food and medicine in other countries. Populations of the orangutan, found only in this hotspot, are in dramatic decline. Some of the last refuges of two Southeast Asia rhino species are also found on the islands of Java and Sumatra. Like many tropical areas, the forests are being cleared for commercial uses. Rubber, oil palm, and pulp production are three of the most detrimental forces facing biodiversity in the Sundaland Hotspot.

Table 1.8 Species Diversity and Endemism in Sundaland hotspot

Taxonomic Group	Species	Endemic Species	Endemism (%)
Plants	25,000	15,000	60.0
Mammals	380	172	45.3
Birds	769	142	18.5
Reptiles	452	243	53.8
Amphibians	244	196	80.3
Freshwater Fishes	950	350	36.8

FLORA — Sundaland is one of the biologically richest hotspots on Earth. It is home to ~ 25,000 species of vascular plants, 15,000 (60%) of which are found nowhere else. One plant family, the Scyphostegiaceae, is confined to the hotspot and is represented by a single tree species, Scyphostegia borneensis from Borneo. There are at least 117 endemic plant genera; 59 of which are found in Borneo, 17 in Sumatra, and 41 on the Malay Peninsula. Borneo boasts a spectacular diversity of trees. There are ~ 3,000 species, including more than 265 species of dipterocarps;

no less than 155 of these are endemic to the island. Borneo also has more than 2,000 species of orchids. The other islands are less diverse than Borneo but still boast an impressive variety of plant life. Sumatran forests include more than 100 dipterocarp species, nearly a dozen of which are endemic, and Java has more than 270 endemic orchids. Notable plants in the hotspot include members of the genus Rafflesia, represented by 16 species with very large flowers. One of these, Rafflesia arnoldii, bears the largest flower in the world, measuring up to one meter in diameter.

4. WESTERN GHATS AND SRI LANKA

The Western Ghats of Southwest India and the highlands of Southwest Sri Lanka are 400 km apart, but are remarkably similar in geology, climate and evolutionary history. The Western Ghats, known locally as the Sahyadri Hills, are formed by the Malabar Plains and the chain of mountains running parallel to India's western coast, ~30-50 km inland. They cover an area of ~160,000 km^2 and stretch for 1,600 km from the country’s southern tip to Gujarat in the north, interrupted only by the 30 km Palakkad Gap. Sri Lanka is a continental island separated from southern India by the 20-meter-deep Palk Strait. The island, some 67,654 km^2 in size, has been repeatedly connected with India between successive inter-glacial, most recently until about 7,000 years ago by a land bridge up to about 140 kilometers wide. The Western Ghats mediates the rainfall regime of peninsular India by intercepting the SW Monsoon winds. The western slopes of the mountains experience heavy annual rainfall (with 80 % of it falling during the SW Monsoon from June to September), while the eastern slopes are drier; rainfall also decreases from south to north. Dozens of rivers originate in these mountains, including the peninsula’s three major eastward-flowing rivers. Thus, they are important sources of drinking water, irrigation, and power.

Table 1.9 The Western Ghats and Sri Lanka hotspot region – the vital features

Hotspot Original Extent (km^2)	189,611
Hotspot Vegetation Remaining (km^2)	43,611
Endemic Plant Species	3,049
Endemic Threatened Birds	10
Endemic Threatened Mammals	14

Endemic Threatened Amphibians	87
Extinct Species†	20
Human Population Density (people/km²)	261
Area Protected (km²)	26,130
Area Protected (km²) in Categories I-IV*	21,259

†Recorded extinctions since 1500. *Categories I-IV affords higher levels of protection.

The wide variation of rainfall patterns in the Western Ghats, coupled with the region's complex geography, produces a great variety of vegetation types. These include scrub forests in the low-lying rain shadow areas and the plains, deciduous and tropical rainforests up to about 1,500 m, and a unique mosaic of montane forests and rolling grasslands above 1,500 m. Precipitation across Sri Lanka depends on monsoon winds, which causes much of the island to experience relatively low rainfall (< 2,000 mm per year), except for the southwestern "wet zone" quarter, where precipitation ranges to as much as 5,000 mm per year. While dry evergreen forests occupy almost the entirety of the "dry zone," dipterocarp-dominated rainforests dominate the lowlands of the wet zone, and some 220 km² of tropical montane cloud forest still persist in the central hills, which rise to a maximum altitude of 2,524 m.

Due in part to the varying effect of the yearly monsoons and the high mountain regions, this hotspot is home to a rich endemic assemblage of plants, reptiles, and amphibians. Sir Lanka alone may be home to as many as 140 endemic species of amphibians. The region also houses important populations of Asian Elephants, Indian Tigers, and the Endangered Lion-tailed Macaque. Freshwater fish endemism is extremely high as well, with over 140 native species. But under the influence of great population pressure, the forests of the Western Ghats and Sri Lanka have been dramatically impacted by the demands for timber and agricultural land. Remaining forests of the Western Ghats are heavily fragmented; in Sri Lanka, only 1.5% of the original forest remains. Population levels are also applying increased stress on the fringes of protected areas where many farms, loggers, and poachers use the resources illegally. Today, approximately 20% of the original forest covers remains in more or less pristine state, with forest blocks larger than 200 km² found in the Agasthyamalai Hills, Cardamom Hills, Silent Valley, New Amarambalam Forests, and southern parts of the South Kannada District in Karnataka State.

Remaining forest patches are subject to intense hunting pressure and the extraction of fuelwood and non-timber forest products. Uncontrolled tourism and forest fires are additional concerns.

Table 1.10 Species Diversity and Endemism – Western Ghats and Sri Lanka

Taxonomic Group	Species	Endemic Species	Endemism (%)
Plants	5,916	3,049	51.5
Mammals	140	18	12.9
Birds	458	35	7.6
Reptiles	267	174	65.2
Amphibians	178	130	73.0
Freshwater Fishes	191	139	72.8

FLORA: Close to 6,000 vascular plant species present in this hotspot region, nearly 52% are endemic. There are also more than 80 endemic plant genera, many of them with only one species. The Western Ghats alone harbors ca. 5,000 species of vascular plants belonging to nearly 2,200 genera, of which ~1,700 species (34%) are endemic. There are also 58 endemic plant genera, and, while some are remarkably speciose (like Niligrianthus, which has 20 species), nearly three-quarters of the endemic genera have only a single species. Some prominent genera and families are represented by large numbers of endemic species, such as Impatiens with 76 of 86 species endemic, Dipterocarpus with 12 of 13 species endemic, and Calamus with 23 of 25 species endemic. Of the 490 tree species recorded from low- and mid-elevation forests, 308 species are endemic. The only gymnosperm tree, Podocarpus (= Nageia) wallichianus, is also endemic. Of the 267 species of orchids, 130 are endemic. Plant diversity and endemism in Sri Lanka too are quite high, with 3,210 flowering plant species in 1,052 genera, of which 916 species and 18 genera are endemic. Amazingly, all but one of the island’s more than 55 dipterocarp species is found nowhere else in the world. In addition, the island’s ferns (although not recently assessed) are estimated to number about 350 species. Approximately 433 plant species, and at least five genera, are confined to Sri Lanka and the Western Ghats combined. In the Western Ghats, the Agasthyamalai Hills in the extreme south are believed to harbor the highest levels of plant diversity and endemism at the species level. Nearly 87% of the region’s flowering plants are found south of the Palakkad Gap (37% being exclusive to this sub-region); these figures decrease to about 60% and 5%, respectively, in the Nilgiri Hills. In Sri Lanka, diversity, richness, and endemism across all taxa are much higher in the wet (including the montane) zone than in the dry zone. Indeed, the wet zone, which accounts for only a quarter of Sri Lanka's territory, contains 88% of the flowering plants occurring in the island, and 95% of its angiosperm endemics.

However, in the last few years, India has lost 90% of the area under its four biodiversity hotspots. The Indo-Burma hotspot has suffered the most – the extent of vegetation in the region has been reduced from 2,373,057 sq km to a mere 118,653 sq km, a loss of 95 per cent. Twenty five species have also gone extinct in these hotspots. (State of India's Environment in Figures 2021, CSE).

1.8.1 Why biodiversity hotspots matter

There are several very important reasons why biodiversity hotspots really matter.

- *Biodiversity underpins all life on Earth*. Without species, there would be no air to breathe, no food to eat, no water to drink. There would be no human society at all. As places on Earth where biodiversity is under the most threat, hotspots are critical to human survival.
- *The map of hotspots overlaps with the map of the natural places that most benefit people*. The significance is obvious. Hotspots are among the richest and most important ecosystems in the world — and they are home to many vulnerable populations which are directly dependent on nature to survive. By one estimate, despite comprising 2.5% of Earth's land surface, the forests, wetlands and other ecosystems in hotspots account for 35% of the "ecosystem services" that vulnerable human populations depend on.
- *The hotspots are home to two billion people, some of them the world's poorest*. These people depend on the area's biodiversity for their livelihood.
- *The hotspots are at a very risk of extinction*. In fact, more than two-fifths of the species found in hotspots face imminent extinction. Almost a quarter is at a very high risk due to climate change according to the Intergovernmental Panel on Climate Change (IPCC).

1.8.2 Biodiversity 'dark-spots'

Biodiversity darkspots are areas that are poorly studied or lack comprehensive data on their biodiversity. These regions might not be well-documented due to various factors, such as inaccessibility, lack of funding, or insufficient research efforts. In other words, they remain "dark" in terms of our understanding of the species and ecosystems they harbor. In fact, more than 15% of all vascular plant species may remain scientifically undescribed, and many of the > 350 000 described species have no or few geographic records documenting their distribution. Studying biodiversity darkspots is crucial because they might contain undiscovered species, unique ecosystems, or significant genetic diversity that could be important for conservation efforts. Identifying and researching these areas can help fill gaps in our knowledge, inform conservation priorities, and contribute to a more accurate understanding of global biodiversity. It was observed that the 33 darkspots largely overlap the 36 biodiversity hotspots, with the notable exception of New Guinea (Fig. 1.). By contrast, there are many hotspots that are not identified as darkspots in our analysis, particularly in the Pacific, Australasia, North America, Africa and Europe (Ondo *et al* 2024).

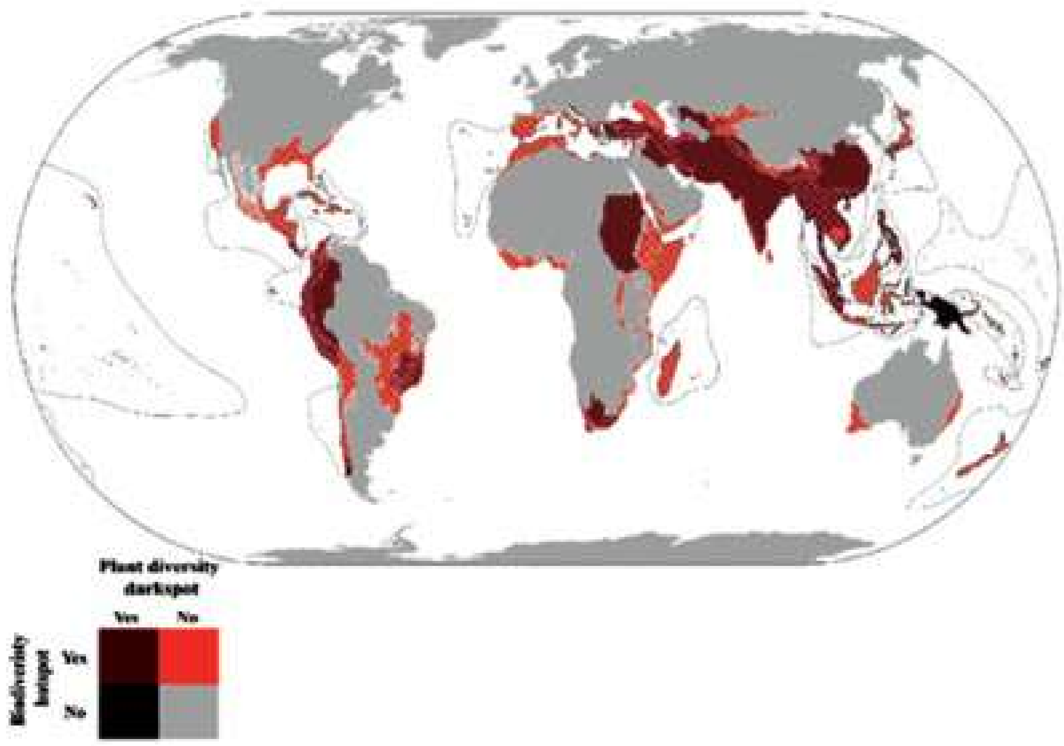

Figure 1.2. Global darkspots of vascular plant diversity and biodiversity hotspots. Dark red indicates countries that are identified as darkspots and that contain hotspots. Black indicates countries uniquely defined as darkspots (i.e. New Guinea). Orange indicates areas containing hotspots but not overlapping with any darkspot and grey indicates areas containing neither darkspots nor hotspots. The cross-hatched areas and black lines indicate the terrestrial and marine delimitation of biodiversity hotspots, respectively. All darkspots overlap with hotspots, except New Guinea.[Source: Ondo et al 2024; https://doi.org/10.1111/nph.20024].

SAQ II

1. What are biodiversity hotspots?
2. How many biodiversity hotspots are there globally according to Conservation International?
3. Which region has the highest number of biodiversity hotspots?
4. What percentage of the Earth's land surface do biodiversity hotspots cover?
5. What are biodiversity darkspots?
6. Why is it important to study biodiversity darkspots?
7. How many biodiversity hotspots are there in India?
8. What is the current status of biodiversity hotspots in India?
9. Fill in the Blanks :

(a) Biodiversity hotspots are regions that have a high level of _______ richness and are under significant threat from human activities.

(b) According to Conservation International, there are ___ biodiversity hotspots globally.

(c) Biodiversity hotspots cover only ___% of the Earth's land surface but support over ___% of the world's endemic plant species.

(d) Biodiversity _____________ are areas that are poorly studied or lack comprehensive data on their biodiversity.

(e) Studying biodiversity darkspots is crucial because they might contain undiscovered _______, unique ecosystems, or significant genetic diversity.

(f) India has _______ biodiversity hotspots, within its political boundaries.

(g) India has lost ___ % of the area under its biodiversity hotspots.

(h) ___________ countries are nations that contain more than 70% of the planet's biodiversity.

(i) The main characteristics of megadiverse countries include a high number of species and _________ species.

(j) Some of the countries considered megadiverse are Brazil, China, and _________(any of the others).

1.9 Summary

Plant diversity is the foundation of life on Earth, supporting ecosystems, agriculture, and human livelihoods. It is the vast variety of plant species, their genetic makeup, and their distribution across different ecosystems. It plays a crucial role in maintaining ecological balance, providing food, medicine, raw materials, and contributing to climate regulation. Understanding plant diversity is essential for conservation, sustainable agriculture, and ecosystem stability. Plant diversity is studied at different levels, including *genetic diversity, species diversity*, and *ecosystem diversity*. Genetic diversity refers to the variation in genes within a species. It is crucial for adaptation, evolution, crop improvement programmes and resilience to environmental changes. Species diversity refers to the variety of plant species in a particular region or ecosystem. It is a key component of biodiversity and is measured using different indices. *Species richness* is the total number of different species in an area. Species evenness is the relative abundance of species in an ecosystem. Simpson's Index and the Shannon-Wiener Index are quantitative measures that assess diversity by considering both species richness and species evenness. Species diversity supports ecosystem stability and function, ensures food security by maintaining diverse crop species and enhances ecological resilience against environmental disturbances. A biological community (biotic components) and the physical environment (abiotic components) that it is a part of constitute an ecosystem. Ecosystem diversity refers to the variety of ecosystems that house different plant communities. Different ecosystems support distinct types of plant species based on climate, soil, and geography. Forests, grasslands, wetlands, deserts are some of the major ecosystems. There are *three* levels of ecosystem diversity. Alpha diversity or within-community diversity is expressed as the number of species in the ecosystem. Beta diversity or between- community diversity is the amount of species change between ecosystems. Gamma diversity is the total species richness over a large geographical area. Ecosystem diversity ensures ecological stability. Different ecosystems provide essential services such as oxygen production, water filtration, and climate regulation; and a habitat for a wide range of plant and animal species. Understanding and measuring diversity at the genetic, species, and ecosystem levels is essential for conservation efforts.

Biodiversity hotspots highlight the urgent need for protection due to their immense ecological value and vulnerability. They are regions with exceptionally

high species richness and endemism (species found nowhere else). They are also under significant threat due to human activities. The criteria for biodiversity hotspots according to Norman Meyers are that they must have at least **1,500 species** of vascular plants as endemics; and that they must have lost **at least 70% of its original vegetation**. Major hotspots include the **Amazon Rainforest (South America)** – home to over 40,000 plant species; the **Congo Basin (Africa)** – rich in tropical flora; the North East Himalayas which contains a variety of alpine and temperate plants; and the **Sundaland (South and South East Asia)** which includes the Western Ghats, Andaman & Nicobar Islands and Sri Lanka with diverse rainforests. India is home to four hotspots: the Himalayas, Indo-Burma, Western Ghats and the Sundaland. Hotspots preserve rare and endemic plant species, act as crucial carbon sinks and climate regulators and provide ecosystem services such as water conservation, pollination, and soil fertility. Preserving plant diversity ensures a sustainable future for both nature and humanity. Each one of us needs to appreciate the importance of biodiversity and sensitise ourselves to the impact that the loss of biodiversity can have.

1.10 Terminal Questions

1. Why is the preservation of biodiversity extremely important?
2. Briefly describe three major ecosystems in the world.
3. What are the main characteristics of megadiverse countries?
4. Which countries are considered megadiverse?
5. **State whether the following statements are 'True' or 'False'.**

(a) Genetic diversity is highest in species that reproduce asexually.

(b) Ecosystem diversity refers to the diverse biomes that exist.

(c) The Western Ghats and Northeast Himalayas are both biodiversity hotspots in India.

(d) Tropical rainforests have the highest plant diversity.

(e) Beta diversity refers to the amount of species change between ecosystems.

(f) India is one of 17 megadiverse nations in the world.

1.11 Answer key

SAQ I

1. Genetic diversity refers to the variety of genes within a species. It is crucial because it allows species to adapt to environmental changes, increases disease resistance, and provides a basis for plant breeding and crop improvement.
2. Species diversity is the variety of different species within a given area. It can be measured using:
   - Shannon-Wiener Index – which considers species richness and evenness.
   - Simpson's Index – which measures the probability that two individuals randomly selected belong to the same species.
3. The number of individuals of a particular species that the resources of an environment can support is known as the carrying capacity.
4. Match the columns A and B.

   (a) → (iii)

   (b) → (i)

   (c) → (ii)
5. Select the correct answer : (a) (iii); (b) (ii); (c) (iii); (d) (ii); (e) (iii)

SAQ II

1. Biodiversity hotspots are regions that have a high level of species richness and endemism and are under significant threat from human activities.
2. According to Conservation International, there are 36 biodiversity hotspots globally.
3. The tropical forests have the highest number of biodiversity hotspots.
4. Biodiversity hotspots cover only 2.5% of the Earth's land surface but support over 50% of the world's endemic plant species.
5. Biodiversity darkspots are areas that are poorly studied or lack comprehensive data on their biodiversity.
6. Studying biodiversity darkspots is crucial because they might contain

undiscovered species, unique ecosystems, or significant genetic diversity that could be important for conservation efforts.

7. India has four biodiversity hotspots: the Western Ghats, the Himalayas, the Indo-Burma region, and the Sundaland (Nicobar Islands).
8. India has lost 90% of the area under its biodiversity hotspots.
9. Megadiverse countries are characterized by a high number of species, high levels of endemism, and a variety of ecosystems. They are mostly located in tropical or subtropical regions.
10. Some of the countries considered megadiverse are Brazil, China, Colombia, India, Indonesia, Mexico, and South Africa.
11. Fill in the Blanks :

    (a) species; (b) 36; (c) 2.5, 50; (d) darkspots; (e) species; (f) three; (g) 90; (h) megadiverse; (i) endemic; (j) India/Australia etc.

Terminal questions :

1. Biodiversity preservation is crucial for several ecological, economic, and cultural reasons :
    - **Ecological Stability :** Diverse ecosystems are more resilient to environmental changes, ensuring ecosystem functions like nutrient cycling and pollination.
    - **Food Security :** A diverse range of plants provides essential genetic material for crop improvement, ensuring resistance to pests, diseases, and climate change.
    - **Medicinal Resources :** Many plants are sources of medicines (e.g., aspirin from willow bark, quinine from Cinchona trees), and biodiversity loss may result in the extinction of potential medicinal plants.
    - **Climate Regulation :** Forests and other ecosystems act as carbon sinks, reducing greenhouse gases and mitigating climate change.
    - **Economic Benefits :** Biodiversity supports industries like agriculture, forestry, fisheries, and ecotourism, contributing to national economies.
    - **Cultural and Aesthetic Value :** Many communities and indigenous groups have deep cultural and spiritual connections with biodiversity.

- **Ecosystem Services :** Plants help in soil formation, water purification, and prevention of natural disasters like floods and droughts.

Without biodiversity, ecosystems would collapse, leading to severe consequences for human life and the planet. Therefore, conservation efforts such as afforestation, sustainable agriculture, and protected areas are essential.

2. Three major ecosystems are : *Tropical moist forests (Rainforests)* – occur between the Tropic of Cancer and Tropic of Capricorn, seen in the Amazon Basin, South and Southeast Asia and Central Africa among other places; characterized by high biodiversity, dense vegetation, and heavy rainfall. *Arid and Semiarid ecosystems* – have poor biological diversity limited by water availability with scarce and unpredictable precipitation; comprise mostly drought-evading, drought-enduring and drought-resisting taxa like cacti. Sahara, Gobi or Thar deserts are common examples. *Grassland ecosystems* – the most common form of natural vegetation on Earth's land surface, dominated by grass and grass-like species, although in some areas shrubby and herbaceous elements (often called 'forbs') as well as trees, may be present alongside grazing animals. They are common in North America (prairies), South America (pampas), and Eurasia (steppes).
3. Megadiverse countries are characterized by a high number of species, high levels of endemism, and a variety of ecosystems. They are mostly located in tropical or subtropical regions.
4. Some of the countries considered megadiverse are Australia, Brazil, China, Colombia, India, Indonesia, Mexico, and South Africa.
5. **'True' or 'False'**

   (a) False; (b) False; (c) True; (d) True; (e) True; (f) True.

1.12 References and Further Reading

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Unit – 2 ❑ Agro-Biodiversity, Values and Uses of Biodiversity

Structure

2.0 Objectives

From this unit you should

- Understand what agrobiodiversity entails, and its significance;
- The centres of origin of cultivated plants across the globe

- The value of maintaining biodiversity in the face of threats that it faces;
- Appreciate the different ecosystem services
- Understand how we can put a value – economic and otherwise – to biodiversity, the various means proposed to value them, and the metrics used for the purpose.

2.1 Introduction

In addition to genetic diversity, species diversity and community or ecosystem diversity (all dealt with in the previous unit), the agricultural ecosystems possess diversity of their own accord – the agrobiodiversity. Cultivated plants and their wild relatives may be the dominant player in such agro-ecosystems but microbes, fungi, cattle, fishes, poultry and other livestock are all involved to various degrees, in the smooth functioning of such ecosystems. Selection for useful traits over the years has led to the maintenance of genetically uniform lines in important crops, making them vulnerable to disease, pests and environmental stress. Therefore, preservation of their wild relatives in different forms, as sources of genetic variation to be tapped when required, is essential. Preservation of germ-plasm in repositories is today one of the prime conservation effort. That different places in the Indian subcontinent are considered Vaviloviancentres of origin of important cultivated plants, is an advantage in our national drive for conservation of genetic heterogeneity. Biodiversity for food and agriculture can be managed to maintain or enhance ecosystem functions to provide options for the optimization of agricultural production, and contribute to the resilience of ecosystems for risk mitigation. Indeed, biodiversity enhances ecosystem services because those components that appear redundant at one point in time become important when changes occur. Overall, the value of biodiversity in a fast-changing world on the brink of disaster cannot be overestimated -- with climate change posing a formidable threat to continuity of life and livelihood.

It is necessary to value biodiversity – of direct or indirect use, or even the intrinsic, non-use value. To be able to ascribe a value will help us to recognize and quantify the benefits that ecosystems provide to humanity. So that, policymakers, conservationists, and the public can make informed decisions to protect and preserve biodiversity. Valuation methods offer a systematic approach to measuring these benefits, ensuring that the economic, ecological, and social importance of biodiversity is acknowledged and considered in decision-making processes. This is crucial for the sustainable management of natural resources and for safeguarding the well-being of both present and future generations.

2.2 Agro-Biodiversity

Biodiversity for food and agriculture, or *agricultural biodiversity*, includes the components of biological diversity that are essential for feeding human populations and improving the quality of life. Therefore, *agrobiodiversity includes the variety and variability of ecosystems, animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain human life as well as the key functions of ecosystems*. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil microbes, predators, pollinators), along with diversity that exist outside – in pastoral, forest and aquatic ecosystems—that bolster the diversity of agro-ecosystems. Such diversity is the result of thousands of years of farmers' and breeders' activities, land and forest utilization, and fisheries and aquaculture activities, sustained through millions of years of natural selection. Indeed, it has been estimated that a greater part of terrestrial biodiversity persists in agricultural landscapes. Such landscapes could therefore be a key to global biodiversity conservation. The struggle to maintain biodiversity is going to be won or lost in agricultural systems. Management of agricultural landscapes will be the litmus test of our ability to conserve species. And most terrestrial biota will eventually have to coexist with human agriculture. However, much biodiversity in agro-ecosystems may have no specific role in agriculture *per se*. Their function, rather than their mere presence, will determine whether the impact of agrobiodiversity on agricultural production is direct or indirect. However, it is important to remember, that human populations have always lived in areas close to food production, and will probably continue to do so. Therefore, sustained management of different biological resources in such areas is of supreme importance for food security and livelihood for such people. In brief, genetic resources that constitutes agrobiodiversity includes :

- Harvested crop varieties, livestock breeds, fish species and non-domesticated (wild) resources within field, forest, rangeland including tree products, wild animals hunted for food and in aquatic ecosystems (e.g., wild fish);
- Non-harvested species in production ecosystems that support provision for

food, soil microbiota, pollinators and other insects such as earthworms, greenflies; and

- Non-harvested species away from agro-ecosystems, but nevertheless sustain food productivity—agricultural, pastoral, forest and aquatic ecosystems.

In areas where high-yield crop and livestock varieties do not prosper, many farmers rely on a wide range of crop and livestock. This helps them to tackle pathogen infestation, uncertain rainfall, unpredictable availability of agro-chemicals, fluctuation in price of cash crops and socio-political upheavals. So-called minor or underutilized crops, more accurately, companion crops, are frequently found next to the main staple or cash crops. Their value is often underestimated. Often, from a livelihoods perspective, they are neither 'minor' nor 'underutilized', as they can prove to be extremely useful in food production systems at the local level. Plants that will grow in infertile or eroded soils, and livestock that will eat degraded vegetation, are often crucial to household nutritional strategies. In addition, the rural folks often indulge in trade with these 'companion species' in urban markets.

2.2.1 Distinctive features of agrobiodiversity

Agrobiodiversity displays certain distinctive features in relation to other components of biodiversity :

- Male and female farmers are actively involved in the management of agrobiodiversity.
- Many components of agrobiodiversity would not survive without such human intervention; local knowledge and culture is an integral part in such agrobiodiversity management practices.
- Many economically important agricultural systems are based on 'alien' crop or livestock species introduced from elsewhere, e.g., horticultural production systems, Friesian cows in Africa and so on. This creates a high degree of interdependence between countries for the genetic resources on which our food systems are based.
- As for crop diversity, the diversity within species is at least as important as diversity between species.
- Because of the degree of human management, conservation of agrobiodiversity in production systems is inherently linked to sustainable use – conservation by establishing protected areas is less relevant here.

- In industrial-type agricultural systems, much crop diversity is now held ex situ in gene-banks or as breeders' stock, rather than on-farm.

2.2.2 The role of agrobiodiversity

Experience and research have shown that agrobiodiversity can:

- Increase productivity, food security and economic returns
- Reduce the pressure of agriculture on fragile areas, forests and endangered species
- Make farming systems more stable, robust, and sustainable
- Contribute to sound pest and disease management
- Conserve soil and increase natural soil fertility and health
- Contribute to sustainable intensification
- Diversify products and income opportunities
- Reduce or spread risks to individuals and nations
- Help maximize effective use of resources and the environment
- Reduce dependency on external inputs
- Improve human nutrition and provide sources of medicines and vitamins,
- Conserve ecosystem structure and stability of species diversity.

2.2.3 Importance of agrobiodiversity

Agriculture is the largest global user of biodiversity. It has selected and added value to biodiversity in the wild, over more than 10,000 years. Agriculture has conserved biodiversity by way of hoof and as seed and planting materials, over this long period. Agriculture extracts value from biodiversity at each harvest or cull, but nurtures the productive and renewable base. Undoubtedly, a very valuable part of global biodiversity is the agrobiodiversity, on which farming, and in turn, global food security depends.

In the past, agrobiodiversity management has played a key role in human civilization, through transfer of surplus production in agricultural practices, to cities. Management of agrobiodiversity to a large extent may determine our future, both in cities and in the countryside, with implications in the unequal distribution of resources between the rich and the poor. The new approach to conservation in the wild has shifted from an emphasis on rare and endangered species to ecosystem function and the importance of ecosystem services. There already exists a knowledge-base to help agricultural practices embrace such changed priorities. Agro-ecosystems - mediated through agrobiodiversity - have always provided the essential ecosystem service of food production. They can be designed to deliver a further range of ecosystem services as the needs and knowledge change. Present knowledge extends from a greater appreciation of traditional agriculture and the needs of farmers, through classical agricultural research in animal husbandry, genetics, statistics, replicated experiments, plant breeding, agronomy, crop protection, rural sociology, information management and many more, to biotechnology,

Biodiversity is an important regulator of agro-ecosystem functions, not only in the strictly biological sense of impact on production, but also in satisfying a variety of needs of the farmer and society at large. Agro-ecosystem managers, including farmers, can build upon, enhance and manage the essential ecosystem services provided by biodiversity in order to work towards sustainable agricultural production. This can be achieved though good farming practices which follow ecosystem-based approaches designed to improve sustainability of production systems. They aim at meeting consumer needs for products that are of high quality, safe and produced in an environmentally and socially responsible way.

2.3 Diversity of cultivated plants

Cultivated plants, broadly, are those that are planted and grown, rather than emerging naturally as part of the biome where they occur. There are many reviews of useful or edible plants, but it is the active process of cultivation of a plant species by man which is the most relevant relationship between humans and plants. The introduction of agriculture (“neolithic revolution”) has been characterized as a milestone in the evolutionary history of mankind. Agro-ecosystems, like other types of ecosystems, vary widely in the amount of biodiversity they contain and how that biodiversity is organized among species, among varieties or cultivars within species, and within cultivars. Cultivated plants are known to possess low species diversity in comparison to most non-agricultural ecosystems; indeed, the farmer’s intention is to eliminate all but one or a few species from a field if possible. Discrimination based on species is also applied by breeders, when they try to separate the species in an ecosystem into two groups: the ones that they are trying to improve (comprising ‘genotypes’) and the rest (which are part of the ‘environment’).

In general, though our knowledge of cultivated plant diversity at the species level is good enough, at the cultivar level it is variable—patchy for improved varieties, just about adequate for some crops (rice, maize, wheat), but poor for landraces. Therefore, the number of cultivated plant species is of general interest and it amounts to ~7,000. Amenity horticulture is a quickly developing area among cultivated plants -- comprising ornamentals and other plants connected with gardening and landscaping. About 28,000 plant species have been estimated to belong to this group. Cultivated forest plants also enter our count and the total number of cultivated plants reaches 35,000 species—about 14% of the number of higher plant species of the world. The commercial ‘‘plant finders’’ (often of less scientific accuracy) give a higher estimate of cultivated plants—50,000 species and cultivars. Such estimates are useful to collate information from commercial plants and seed lists. In the plant lists of the Royal Horticultural Society (RHS 2006), more than 70,000 species and cultivars, including many notomorphs, i.e., taxa of hybrid origin have been reported. However, amalgamation of counts of ornamental (hybrid) species and cultivars is problematic.

2.3.1 Centres of Origin of Cultivated Plants

Centres of origin of cultivated plants are separated from one another by mountain chains, deserts, or vast expanses of water, which has given rise to independent and isolated agricultural civilisation. Together they occupy ~ 2.5% of the total land area, leaving aside mountainous regions and deserts within each centre. Often, a particular genus or species is associated with a single centre, but some crops are associated with two or more centres of diversity. Therefore, the Russian-Soviet agronomist and botanist Nikolai Vavilov, visualized primary centres of origin of cultivated plants as regions, where the plant in question takes the most diverse forms and was the place where it was domesticated for the first time. Secondary centres of origin arise as a result of migration of individual variants from the primary centre. For, e.g., though primary centre of origin of maize was in Mexico, the centre of origin of its waxy varieties was in China, which was the secondary centre of origin.

Vavilov (1935) identified eight independent centres of origin of the major cultivated plants worldwide, which means, eight regions of domestication of various plants (Fig. 2.1). These centres include Chinese centre of origin (136), Indian centre of origin (117), Indo-Malay centre (42), Near Eastern centre (38), Mediterranean centre (84), Abyssinian centre (38), South Mexican & Central American centre, South American (Peruvian-Ecuadorian-Bolivian) centre (45). In addition to the main South American centre of origin, Vavilov also recognized two sub-centres: The

Chilean centre (4) and Brazilian-Paraguayancentre (13) (see Tab2.1). [The numbers within the parentheses indicate the number of diversity of cultivated plants in the concerned centre].

N.I. Vavilov (1887-1943)

Table 2.1 Vaviloviancentres of origin of cultivated plants

Vavilovian Centres	Cultivated plants
1. Chinese Centre	Millets, Sorghum, Buck wheat, soybean, Kidney bean, Yam, Radish, Cannabis, Tea (Total cultivated taxa: 136)
2(a) Indian Centre	Rice, Finger Millet, Pigeon Pea, Green gram, Horse gram, Winged bean, Cluster bean, Amaranthus sp., Brinjan, Bitter gourd, Bottle gourd, Snake gourd, Taro, Mango, Orange, Lemon, Mybrobalan, Breadfruit, Tamarind, Sugar-cane, Mustard (Total: 117)
2(b) Indo-Malayan Centre	Coix, Velvet bean, Zinger, Pomelo, Litchi, Banana, Durio, Coconut, Cardamom, Black pepper, Turmeric, Gutta-percha (Total: 55)
3. Inner Asiatic Centre	Peas, Lentils, Chick-pea, Flax, Safflower, Melon, Carrot, Onion, Basil, Pistachio, Pear, Grapevine (Total: 42)
4. Asia Minor	Eincorn type wheat, Soft wheat, Secabe, Cereals, Pea, Alfalfa, Vetch, Sesame, Castor, Figs, Poppy, Pumpkin, (Total: 83)
5. Mediterranean Centre	Aritchoke, Emmer, Oats, Barley, Lentils, Horse bean, Chick-pea, Flax, Black mustard, Olive, Beetroot, Cabbage, Onions, Cumin, Fennel, Lavender (Total: 84)

Vavilovian Centres	Cultivated plants
6. Abyssinian Centre	Triticum durum, Barley, Finger millet, Lentil, Fenugreek, Niger, Safflower, Sesame, Coraindér, Coffee, Bhendi, Pearl, millet, Sorghum (Total: 38)
7. South Mexican & Central American Centre	Maize, Jack-bean, Squash, Chayote, Pumpkin, Sweet potato, Pepper Chilli, Upland cotton, Sisal, Papaya, Guava, Cherry, Tomato, Cocoa, Avocado (Total: 49)
8(a) South American (Peru, Ecuador, Bolivia) Centre	Patato, Lupine, Maize, Tomato, Peanut, Tobacco (Total: 45)
8(b) Chilean Centre	Strawberry (Total: 4)
8(c) Brazil-Pagaguay Centre	Manihot, Peanut, Hevea rubber, Pineapple, Yam, Cassava (Total: 13)

Figure 2.1 The centres of origin of cultivated plants identified by Nikolai Vavilov: 1. China; 2. India; 2a. The Indo-Malayan region; 3. Central Asia (including Pakistan, Punjab, Kashmir, Afghanistan and Turkestan); 4. The Near East (Fertile Crescent); 5. The Mediterranean; 6. Ethiopia; 7. Southern Mexico and Central America; 8. South America (small regions of Ecuador, Peru, Bolivia, Chile, and Brazil-Paraguay).

2.4 Why biodiversity matters

Biodiversity is the variety of life on Earth in all its forms and all its interactions. The diversity of nature provides us with food, shelter, water, medicine and air to breathe. To ensure they remain healthy and vibrant, ecosystems–no matter where they are–require a diverse range of life within them. Even very small, insignificant and apparently innocuous organisms may play a crucial role in the ecological balance or may prove to be a potential source of some invaluable drug for dreaded ailments like cancer or AIDS. Biodiversity is at the heart of important natural systems such as nutrient cycling, water cycle and the climate. Overexploitation of the natural world and widespread landscape change as habitats are cleared to make way for agriculture, livestock silos and urbanization are eroding biodiversity. In addition, climate change over the years through human activities is eroding biodiversity at an accelerated pace. However, innovations such as precision agriculture, GM crops and indoor farming can help grow food more efficiently and lessen our impact on the natural world. Science can also help to shape how we build our cities and infrastructure. It can inform our use of oceans and help us develop 'clean energy'. Reframing the way we look at nature, can help us check the loss of more biodiversity, while also allowing us to take advantage of the many nature-based solutions to the problems we face.

Let us draw up a list of benefits that accrue from existing biodiversity.

- Diverse forms of biota are essential for functioning of a healthy ecosystem – which provides us with the air we breathe, food we eat and exhibit resilience under adverse natural situations.
- Soil microbes regulate biogeochemical cycles and liberate nutrients to plants which they pass to us when we eat them.
- Pollinators – birds, bees and insects – are estimated to be responsible for one-thirds of world's crop production.
- Soil health is maintained by invertebrates and thereby sustains agriculture.
- Trees, bushes and wetlands recharge ground water with rainfall. Trees clean the air we breathe and help mitigate to some extent global warming by acting as a carbon sink. Deforestation leads to flooding, water scarcity and global warming among other disasters.

- Lives from the oceans are the chief source of animal protein for many communities.
- Coral reefs and mangroves act as natural defenses protecting coastlines from tidal waves and storms.
- Many medicines, nutraceuticals, complex molecules and several items of our daily use such as paper, rubber, dyes, perfumes, come from plants.
- Verdant nature and greenery are important to people's physical and mental health. It was shown that simply by having open green spaces and trees in cities decrease hospital admission, reduce stress and lowers blood pressure.

2.4.1 Values and uses of Biodiversity

The value of biodiversity in terms of its commercial utility, ecological services, social, ethical and aesthetic value is enormous. Sometimes, we come to realize and appreciate the value of the organism only after it is lost from this earth. The multiple uses of biodiversity or biodiversity value may be broadly categorised as follows:

A. Ethical and Aesthetic Values

Sometimes referred to as existence value, it involves ethical diktats like *"all life must be preserved", "live and let live", that all forms of life have the right to exist on earth*, that all life-forms are *members of the Earth family (VasudhaivaKutumbakam)*. Man is only a miniscule part of planet Earth's greatfamily of species. Ecosystems and natural communities are not merely property that can be owned but are living beings that have an independent right to exist and flourish. One country, Ecuador, has even put the Rights of Mother Earth in its constitution. Plants and animals have an equal right to live and exist on Earth, a spaceship teeming with life. Though we do not know if life as we know itexists elsewhere in the universe but protecting biodiversity on Earth is protecting our future. However, this requires a shift away from anthropocentrism that privileges the human species, which has ultimately resulted in what some researchers call, the 'Anthropocene' age. We may not find an immediate usefulness for a species, but we derive comfort from the fact that it does exist. This is the *ethical* aspect.We all feel sorry whenwe learn that "passenger pigeon" or "dodo" is no more on this earth. In other words, we seek to attach an *ethical value* or *existence value* to each and every species. Indian civilization has always laid great emphasis on preserving nature through local traditions and practices. It is a part of our cultural heritage, our philosophy. Recall the existence in our country of a large number of *sacred groves* or *'deorais'*, preserved by tribal people in several states. These sacred groves preserved around ancient sacred sites or temples act as gene banks of wild plants. Symbols from wild species such as the lion of Hinduism, the elephant of Buddhism and deities such as Lord Ganesh, and the vehicles of several deities that are animals, have all been venerated for thousands of years. Valmiki begins his epic story with a couplet on the unfortunate killing of a crane by a hunter. The Tulsi (Basil) plant has been placed at our doorsteps for centuries. Such examples abound.

Great aesthetic value is attached to biodiversity. None would like to visit vast stretches of barren lands with no signs of visible life. People from far and wide spend a lot of time and money to visit areas in wilderness, where they can enjoy diverse flora and fauna in all their beauty. This has given rise to eco-tourism. The *"willingness to pay"* concept, a monetary value attached to eco-tourism, is one way of quantifying the aesthetic value of biodiversity, and its goods and services. In a world where everything is measured against money, ecotourism, which is estimated to generate about 12 billion dollars of revenue annually, gives us a rough aesthetic value of biodiversity.

B. Economic value

Biodiversity play an important role in boosting the economy of a country by providing the daily needs for the common people. Each species is of potential value to humans. So are healthy ecosystems. The global collection of genes, species, habitats and ecosystems is a resource that provides for human needs now and looks after our future. Humans depend on other species for their food, medicines and industrial products, It regulates important planetary cycles that provide us with the air we breathe and water we drink, and contribute to our overall well-being. Important economic commodities that biodiversity supplies to humankind include:

Food: crops, livestock, forestry, fish, etc.

Medicine : Wild plant species have been used for medicinal purposes since time immemorial. For example, quinine comes from the cinchona tree (used to treat malaria), digitalis from the foxglove plant (chronic heart ailments) and morphine from the poppy plant (analgesic). Up to 80% of the people in the poor countries depend on traditional medicine for primary healthcare, most of which is derived from plants and some from animal and mineral sources. According to the National Cancer Institute, over 70 % of the promising anticancer drugs come from plants in the tropical rainforests. Animals also play a significant role in medicinal research. With 77% of undescribed species predicted to be threatened with extinction, the race is on to find and conserve them, because, with them we would lose forever potential sources of cure for our ailments (State of the World's Plants and Fungi, 2023).

Industry : It provides among others, fibres for clothing and wood for shelter and warmth. Biodiversity could be a source of energy (such as biomass). Other industrial products include oils, lubricants, dyes, perfumes, fragrances, paper, waxes, rubber, latexes, resins, cork and poisons–all of which are derived from various plant species. From animals we obtain various items of daily use, such as wool, silk, fur, leather, lubricants, and waxes. Animals also carry people and goods far and near.

Tourism and Recreation : Biodiversity is a source of economic wealth for many parks and forests, where wild nature is a source of silent wonderment, joy and relaxation for many people. Ecotourism has turned out be a source of recreation, livelihood and revenue for many people, in different regions and countries.

C. Evolutionary value :

The form and function of a plant species is a product of its evolutionary history. Each species exhibits a suite of characteristics–based on its underlying genetic make-up and responses to its environment. This endows it with particular traits, such as whether it is woody, the type of fruits it bears and its capacity to tolerate different environmental stresses. Closely related species that only diverged from one another recently, usually exhibit many similar traits, while a species found alone on a single, long evolutionary branch, such as the 'living fossil' the Wollemi pine *(Wollemia nobilis)*, is more likely to contain traits, or combinations of traits, not present elsewhere. Species that evolved in isolation such as plant species atop Venezuela's *tepuis* (table-top mountains) are not found anywhere else in the world. The Canaima National Park in Venezuela with many tepuis, has been classified as a World Heritage Site by UNESCO. The island of Madagascar hosts many unique species on distinct evolutionary branches. South Africa has an exceptionally diverse flora with many plant lineages that arose before the fragmentation of the ancient supercontinent of Gondwana. An example is the Proteaceae family.

The *World Checklist of Vascular Plants* (WCVP) offered the unique opportunity to learn where most branches of the tree of life are actually found on the map. It shows that *phylogenetic diversity* is more evenly spread around the globe than species diversity. This means, focusing attention for conservation in a limited number of species-rich spots would be short-sighted. Because phylogenetic diversity, unlike ‘species richness’, is measured as the sum of the length of all the branches on the tree of life that connect a set of species back to their common ancestor. In other words, it is as a summary of the amount of evolutionary history connecting all the species in the area in question.

Actually, the phylogenetic history at the root of biodiversity found today is the result of close to four billion years of evolution. Until ca. 600 million years ago (mya), all life consisted of bacteria and other unicellular forms. Explosion of life as seen in fossil records, suggests that the last few million years witnessed the greatest biodiversity in Earth’s history. Biodiversity today is not much different from biodiversity as it existed, say 300 mya. Estimates of the present global macroscopic species diversity vary from 2 -100 million species, with a working estimate of somewhere near 10 million. New species are discovered regularly, for example, about three new species of birds on average each year. Many newly discovered species is yet to be catalogued. An estimated 40% of freshwater fish from South America are not yet classified. Plant species that are yet to be scientifically named, described and mapped constitutes ~15% of the world’s flora --they are the *dark matter* of botany. And underexplored areas in the world are called *plant diversity darkspots* There are 32 such darkspots in the world with the Eastern Himalayas, Western Himalayas and Assam featuring in the list (along with Myanmar and Bangladesh) (Ondo I *et al* 2023).

D. Cultural Value

India is a nation of syncretic culture. Its natural environment will continue to provide for its people from all cultures, many of the inspirational, aestheticand educational needs. Indian society places great cultural value on plants, birds and animals. Biodiversity is at the heart of many of our religious, spiritual and cultural practices. Whether offering flowers such as *Hibiscus* to goddess Kali, Akanda (*Calotropis* sp.) and Datura flowers to Lord Siva, Palash (*Butea monosperma*) to Goddess Saraswati, Padma (*Nelumbo nucifera*) to Goddess Durga, or using Sami (*Prosopis spicigera*) in sacrificial fires in Gujarat, or the value of Mahua (*Madhuca indica*) to tribal communities, and such examples abound—all point to their integral role in community practices. Importantly, many species that are unknown to science are, in fact, well known to indigenous communities.

2.4.2 Ecosystem Services

The idea that natural systems support human welfare is quite old. The concept that ecosystem provides an array of service to human welfare gained currency in the 1970s and gained increasing recognition over the following decades. In the late 1990s, *ecosystem service* was looked upon as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life." They maintain biodiversity and production of ecosystem goods – seafood, forage, timber, biomass fuels, natural fibres, pharmaceuticals, industrial products, and their precursors. Moreover, ecosystem services provide life-support functions, in addition to many intangible aesthetic and cultural benefits (Daily 1997). In 2005, the *Millennium Ecosystem Assessment* (MA) further developed and popularized the concept, and went on to define ecosystem services as "the benefits people obtain from ecosystems" and divided them into *four* categories: provisioning, regulating, supporting, and cultural services.

A. Provisioning Services : These are the tangible products obtained from ecosystems. They include:

- *Food :* Crops, fruits, vegetables, fish, and livestock.
- *Water :* Freshwater for drinking, irrigation, and industrial use.
- *Fibre :* Wood, cotton, wool, and other materials for construction and manufacturing.
- *Medicinal resources :* Plants and animals that provide pharmaceutical compounds.

B. Regulating Services : These are the benefits derived from the natural regulation of ecosystem processes. They include :

- *Climate regulation :* Forests and oceans act as carbon sinks, and help regulate the global climate.
- *Water purification :* Wetlands and riparian zones filter and clean water by trapping pollutants and sediments.
- *Pollination :* Insects, birds, and other animals pollinate plants, crucial for the production of many crops.
- *Pest and disease control :* Natural predators and biological controls help manage agricultural pests and diseases.

C. Cultural Services : These are the non-material benefits people obtain from ecosystems. They include :

- *Recreational :* Natural landscapes provide spaces for activities like hiking, bird-watching, and tourism.
- *Aesthetic :* The beauty of natural environments inspires art, culture, and personal enjoyment.
- *Spiritual and religious :* Many ecosystems hold spiritual and religious significance for different communities.
- *Educational :* Ecosystems provide opportunities for learning and scientific research.

D. Supporting Services : These are the services that are necessary for the production of all other ecosystem services. They include :

- *Soil formation :* Processes like weathering and decomposition create fertile soil necessary for plant growth.
- *Nutrient cycling :* Ecosystems recycle nutrients like nitrogen and phosphorus, which are essential for life.
- *Primary production :* The conversion of solar energy into biomass through photosynthesis, forming the base of food chains.
- *Habitat provision :* Ecosystems provide habitats for diverse species, maintaining biodiversity.

Importance of Ecosystem Services

Ecosystem services are vital for human survival and economic development. They contribute to food security, health, and livelihoods. For example, pollinators like bees are essential for the production of many fruits and vegetables, while wetlands help protect communities from flooding by absorbing excess water.

Threats to Ecosystem Services

Ecosystem services are under threat from human activities such as deforestation, pollution, overfishing, and climate change. These activities can degrade ecosystems and reduce their ability to provide essential services. For instance, deforestation can lead to loss of biodiversity, soil erosion, and disruption of water cycles.

Conservation and Sustainable Use

To protect and sustain ecosystem services, it is essential to adopt conservation practices and promote sustainable use of natural resources. This includes :

- **Conservation areas :** Establishing protected areas to preserve critical habitats and biodiversity.
- **Sustainable agriculture :** Implementing practices that maintain soil health, reduce chemical use, and promote biodiversity.
- **Restoration projects :** Restoring degraded ecosystems to enhance their functionality and resilience.
- **Community involvement :** Engaging local communities in conservation efforts and recognizing their role in ecosystem management.

2.4.3 Precautionary Principle

Today, relatively only a small amount of biodiversity is actively exploited by man and valued. However, there are other elements of biodiversity that may be very important for the different reasons listed below:

(i) They may have values unused or unknown at present, but once discovered and exploited, could substantially enhance the well-being of humankind, and

(ii) They may prove useful at some future time, due to changing circumstances. It is the so-called 'option value', placed while trying to assess the *total economic value* (TEV) of biological resources at a future point in time, a value which is not apparent today. This concept has been elaborated in the following section.

These are the reasons why we must be circumspect and take a precautionary approach to maintenance of all biodiversity. Biodiversity elements with actual (yet unknown) or potential use should not be lost simply because we presently do not know their value. Further, it must be understood that biodiversity elements once lost cannot be recreated even with our best technologies. (Krishnamurthy, 2003). Let us then move on to the major methods adopted for valuing biodiversity.

2.4.4 Methodologies for Valuation

The United Nations Environment Programme (UNEP) in 1995 published for the first time a comprehensive analysis – the *Global Biodiversity Assessment* report – at the Jakarta Conference of Parties to the Convention on Biological Diversity

(CBD). This document provides a comprehensive framework for biodiversity valuation. They found that the Earth's biological resources are under serious threat, being used inefficiently and inequitably. The damage to its invaluable resources will limit our range of options for remedial action in the future. They emphasized the importance of considering multiple valuation methods to capture the full range of biodiversity values, including economic, ecological, social, and cultural dimensions. While some methods may be described differently or grouped under broader categories, the core principles and approaches remain consistent with contemporary understanding. [For details, you can look up the original UNEP document (1995)].

There are various cogent reasons for attaching an economic and market value to biological resources and/or ecosystem services.

(i) It reinforces the idea that human created capital cannot substitute natural capital, and this thinking is conducive to inclusive growth.

(ii) Economic valuation of biodiversity contributes to successful conservation as it impacts multiple stakeholders, beyond environmentalists and conservationists. This ensures that biodiversity is included in cost-benefit analyses and is not disregarded as an environmental externality. The Dasgupta Review (2021) highlights the importance of natural capital for decision units at different scales – household sectors, private sectors and governments.

(iii) Economic biodiversity indicators can be beneficial when planning for implementation of sustainability development goals (SDGs).

The *economic values of biodiversity* were assessed using different methodologies and indices. Before dwelling on some common methodologies for economic/monetary valuation, it is important to note that the 'intrinsic' value of biodiversity is ordinarily not taken into consideration here– this being more relevant to conservation decisions. Rather, it tries to measure the economic value of *'biological resources'*, undisturbed or sustainably managed, which maintain current or potential human uses. Such a focus is more tractable. Because biological resources are subject to human preferences, it places them firmly within the purview of economic analysis (Pearce and Moran 1994). Valuation typically focuses on the *economic values* of the goods and services, generated by biodiversity resources and/or functions.

Endnote. Environmental externalities refer to the economic concept of uncompensated **environmental effects of production and consumption** that affect consumer utility and enterprise cost outside the market mechanism. As a consequence of negative externalities, private costs of production tend to be lower than its "social" cost.

The general framework commonly used for valuing natural resources is termed the ***Total Economic Value*** **(TEV)**. It comprises **use values** (direct, indirect and option value) and **non-use values**. Let us clarify the concepts with the help of two examples, one for tropical forests (Tab 2.2), and another for mangroves (Tab 2.3). *Direct use values* are those derived from direct use or interaction with environmental resources and services, as exemplified in Tables 2.2 & 2.3. They can be 'consumptive' (e.g. direct harvest of forest products, fish or medicinal plants) or 'non-consumptive' (e.g. recreation). *Indirect use value* relates to the indirect support and protection provided to another activity which has economic value. Thus, the watershed protection function of a tropical forest may have 'indirect use value' through controlling sedimentation and flood drainage that affect downstream agriculture, fishing, water supplies and other economic activities. The *option use value or bequest value* is reserved for future direct and indirect uses – where the individuals may choose to exercise the 'option' to keep a biological resource intact for future use, for example in the hope to discover new medicinal plants. *Non-use* values are not derived from current direct or indirect use of the environment, but from other considerations (see Tab. 2.2 & 2.3). To clarify, one may not have any direct link with tropical forests, but nevertheless would wish to see them preserved. Let us take another example. We know that mountain gorillas are still found in Rwanda. We may derive comfort from this fact but do not find it necessary to trek to the Virunga Mountains to actually see them, and in the process spend $1500-$2500 for the expedition. These resources are prized 'in their own right', for their 'intrinsic value'. Such 'intrinsic' values are also termed *'existence values'*, i.e., the value obtained from knowing certain things exist for economic, moral, ethical or other reasons.

Some of the most common measures of valuation of biodiversity by way of evaluating biological resources / ecosystem services / environmental goods include :

A. Market-based valuation :

- *Direct Market Valuation :* Valuing biodiversity by market prices for goods and services (e.g., timber, fish).
- *Production Function Approach :* Commonly used in the 1990s, it values biodiversity based on the impact natural capital (input) exerts on marketable production processes (outputs). Examples are pollination services for crops, diversity of bird populations in supporting pest control services in agriculture, habitat functions of mangroves in supporting the fishing (shrimp) industry, and so on.

Table 2.2 Total economic value of a tropical forest (Source : Moran & Bann 2000)

Use Values			Non Use Values
(1) Direct Value	(2) Indirect Value	(3) Option Value	
Sustainable forest products Recreation and tourism Medicine Plant genetics Education Human habitat	Watershed protection Nutrient cycling Air pollution reduction Micro climatic functions Carbon store Biodiversity	Future use as per (1) and (2)	Existence value Cultural heritage Biodiversity

Table 2.3 Total economic value of a mangrove resource (Source : Bann 1998, with modification)

Direct Value	Indirect Value	Option Value	Non-use Value
Timber, Charcoal Fisheries Forest products : food, medicine, wildlife, etc Agricultural resources Water supply Water transport Genetic resources Tourism & recreation Human habitat Information	Shoreline, riverbank, stabilisation Ground water, recharge/discharge Flood & flow control Waste storage & recycling Biodiversity maintenance Provision of migration habitat Nutrient retention Coral reef maintenance & protection Prevention of saline water intrusion	Future direct & indirect values	Cultural, aesthetic Spiritual, religious Global existence value

B. Stated Preference methods : For many environmental goods, a market value needs to be constructed using questionnaires. This is the essence of stated preference (SP) methods, so called because it asks people to directly state their values, rather than inferring values from actual choices, as the 'revealed preference' methods do. Drawing on advances in market research and cognitive psychology, the stated preference method has been applied widely in environmental economics over the last two decades. It includes:

- *Contingent Valuation and Ranking :* The *Contingent Valuation Method* (CVM) involves surveys where, individuals are asked how much they would be willing to pay (WTP), for specific environmental services or biodiversity conservation. It is so called because people state their WTP, *contingent* on or subject to, a specific hypothetical scenario and description of the environmental service, including trade-offs (*choice modelling*) between biodiversity and other factors. It can be used to estimate both *use* and *non-use values*, though most often for estimating the latter. Contingent Ranking is a SP method, where respondents are presented with a set of choices and asked to rank them on the basis of their preference. For example, they might rank different forest management standards based on their biodiversity impact.

C. Revealed Preference methods : These techniques are indirect valuation approaches that infer people's preferences based on their actual choices or behavior in the marketplace or from other observable contexts. It includes:

- *Travel Cost Method (TCM) :* Estimates the value of recreational sites such as national parks, wildlife reserves by analyzing travel expenses actually incurred by visitors. Usually, only visitors are surveyed.

- *Hedonic Pricing Method (HPM) :* Examines property prices to assess the value of environmental amenities such as proximity to green spaces, air quality and so on.

Sometimes these two can be combined to constitute the hedonic travel cost method (HTCM).

- *Labour Market Approach :* Analyzes wage differentials due to environmental quality like cleaner air leading to higher wages.

- *Damage Cost Assessment :* Quantifies the economic impact of environmental degradation like pollution-related health costs and so on.

D. Cost-based valuation : These methods consider the value of biodiversity in terms of what we forego when choosing one use of environmental goods over another.

- *Replacement Cost :* Estimates the cost of replacing biodiversity or ecosystem services with man-made systems. For example, the cost of building artificial barriers to prevent coastal erosion can be used to value the natural protection provided by mangrove forests. Thevalidity of the replacement will depend on: (i) the substitute providing exactly the same function as the replaced service; (ii) the substitute being the least-cost alternative; and (iii) evidence that the producer would demand the substitute.
- *Restoration Cost :* Values biodiversity based on the cost of restoring degraded ecosystems.
- *Marginal Abatement Cost :* Evaluates the cost of reducing pollution or conserving biodiversity.
- *Avoided Cost :* Values biodiversity by estimating the costs that are avoided by maintaining ecosystem services like flood protection by wetlands.
- *Shadow Pricing :* Assigns a monetary value to ecosystem services (e.g., carbon sequestration) to inform decision-making.
- *Compensation Costs :* Estimates the value of biodiversity based on the compensation required to offset biodiversity loss. This could include payments to communities for conservation efforts or investments in habitat restoration projects to compensate for environmental damage.
- *Land Use Change Analysis :* Compares the benefits of different land uses (e.g., agriculture vs. conservation) to assess opportunity costs.
- *Change in Productivity :* Estimates the value of biodiversity by examining how changes in biodiversity affect the economic productivity. For instance, the presence of diverse pollinators can enhance crop yields, and the economic value of this increase in productivity can be attributed to biodiversity.
- *Change in Earnings :* Values biodiversity by looking at changes in earnings that result from variations in biodiversity. For example, improved fish stocks due to healthy aquatic ecosystems can lead to higher earnings for fishermen.

- *Benefits Transfer :* It involves using existing valuation studies to estimate the value of biodiversity in another, similar context. This method is cost-effective and can be useful when time or resources for a new valuation study are limited. For example, if a study has valued the recreational benefits of a national park, those values can be applied to a similar park elsewhere.

These methods provide valuable insights to help capture different aspects of biodiversity value, reflecting its multifaceted importance to ecosystems, economies, and human well-being. However, it bears repetition that biodiversity's intrinsic worth extends beyond monetary valuation. It embraces cultural, ecological and ethical considerations. Let us quickly sum up the relative merits of the popular valuation methods. *Market Pricing* is straightforward and applies well to goods with established markets but is limited to direct use values. *Productivity Method* captures the indirect contributions of biodiversity to production processes but requires detailed production and ecosystem data. *Contingent Valuation* is versatile and can value both use and non-use values but relies heavily on survey design and respondent honesty, which can introduce biases. *Travel Cost Method* is effective for valuing recreational sites by analyzing travel expenditures but is limited to sites that attract visitors. *Benefit Transfer* is efficient and can be applied to various contexts using existing studies but may lack precision compared to primary data collection. Each method has its strengths and weaknesses, making some more suitable than others depending on the specific context and available data. By using a combination of these methods, a more comprehensive valuation of biodiversity can be achieved.

Now, let us look at a few examples of valuation of biodiversity in actual practice. It will clarify its importance.

- **Costa Rica's Payment for Ecosystem Services (PES) Program :** Costa Rica has implemented a PES program to compensate landowners for maintaining forest cover, which provides ecosystem services like carbon sequestration, water regulation, and biodiversity conservation.
- **The New York City Watershed Case :** New York City invested in protecting the Catskill/Delaware watershed to maintain water quality instead of building a costly water filtration plant. This approach values the ecosystem services provided by the watershed, such as water purification and flood control.
- **The UK National Ecosystem Assessment (NEA) :** The NEA is a comprehensive assessment of the UK's natural environment, including the

economic value of ecosystem services like pollination, flood protection, and recreation.

- **The Great Barrier Reef Valuation :** The Great Barrier Reef in Australia has been valued using contingent valuation methods to estimate the economic value of its ecosystem services, including tourism, fisheries, and biodiversity conservation.
- **The Economics of Ecosystems and Biodiversity (TEEB) Initiative :** TEEB is a global initiative that aims to highlight the economic benefits of biodiversity and ecosystem services, providing case studies and valuation methods to inform policy decisions.

These examples illustrate how biodiversity valuation can inform conservation strategies and policy decisions, ensuring that the benefits of ecosystems are recognized and preserved [https://scbd.unssc.org/course/].

Many methods for quantifying the benefits of biodiversity exist – many different kinds of valuation have been proposed and refined by environmental economists. However, in order to value biodiversity, we need to keep in mind certain considerations or caveats. Some of these are :

(a) An element of *uncertainty* in valuation methods will always remain due to gaps in knowledge about ecosystems and human preferences.

(b) Non-market valuation can be subjective – an '*instrumental value.*' Often, there is also a difference between what people are willing to pay and what they actually pay – *consumer surplus*.

(c) Travel costs, hedonistic prices, contingent valuation are all subject to change over spatial and temporal scales.

(d) Demand curves shift based on income changes – *income dependence*.

(e) The inherent problem of *public goods*, i.e., valuing non-market goods (e.g., clean air) without direct market prices will remain.

(f) Assigning an economic value is tantamount to commodification of nature – and may lead to "green grabbing" by the wealthy at the cost of the poor people, who are likely to be dispossessed of their life and livelihood (Fairhead *et al* 2012).

SAQ I

(a) Who was Nikolai Vavilov?

(b) How is a 'centre of origin of cultivated plants' generally defined?

(c) How do 'secondary centres of origin' arise?

(d) Name any two cultivated plants that belong to the Indian Centre of Origin (2a)?

(e) Match the following crops with their Vaviloviancentres of origin :

	Column A (Crops)		Column B (Centres of Origin)
(a)	Tea	(i)	China
(b)	Banana	(ii)	Inner Asiatic Centre
(c)	Grapes	(iii)	Abyssinian Centre
(d)	Potato	(iv)	South America (Andean region)
(e)	Barley	(v)	Indo-Malayan Centre

Box 2.1 Choosing the best valuation method

If you must choose the best valuation method for your project, you need to proceed systematically. Here is a step-by-step guide to help you decide :

1. *Define the Purpose*. Determine the specific goals of your project. Are you looking to value direct use, indirect use, or non-use values of biodiversity? Your objective will guide the choice of valuation method.
2. *Identify Available Data*. Evaluate the data you have or can feasibly collect :
   - Market Pricing requires market prices and quantity data.
   - Productivity Method needs production and ecosystem data.
   - Contingent Valuation relies on survey data.
   - Travel Cost Method needs visitor and travel cost data.
   - Benefit Transfer requires access to existing valuation studies.
3. *Consider the Context*. First, assess the context of your project.
   - If you are valuing recreational sites, the Travel Cost Method might be appropriate.

- For tangible goods like timber or fish, Market Pricing could be suitable.
- To capture non-use values, Contingent Valuation might be best.

4. *Budget and Time Constraints*. Consider your project's budget and time constraints :
   - Benefit Transfer is cost-effective and quick, ideal for projects with limited resources.
   - Contingent Valuation can be resource-intensive and time-consuming.
5. *Expertise and Resources*. Evaluate the expertise and resources available to you:
   - If you have access to survey design experts, Contingent Valuation could be effective.
   - If you have limited expertise, Benefit Transfer might be easier to implement.
6. *Stakeholder Preferences*

Take into account the preferences and expectations of stakeholders involved in the project. Some stakeholders might prioritize certain values or methods over others.

Example Scenarios

- Scenario A : Valuing a National Park's recreational benefits—The Travel Cost Method would be suitable as it focuses on visitor expenditures.
- Scenario B : Estimating the economic impact of pollination on agriculture—The Productivity Method would be ideal since it quantifies ecosystem services' contribution to production.
- Scenario C : Assessing public willingness to pay for conservation—Contingent Valuation is appropriate due to its flexibility in capturing both use and non-use values.

By carefully considering these factors, you can select the most appropriate valuation method for your project, ensuring accurate and meaningful results.

SAQ II

1. *Answer in brief :*

(a) What are direct use values of biodiversity?

(b) State briefly what you understand by 'ecosystem services'.

(c) What is contingent valuation, and how is it used to assess biodiversity?

2. *Choose the correct answer :*

(a) Which of the following is an example of an indirect use value of biodiversity?
(i) Timber; (ii) Pollination; (iii) Fish; (iv) Medicinal plants.

(b) Which method uses existing valuation estimates from similar contexts to infer the value of biodiversity in a new context?
(i) Market Pricing; (ii) Contingent Valuation; (iii) Productivity Method; (iv) Benefit Transfer.

3. *State whether the following statements are 'True' or 'False'.*

(a) Cultural practices are not a part of ecosystem services.

(b) Biodiverse ecosystems can control spread of diseases.

(c) Existence value is the value of preserving biodiversity for future generations.

(d) Travel cost method estimates the value of recreational sites by the amount people spend to travel to them.

4. *Fill in the Blanks :*

(a) ________ services, such as climate regulation and water purification, are examples of indirect use values of biodiversity.

(b) The ___________ method estimates the value of ecosystem services by their contribution to the production of goods.

5. *Match the following valuation methods to their descriptions :*

1. Market Pricing
2. Travel Cost Method
3. Bequest Value
4. Contingent Valuation

Descriptions : A. Uses surveys to determine willingness to pay for conservation. B. Values recreational sites based on travel expenses. C. Uses market prices of goods and services derived from biodiversity. D. Values biodiversity for future generations.

2.5 Summary

Agrobiodiversity, also known as agricultural biodiversity, refers to the variety and variability of animals, plants, and microorganisms used directly or indirectly for food and agriculture. This includes crops, livestock, forestry, and fisheries. Agrobiodiversity encompasses the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel, and pharmaceuticals. It also includes non-harvested species that support production, such as soil micro-organisms, pollinators, and predators. Agrobiodiversity is crucial for several reasons: food security, nutrition, ecosystem services, and adaptation to changing environmental conditions, and support to livelihoods by providing income and employment opportunities through agriculture by providing income and employment opportunities through agriculture.

Nikolai Vavilov, a Russian botanist, identified eight geographical areas known as VavilovianCentres of Origin where domestication of plants first occurred. These centers are regions with high genetic diversity of crop wild relatives, which are essential for plant breeding and crop improvement. These centers are critical for preserving genetic diversity and ensuring the resilience of agricultural systems

Biodiversity is of immense value both for ecosystems and human society. Its value can be broadly categorized into two types: use values and non-use values. Use values may be *direct* with tangible benefits derived from biodiversity, such as for provisioning services like food, timber, fuel, and medicinal resources; or cultural services such as recreational activities, tourism, and educational research. *Indirect* use values include the ecosystem services that indirectly benefit humans, whether for climate regulation, water purification, pollination, and erosion control (regulating services), or for nutrient cycling, soil formation, and primary production (supporting services). The *non-use values* include the sheer existence or intrinsic value of biodiversity, irrespective of any direct or indirect benefit to humans – the value derived simply from knowing that a species or ecosystem exists. The option or bequest value refers to the value of preserving biodiversity for posterity, ensuring that they can enjoy and benefit from it. Environmental economists and others have come up with a number of *valuation methods* for effective conservation of biodiversity. Popular among them are the *market-based approaches* – market pricing of goods and services derived from biodiversity (e.g., timber, fish); and productivity methods – which estimates the value of ecosystem services by their contribution to the production of goods (e.g., pollination's impact on crop yields). The *non-market approaches* employ 'contingent valuation' – with surveys to ask people their willingness to pay for conserving biodiversity or their willingness to accept compensation for its loss; or they use 'travel cost methods' – to estimate the value of recreational sites by the amount people spend to visit them. There is also a *benefit transfer method* that uses existing valuation estimates from similar contexts to infer the value of biodiversity in a new context. Only by understanding and recognizing the multifaceted value of biodiversity, can we make informed decisions to protect and preserve it for current and future generations.

2.6 Terminal Questions

1. What is agrobiodiversity? Briefly state its importance.
2. Name the four broad categories of ecosystem services provided by biodiversity.
3. Briefly explain the concept of bequest value in biodiversity.
4. Fill in the blanks :

(a) Forests and wetlands help regulate the ______ cycle, to provide clean water.

(b) The intrinsic value of biodiversity, irrespective of any direct or indirect benefits to humans is termed __________ value.

2.7 Answer key

SAQ I

For questions (a) to (d) see section 2.3.1;

(e) Match the columns: (a)–(i); (b)–(v); (c)–(ii); (d)–(iv); (e)–(iii)

SAQ II. 1.

(a) Direct use values refer to tangible benefits derived from biodiversity, such as food, timber, fuel, and medicinal resources.

(b) Ecosystem services are the conditions and processes through which natural ecosystems and their constituentspecies, sustain and fulfill human life.

(c) Contingent valuation is a non-market approach that uses surveys to ask people their willingness to pay for conserving biodiversity or their willingness to accept compensation for its loss.

2. (a) (ii); (b) (iv)

3. (a) False; (b) True; (c) False; (d) True

4. (a) Regulating; (b) Productivity;

5. 1.–C, 2.–B, 3.–D, 4.–A

Terminal Questions

1. See section 2.2.

2. Provisioning, Regulating, Cultural and Supporting services.

3. Bequest value refers to the value of preserving biodiversity for future generations, ensuring that they can enjoy and benefit from it. It's an acknowledgment of our responsibility to protect natural resources for those who come after us.

4. (a) water; (b) existence.

2.8 References and Further Reading

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Unit – 3 ❑ Uses of plants and uses of microbes

Structure

3.0 Objectives

From this unit you will be able to

- Have a clear idea about the extent of diversity that exists in the plants and the variety of microorganisms;

- The diversity of plants and microbes in our country;
- Appreciate why India is a megadiverse country with biodiversity hotspots;
- Understand why protection of our planet's green cover is essential to sustainable livelihoods;
- Gain an idea about the uses of plants as food, fodder, timber, firewood, rattans & canes, for aesthetic appeal and as sources of medicinally active principles and other therapeutic uses;
- Realize the great importance of microorganisms not only for our food, our health, but also for the health and fertility of soils – as a part of the plant microbiome.

3.1 Introduction

The world is home to an immense diversity of plants and microbes, which play a critical role in maintaining ecological balance and supporting human welfare. Plants, with over 390,000 known species, contribute to food security, medicine, industry, and environmental stability. They form the foundation of terrestrial ecosystems, supporting animal life and contributing to global biogeochemical cycles. From towering trees in rainforests to tiny aquatic plants in wetlands, their diversity underpins ecosystem functions and human survival. Microbes, including viruses, archaea, bacteria, protists and fungi, are equally diverse and essential, performing roles in nutrient cycling, disease control, biotechnology, and food production. They inhabit extreme environments, such as deep-sea hydrothermal vents and arid deserts, showcasing their adaptability and significance in sustaining life.

India, recognized as one of the 17 megadiverse countries, harbours a vast array of flora and microorganisms due to its varied climatic zones, ranging from the snow-clad Himalayas to tropical rainforests, arid deserts, and very extensive coastal ecosystems. The country is home to over 45,000 plant species and countless microorganisms adapted to diverse habitats. Biodiversity hotspots like the Western Ghats, the North East Himalayas and the Indo-Burma region, further contribute to this richness. India's traditional knowledge systems, such as Ayurveda, extensively use plant-based remedies, demonstrating the integral link between biodiversity and healthcare. Indigenous communities have developed a wealth of ethnobotanical knowledge, using plants for treating ailments, enhancing nutrition, and ensuring food security.

Plants contribute significantly to human welfare by providing food, fuel, fibre, timber, and medicine. They maintain atmospheric balance by producing oxygen and sequestering carbon dioxide, mitigating the effects of climate change. Forests, comprising a large portion of plant diversity, prevent soil erosion, regulate water cycles, and provide habitat for wildlife. Agricultural crops like rice, wheat, and pulses are staples in Indian diets, while fruits like mango, banana, and spices like cardamom and pepper add to the country's agricultural diversity. Medicinal plants like neem, turmeric, ashwagandha, and tulsi are widely used in Indian households and global pharmaceuticals for their healing properties and immune-boosting effects.

Microbes, often unseen, are vital to human well-being. Beneficial bacteria in agriculture improve soil fertility through nitrogen fixation, while mycorrhizal fungi form symbiotic relationships with plant roots, enhancing nutrient uptake. Decomposer microbes break down organic matter, enriching soil nutrients and supporting plant growth. Microorganisms aid in waste management through biodegradation and play a pivotal role in the production of antibiotics, vaccines, enzymes, and fermented foods like curd, pickles, and idli. In India, microbial diversity supports traditional fermentation processes, probiotic foods, and biopesticides, contributing to sustainable agriculture and food security. Microbes are also employed in bioremediation to clean up oil spills and industrial pollutants, demonstrating their environmental significance.

However, biodiversity loss due to deforestation, habitat destruction, pollution, invasive species, and climate change threatens this delicate balance. We shall deal with this aspect at a later chapter. The extinction of plant and microbial species can disrupt ecosystems and diminish resources vital for human survival. Conservation efforts and sustainable practices are crucial to safeguard plant and microbial diversity, ensuring their continued contributions to human welfare. India's rich biodiversity, coupled with indigenous knowledge, offers a unique opportunity to harness natural resources responsibly for future generations.

3.2 Uses of plant

You understandthat species of plants provide an array of products used by people worldwide. Certain plants can be exploited directly from the wild, while others sustain humanity through cultivation. Despite vast amounts of research, the different aspects of plant biodiversity as a global resource are still not properly understood. Knowledge of plant use from indigenous people has not been translated into wider use largely because of poor documentation of ethnic information. However, plants have been a major source of food, medicine, horticultural and ornamental plants, timber, fibre, dyes and other chemicals, fuel and renewable energy, and a host of other products used in industry and commerce. A general outline of the major uses of plants is provided below.

3.2.1 Food

The most important contribution of plants to humanity is food. In the early years of man's evolution, plants were consumed raw, obtained from the wild. Tribal communities gather food from the wild even today, throughout the world. However, as civilisation progressed, man began to domesticate plants for food. Of the ca. 250,000 species of flowering plants, 75,000 species are considered edible, but till today, only ~3000 are regarded as a source of food. Of these, around 200 plant species have been domesticated with 15-20 constituting crops of major economic value. Species belonging to families Poaceae, Papilionaceae, Brassicaceae, Rosaceae, Apiaceae, Solanaceae, Lamiaceae, Chenopodiaceae, Araceae, Cucurbitaceae and Asteraceae are the major sources of food. Global climatic changes are expected to cause large-scale shifts in natural vegetation and agricultural crops. Hence there is urgent need to protect genetic resources of food plants to maintain crop productivity in different climatic conditions. There are several species of useful plants in the tropics alone, whose uses could be extended from emergency sustenance in isolated locations or disaster areas to fully exploitable alternative sources of food. Future prospects are limitless but unforeseeable.

3.2.2 Fodder & Forage

Fodder crops are those used primarily for animal feed. Many species of plants are used as *fodder*. They are either used directly from the wild, as in pastures and rangelands, or domesticated. Grasses and legumes are the most important fodder sources. *Forages* are plants or parts of plants eaten by livestock (cows, horses, sheep, and goats) and wildlife (deer, elk, moose, rabbits).

3.2.3 Timber

Wood, the source of timber, is one of the most utilised commercial plant commodities. Although predominantly harvested from the wild, monoculture plantations under agro-and social-forestry programmes are increasingly being raised as a source of timber. Malaysia, Myanmar, Indonesia, Papua New Guinea and Gabon are the most important tropical countries involved in timber trade. Wild sources of timber, especially from *hardwoods*, are predominantly tropical and they account for a very significant proportion of export earnings for developing countries. *Softwoods* come mostly from the USA, some European countries and former USSR provinces. Wood is exported as logs, sawn wood or plywood. It is difficult to assess the extent to which timber, either for domestic consumption or for export, is derived from plantations. Industrial timber plantations of temperate countries predominantly consist of coniferous species. Ghana has 674 tree species of great timber potential, but timber is exploited from only 60 of those species. Peninsular Malaysia has about 3000 tree species, of which over 400 have been a source of good timber for national and international markets. Because of continual exploitation and dearth of adequate replantation, most timber tree species of the tropics are now threatened. Habitat losses, forest fragmentation, improper and inadequate management, have all contributed to this threat. More than 80 tree species of timber value are already listed as endangered all over the world.

3.2.4 Rattans & Canes

Rattans are species of Old World, mostly climbing vine-like palms of family Arecaceae, subfamily Calamoideae, such as *Calamus manan, C. thwaitesii*, *C. oblongus*, ssp. *mollis*. About 600 species spread across 13 genera, they are abundant in the tropics of SE Asia, Australasia and Africa. A majority of them are endemics. They play a crucial role in the ecosystem of tropical forests, providing habitat and food for much wildlife. They are strong and flexible and can withstand a pressure of 350 MPa. Rattan palms are prized for lightweight and durable furniture, handicrafts and building materials, among other uses. Most commercially harvested species are *pleonanthic* (flowers and fruits continually), because *hapaxanthic* (those that flower and fruit only once and then die) rattans tend to have soft piths making them unsuitable for bending.

Rattan canes are the outer barks of rattan palms. They are one of the world's most valuable non-timber forest products, widely used for cane furniture, mats, baskets, fish traps, dyes, medicines etc. Rattans and canes are one of the most important resources which are exported from the tropics. The Philippines, China, Indonesia, India, Sri Lanka and Thailand are the most important rattan exporting countries.

3.2.5 Medicinal plants

Plants are very important in health care. In less developed/ developing countries, 80% of the people still rely only on traditional medicines obtained from local plants and 85% of traditional medicine involves the use of plant extracts. Further, since adequate healthcare facilities and allopathic doctors are absent in much of the tropics, any destruction of tropical forests would simultaneously destroy the primary healthcare network involving local plants and traditional doctors. Some 200 chemicals extracted in pure form from ca. 90 plant species are used in medicine throughout the world, i.e., about half of the world's medicinal compounds are still derived or obtained from plant sources. Many of these chemicals cannot be synthesised. There is clearly a great range of higher plants from which to draw and there is also a great repository of traditional knowledge in the various cultures/societies of people using medicinal plants. WHO has listed over 21,000 plant species worldwide, which are reportedly of medicinal value. More than 2500 species of plants are used in the Ayurveda, Siddha, Unani and other traditional healthcare systems. According to the IUCN Red List 2020, a total of 457 species are listed under medicine for human and veterinary use. Of these, 73 are 'threatened'. Natural plant diversity might be increasingly valued for the 'blueprints' it provides for new synthetic drugs, in spite of an increasing technology to design and manufacture synthetic drugs. In OECD (Organization of Economic Cooperation and Development) countries, the potential annual market value of medicinal plant species likely to disappear before the year 2050, is US $60 million. This figure is a mere 0.15% of the amount spent on plant-based medicines. It represents a benefit foregone rather than an actual loss. It is, however, only a market value and does not include other components of the total economic worth of the drugs, such as the cost to a society deprived of them and the benefits of good health. Therefore, the total economic value could be 5 to 50-fold higher.

Medicinal plants, especially those used in traditional medicine, are still largely harvested from the wild and relatively few are cultivated. Cultivation has been attempted only for the last 25 years and a number of medicinal plants have reportedly lost/ become poor in medicinal properties upon cultivation. Yet species such as *Papaversomniferum, Cinchona officinalis, Mentha piperita, Ocimum sanctum, Digitalispurpurea, Gentiana lutea, Valeriana mexicana, Catharanthus roseus* and others have been effectively domesticated. Because of constant exploitation, a number of medicinal taxa have become threatened in various parts of the world. Such taxa include species that are critically endangered (CR)–*Commiphora wightii, Gymnocladusassamicus, Nardostachysjatamansi, Paphiopedilum druri, Saussureacostus*; endangered (EN)–*Aconitum heterophyllum, Coffea arabica, Nepenthes khasiana, Taxus wallichiana*; vulnerable (VU)–*Boswellia ovalifoliolata,* *Cephalotaxusmannii, Cinnamomum macrocarpum, Curcuma pseudomontana, Hydnocarpuspentandrus*; near-threatened (NT)–*Albizzia thomsonii, Allium roylei, Dioscorea hamiltonii, Pterocarpus marsupium* and others.

3.2.6 Ornamentals

Ornamentals are domesticated wild plants and like food plants have a long history. In China, lilies have been cultivated for more than 2000 years; roses, violets, anemones, narcissi and lavender have a similar long history of cultivation in Rome. The number of ornamental and decorative plants under cultivation far exceeds the number of food plants. In the UK alone, ca.3000 species are ornamentals. Ornamentals contribute significantly to international trade, the major exporters being the Netherlands, Colombia, Italy, Germany and Ecuador. The global market size in flowers and ornamentals in 2023 was US$ 43.09 billion. India's total export of floriculture was Rs. 717.83 crores / US$ 86.63 million in 2023-24.Both whole plants and cut organs such as flowers, leaves and twigs have ornamental value. Among whole plants of importance, the most important are orchids, cycads, succulents (cacti and euphorbias), insectivorous plants and bulbous species. Cut flowers of orchids, tulips, lilies, narcissi, violets, roses and anemones are prized commodities. The Indian floriculture industry comprises flowers such as rose, tuberose, gladiolus, anthurium, carnations and marigold. Thailand, Malaysia and India account for major trade in tropical orchids. Although a number of these orchids are artificially propagated in vivo and in vitro, exploitation from natural habitats is still enormous, threatening endangerment of many orchid species. In Japan, already 70 taxa of orchids have entered the Red data lists. Plants listed in Appendix I of CITES (endnote) are accorded the highest level of protection. Included in the list are orchids like *Dendrobium cruentum, Paphiopedilum* species and a few others. The rest of the orchids are in Appendix II, in which international trade may be authorized by granting of an export permit or re-export certificate. Over 25 million orchids are traded annually in the world – 95% of which are actually propagated Appendix II species or hybrids. All species of cycads are in Appendix II, except *Cycas beddomei*, which is native to India (and included in Appendix I). The highest trade in cycads is as an ornamental, 90% of which is in one species, *Cycasrevoluta*.

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endnote : CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species.

They are cultivated mostly in Costa Rica. The average international trade in cacti per annum is ~ 14 million plants as per CITES statistics, which appears to be a gross underestimate. One nursery in the Netherlands alone produces over 18 million cacti annually, between 10-50 million in the USA, while Mexico exports around 50,000 every year.

3.2.7 Other uses

Plants have several other uses but only the most important are mentioned here. A number of species yield fibres of great value for cloth and other industrial purposes. Cotton, linen, jute, sisal, hemp, coconut, etc. are some of the fibres obtained. A number offibre plants have been domesticated (cotton, linen, jute etc) but fibres from wild taxa are still widely obtained, especially in tribal and rural areas. Plants offer a good source of fuel, either wood (firewood) or its transformed product, charcoal. Plant biomass from any source can also be converted into fuel. In fact, plants are very efficient sources of renewable energy. Natural rubber, latex, gums, resins, dyes, essential oils and beverages are some of the other products of commercial value obtained from plants.

3.3 Uses of microbes

Humans and microbes have an intimate and intricate relationship at many levels of our existence. We are hosts to many prokaryotic and eukaryotic symbionts, and of course victims, of bacterial and protozoan pathogens. Before the existence of microbes was even known, humans have utilized various microbial processes and have learnt to prevent their adverse effects too. Microbiological technologies which have been in use since prehistoric times include use of fermented foods involving lactic acid bacteria and propionic acid fermenters; and the production of vinegar from ethanol. Their gastronomic contributions apart, these techniques have served to prevent or control undesirable or even dangerous microbial spoilage of food -- the purpose behind salting, smoking or acidifying food. It has also been suggested that the use of spices and drinking of wine, rather than water, also served to control pathogenic microbes. A list of some microbes used in food and beverage preparation has been listed in Table 3.1.

A quite different use of microbes is in acid mine leaching, which was also in use long before the underlying mechanism was understood. In copper mines, circulating water through crushed copper ore leads to acid conditions and dissolution of the ore; metallic Cu is then recovered from the leachate by chemical methods. The underlying microbial process involves a consortium of acidophilic and chemoautotrophic bacteria (including *Thiobacillus ferrooxidans*) which oxidize both the reduced S and the reduced Fe of pyrite (FeS_2), which is omnipresent in many ores. The resulting sulphuric acid dissolves the ore.

Biological sewage treatment serves primarily to mineralize organic material. Various types of sewage treatment are in use, depending, among other factors, on the scale of the plant; most systems involve aerobic and anaerobic microbial processes. An important aspect is the flocculation of bacteria, a process which is enhanced by the presence of protozoa. Removal of nitrate by microbial denitrification is another important function of biological sewage treatment, whereas phosphate is primarily removed by chemical precipitation. Mainly in smaller plants, anaerobic mineralization can be exploited to produce methane, which can be collected and subsequently used for heating. In recent times, mass production of certain species of bacteria for the production of enzymes and antibiotics has played an important industrial role. Recently, genetically engineered bacteria that express human protein genes (e.g., insulin and other hormones) have been used in the pharmaceutical industry. Microbial diseases, of which there are many, represent the most direct encounter between humans and microbes. Through recorded history such diseases have played an important role for human populations, most dramatically illustrated, perhaps, by the recurrent plague epidemics in Europe from medieval times to ca 1700 AD. However, many other bacterial diseases such as cholera, tuberculosis, leprosy, typhoid fever, and protozoal diseases such malaria, were also important. In North America, Europe, and in some other parts of the world serious bacterial and protozoal diseases have, especially after World War II, largely been brought under control due to the combined effects of hygienic measures, vector control (mosquitoes and rats), immunization programmes, antibiotics and other forms of chemotherapy. However, globally, tuberculosis and malaria remain among the most frequent causes of death. Many bacterial and protozoal diseases of livestock are economically significant. Evolving resistance to antibiotics and other types of chemotherapy in pathogens of humans and animals is a major problem. This indicates that our interactions with pathogenic microorganisms are not yet over, nor will it ever be. They are all part of the web of life.

Table3.1. List of some microorganisms used in food and beverage preparation

Name of Microorganisms	Type	Food and Beverages
Acetobacter aceti	bacterium	chocolate, vinegar
Aspergillus acidus, A. oryzae	fungus	tea, liquor sake
Bacillus cereus, B. coagulans, B. licheniformis	bacterium	Chocolate, dairy, products
Brachybacterium alimentarium	bacterium	cheese
Candida colliculosa	fungus	cheese
Enterococcus faecium	bacterium	soy sauce, vegetable pickle
Lactobacillus acetotolerans, L. acidophilus, L. fermentum, L. fermentum, L. gasseri, L. paracasei, L. plantarum	bacterium	fruit, bread, vegetables, yogurt, dairy, meatcheese
Lactococcus lactis,	bacterium	dairy buttermilk
Leuconostoc mesenteroides, L. citreum	bacterium	vegetables, wine, fish
Mucor hiemalis	fungus	soy bean
Pemicillium camemberti, P. commune, P. roqueforti	fungus	cheese, medicines, antibiotic
Saccharomyces cerevisiae	fungus	beer, bread, cider, cheese, chocolate, wine
Staphylococcus succimus S. vitulinus, S. warneri	bacterium	dairy, meat, cheese, meat

SAQ I.

(a) What role do plants play in maintaining atmospheric balance?

(b) Why is India considered a megadiverse country?

(c) How do microbes contribute to soil fertility?

(d) Mention two medicinal plants widely used in India.

(e) What is bioremediation?

3.4 The Plant Microbiome

The plant microbiome refers to the diverse community of microorganisms, including bacteria, fungi, viruses, and archaea, that live in and around plants. These microbes are found in different plant-associated environments, such as the rhizosphere (soil near plant roots), phyllosphere (aerial plant parts), and endosphere (inside plant tissues). The plant microbiome plays a crucial role in maintaining plant health, improving growth, and contributing to human health through its impact on agriculture and food quality.

3.4.1 Importance of the Plant Microbiome for Plant Health

A. **Nutrient Acquisition :** Microbes enhance the availability and uptake of essential nutrients such as nitrogen, phosphorus, and potassium. Nitrogen-fixing bacteria, like Rhizobium, form symbiotic relationships with legumes to convert atmospheric nitrogen into a form plants can use.

B. **Plant Growth Promotion :** Certain bacteria, known as plant growth-promoting rhizobacteria (PGPR), produce phytohormones like auxins that stimulate plant growth and root development.

C. **Disease Suppression :** Beneficial microbes can inhibit the growth of plant pathogens through competition, production of antimicrobial compounds, or by inducing plant resistance mechanisms.

D. **Stress Tolerance :** Microbes help plants withstand abiotic stresses like drought, salinity, and heavy metals by enhancing root water absorption, producing stress-relieving compounds, and improving soil structure.

E. **Biocontrol Agents :** Microbial biocontrol agents can be used as eco-friendly alternatives to chemical pesticides, reducing environmental pollution and improving plant resilience.

3.4.2 Importance of the Plant Microbiome for Human Health

A. **Food Security :** A healthy plant microbiome enhances crop yield and quality, ensuring a stable and nutritious food supply. Microbes can reduce the need for chemical fertilizers and pesticides, promoting sustainable agriculture.

B. **Nutritional Quality :** Microbial interactions influence the nutrient content and bioavailability in crops, contributing to human nutrition and reducing the risk of micronutrient deficiencies.

C. **Food Safety :** Certain plant-associated microbes can prevent contamination by harmful pathogens (e.g., Salmonella, E. coli), ensuring food safety from farm to table.

D. **Environmental Sustainability :** Microbiome-based agricultural practices reduce chemical inputs, minimizing soil and water pollution, thus promoting environmental health, which indirectly benefits human health.

E. **Phytochemicals and Medicinal Plants :** Microbes can stimulate the production of bioactive compounds in plants, enhancing their medicinal properties and supporting pharmaceutical advancements.

3.5 Summary

The world is a host to over 390,000 plant species and an immense variety of microbes, including viruses, archaea, bacteria, protists and fungi. Plants sustain ecosystems, support the food chain, and contribute to oxygen production and carbon dioxide absorption. Microbes play critical roles in nutrient cycling, decomposition, agriculture, medicine, food production, and environmental management. India is one of the 17 megadiverse countries, with over 45,000 plant species and countless microbes due to its varied climatic zones. Biodiversity hotspots like the Western Ghats, the North East Himalayas and the Indo-Burma region, contribute significantly to this richness. Traditional knowledge systems like Ayurveda and ethnobotanical practices are deeply linked to this biodiversity.

Plants provide food, fuel, fibre, timber, and medicine; regulate atmospheric balance; prevent soil erosion; and support biodiversity. Microorganisms improve soil fertility, decompose organic matter, produce antibiotics and vaccines, aid in fermentation, and assist in bioremediation. However, a number of factors threaten plant and microbial diversity, posing risks to ecosystems and human welfare.

The plant microbiome is a critical component of both plant and human health. Leveraging the potential of beneficial plant-associated microbes can lead to sustainable agriculture, improved food security, and better health outcomes. Understanding and managing the plant microbiome is a promising approach to address global challenges like climate change, food scarcity, and environmental degradation.

3.6 Terminal Questions

(a) Answer the following questions in brief :

(i) What is the importance of plant diversity in sustaining human welfare and environmental balance?

(ii) State the role of microbes in agriculture, medicine, and environmental management.

(iii) How do plants and microbes collectively contribute to food security and health in India?

(iv) Define a plant microbiome.

(v) Outline the importance of plant microbiomes in promoting and sustaining plant health.

(b) Fill in the blanks :

(i) _____________ is a symbiotic association between fungi and plant roots.

(ii) India is home to over ________plant species.

(iii) Microorganisms aid in the production of __________which are essential for disease treatment.

(iv) _________ help prevent soil erosion and regulate water cycles.

(v) Neem is a ____________medicinal plant known for its antibacterial properties.

(c) State whether the following statements are 'True' or 'False'.

(i) Microbes are only harmful to humans.

(ii) Plants do not contribute to climate change mitigation.

(iii) India has biodiversity hotspots like the Western Ghats and NE Himalayas.

(iv) Decomposer microbes deplete soil nutrients.

(v) Ayurveda relies heavily on plant-based treatments.

3.7 Answer key

SAQ I.

(a) Plants produce oxygen through photosynthesis and absorb carbon dioxide, helping to mitigate climate change.

(b) India with only 2.4 per cent of the world's land area supports 8.1 % of the world's species diversity, making it one of the world's 12 mega diversity countries. It has diverse climatic zones and ecosystems, and globally identified biodiversity hotspots like the Western Ghats and the Himalayas, and is home to over 45,000 plant species and twice as many animal species, making it one of the richest biodiversity regions on Earth.

(c) Microbes, such as nitrogen-fixing bacteria and decomposers, enrich soil nutrients and enhance plant growth.

(d) Neem and turmeric.

(e) Bioremediation is the use of microorganisms to remove pollutants and restore contaminated environments.

Terminal Questions

(a) (i) Plant diversity ensures ecological stability, provides food, medicine, raw materials, and mitigates climate change by maintaining atmospheric balance and preventing soil erosion.

(ii) Microbes improve soil fertility, decompose organic matter, produce antibiotics and vaccines, aid in fermentation, and clean up pollutants through bioremediation.

(iii) Plants provide staple crops and medicinal herbs, while microbes enhance soil fertility, support fermentation, and produce antibiotics, ensuring agricultural productivity and healthcare.

(iv) It is the diverse community of microorganisms, including viruses, archaea, bacteria, fungi, and protists that live in and around plants.

(v) See Section 3.4.1

(b) Fill in the blanks.

(i) mycorrhiza; (ii) 45,000; (iii) antibiotics; (iv) forests; (v) traditional

(c) 'True' or 'False'

(i) False; (ii) False; (iii) True; (iv) False; (v) True

3.8 References and Further Reading

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Unit – 4 ❑ Loss of Biodiversity

Structure

4.0 Objectives

- To learn about the reasons for the loss of species, genetic, ecosystem, and agrobiodiversity.
- Learn about IUCN and its threat categories.
- To know the current status of threatened species from its census.

- To understand the current scenario of biodiversity loss and its implications.

4.1 Introduction

We already know that biodiversity can be expressed at different levels of biological organisation such as genes, species, ecosystems and agricultural crops, livestock and beneficial microbes. All these four forms of biodiversity can be subjected to loss, although the most easily recognisable form of loss is that of species. Since the different forms of diversity are intimately related to one another, biodiversity loss at any one level will lead to loss at all other levels. *Genetic Diversity* refers to the total number of genetic characteristics in the genetic makeup of a species. It is crucial for the adaptability and survival of species, as it allows them to adapt to changing environments and resist diseases. *Species diversity* is the variety of species within a specific ecosystem. It includes both the number of species and their relative abundance. High species diversity is often associated with ecosystem stability and resilience. Ecosystem Diversity refers to the variety of ecosystems in a given place. It encompasses different habitats, biotic communities, and ecological processes. This diversity is essential for providing ecosystem services such as air and water purification, pollination, and climate regulation. *Agrobiodiversity* is the variety and variability of plants, animals, and microorganisms used directly or indirectly for food and agriculture. It includes the diversity of crops, livestock, and wild species that contribute to sustainable agricultural systems. The International Union for Conservation of Nature (IUCN) Red List categorizes species based on their risk of global extinction. There are nine such categories. The census of threatened species involves assessing the population sizes and distribution of species to determine their conservation status. This data is crucial for prioritizing conservation efforts and allocating resources effectively. The primary factors responsible for biodiversity loss include habitat destruction–deforestation, urbanization, and agricultural expansion lead to the loss of natural habitats; climate change–changes in temperature and precipitation patterns which affect the survival and distribution of species; overexploitation–overfishing. hunting, and harvesting of species at unsustainable rates; pollution–contamination of air, water, and soil which affects the health of ecosystems and species; invasive species–non-native species can outcompete, prey on, or bring diseases to native species; human population growth – increased demand for resources which lead to habitat destruction and overexploitation.

Currently, biodiversity loss is occurring at an alarming rate. According to the IUCN Red List, more than 46,300 species are threatened with extinction, which is about 28% of all assessed species. Amphibians, mammals, conifers, birds, sharks, and reef corals are among the most affected groups. If current trends continue, biodiversity loss is projected to accelerate. Climate change, habitat destruction, and overexploitation are expected to drive many species to extinction. Conservation efforts and sustainable practices are crucial to mitigate these impacts.

4.2 Loss of biodiversity–factors responsible

As you know, biodiversity is the intricate web of life on Earth, which is crucial for ecosystem stability, resilience, and health. Let us have a quick glimpse at the primary factors that contribute to its decline.

- *Habitat Destruction*—it includes deforestation, urbanization, and agricultural expansion, all of which result in the loss of natural habitats for many species. Fragmentation of habitats into smaller, isolated patches limits the ability of a species to move, find mates, and access resources, leading to population declines and reduced genetic diversity. Modern agricultural practices, including monoculture and pesticide use at the same, reduce habitat diversity and harm pollinators and other beneficial species. They also contribute to soil degradation and water pollution.

  Climate Change–It is a significant driver of biodiversity loss. Changes in climate patterns affect ecosystems and species. Rising temperatures, altered precipitation patterns, and more extreme weather events disrupt habitats and the species that depend on them. Key impacts include:

  - Shifts in Species Distribution—Many species are forced to migrate to new areas with suitable climates, which can lead to changes in species composition and ecosystem dynamics.

  - Altered Phenology—Changes in the timing of biological events, such as flowering, migration, and breeding, can disrupt ecological interactions and lead to mismatches in food availability.

  - Coral Bleaching—Rising ocean temperatures leads to coral bleaching, where the corals expel the symbiotic algae that rely on them for nutrition, leading to coral mortality.

- Melting Polar Ice—The loss of polar ice habitats threatens species like polar bears and seals, which depend on ice for hunting and breeding.

- *Overexploitation*—It refers to the unsustainable harvesting of species for commercial, recreational, or subsistence purposes. It can lead to population declines and extinctions. Key examples include:

  - Overfishing—The depletion of fish stocks due to excessive fishing pressure disrupts marine ecosystems and affects the livelihoods of coastal communities.

  - Hunting and Poaching—The illegal hunting of wildlife for bush-meat, trophies, and traditional medicine endangers species such as elephants, rhinoceroses, and tigers.

  - Timber Extraction—Unsustainable logging practices deplete forest resources and disrupt habitats for forest-dwelling species.

  - Wildlife Trade—The trade in exotic pets, plants, and animal products contributes to the decline of many species.

Overexploitation often affects species faster than they can reproduce.

- *Pollution*–pollutants, including pesticides, plastics, and industrial chemicals, can harm or kill wildlife and disrupt ecosystems. Water pollution affects aquatic life, while air pollution can damage terrestrial habitats and species.

- *Invasive Species*–non-native species introduced by human activities can outcompete, prey on, or bring diseases to native species, leading to declines in biodiversity. Invasive species often disrupt the balance of local ecosystems.

  - Competition—Invasive species can outcompete native species for resources such as food, space, and nesting sites.

  - Predation—Introduced predators can significantly reduce native prey populations, especially on islands where species may have evolved without natural predators.

  - Disease Transmission—Invasive species can introduce new pathogens to which native species have no immunity, causing outbreaks and population declines.

  - Habitat Alteration—Some invasive species can alter habitats by changing soil composition, water availability, or fire regimes, making them unsuitable for native species.

- *Human population growth*–it is bound to increase demand for resources which lead to habitat destruction and overexploitation. The demand for land, resources, and goods often leads to practices that harm biodiversity.
- *Disease*–emerging infectious diseases can decimate species populations. Pathogens can spread quickly, particularly in areas where species are already stressed by other factors like habitat loss and climate change. When biodiversity is high, the risk of disease transmission from animals to humans (zoonotic diseases) is often lower.
- *Poor Governance*–lack of effective environmental policies, enforcement, and management can lead to unsustainable practices that degrade ecosystems and biodiversity. Corruption and inadequate funding also contribute to poor conservation outcomes.

Biodiversity loss is a complex issue influenced by interrelated factors. Addressing it requires coordinated efforts at local, national, and global levels, including conservation strategies, sustainable practices, and policy interventions.

Addressing biodiversity loss is crucial not only for the health of our planet but also for the well-being of humanity. Often it exerts a significant impact on local economies. *Ecosystem services* are usually affected. For example, we know that forests and wetlands filter and regulate water supplies and act as natural buffers against floods. A degraded ecosystem can lead to reduced water quality and increased treatment costs for local communities. Loss of such nature's buffers lead to more damages and a higher cost to flood control. Conservation efforts, sustainable practices, and policies that protect and restore biodiversity are essential for maintaining the ecosystem services and benefits that support our lives. Healthy marine ecosystems support tourism and recreational fishing, which can be important sources of income for coastal communities. Biodiverse regions attract tourists for activities like wildlife watching, hiking, and diving. Biodiversity loss can reduce the appeal of these destinations, leading to decreased tourism revenue. Many cultures are deeply connected to their natural environment. The loss of biodiversity can erode cultural practices and traditions.

Long back, Sala *et al*. (2000) had identified five important determinants for changes in biodiversity at the global scale. They were—changes in land use, atmospheric CO_2 concentration, nitrogen deposition and acid rain, climate, and biotic exchanges (i.e. deliberate or accidental introduction of organisms into an ecosystem). Next, they calculated the expected change from these drivers in each biome. This was followed by estimation of the impact on biodiversity in each biome, which a unit change in each driver would exert. They found that for terrestrial biomes, land-use changes would probably have the largest effect, followed by the effect of changes in climate, nitrogen deposition, biotic exchanges and elevated CO_2 concentrations. Biotic exchange is however much more important for a freshwater ecosystem. Mediterranean and grassland ecosystems were likely to experience the greatest losses in biodiversity. Loss of biodiversity in North Temperate ecosystems was likely to be the least because major land-use changes have already occurred in this region (Sala *et al.*, 2000).

4.3 Loss of Genetic Diversity

You must remember that uncontrolled loss of species is almost always accompanied by the loss of genetic diversity. When a species is lost, all genetic information carried by that species, a substantial amount of the gene pool, is also lost. Species loss is usually preceded by fragmentation of its contiguous populations to result in many small, isolated populations. Genetic diversity present in the whole contiguous population is also fragmented and with the gradual loss of fragmented populations, their genetic diversity is also lost. Genetic diversity is usually analysed at the population level. Hence, loss of genetic diversity is also examined in populations. The annual losses of populations are around 0.8%, which is equivalent to about 1800 populations every hour (Hughes *et al.*, 1997). Genetic diversity is important for fitness and adaptive changes; loss of genetic diversity, therefore, becomes a serious matter for concern, as it will affect the suitability and evolutionary adaptability of a species.

4.3.1 Factors Causing Loss of Genetic Diversity

Reduction in genetic diversity within populations of species usually results from *four* factors : founder effects, demographic bottlenecks, genetic drift and inbreeding depression.

Founder Effects : Founder effects occur when only a few individuals (called 'founders') of an originally larger population establish a new population. The genetic constitution of the newly established population will depend on the genetics of its founders. If the founders are not true representatives of the larger parent population in terms of their genetic constitution, or if only a few founders are involved in establishing a new population, then the newly established population is a *biased* (in terms of genetic diversity) representation of the original larger gene pool (of the parent population of founders) from which it came; thus it may have lower overall genetic diversity.

Demographic Bottlenecks : When a larger population suddenly experiences a severe, temporary reduction in size for whatever reasons, a demographic bottleneck results. The outcome of such a bottleneck is that the genetic diversity of all subsequent generations is contained in the few individuals (of the original population) that survive the bottleneck and reproduce. We could expect to lose some genetic diversity in the process.

Genetic Drift : This represents a random change in gene (or allele) frequencies in small populations. In mathematical terms, it represents a chronic bottleneck that results in repeated erosion of heterozygosity (i.e., increase in homozygosity), loss of variability and eventual loss of genes or alleles; rare alleles are frequently lost. A reduction in diversity of allelic combinations is also evident in subsequent generations. Genetic drift is believed to be a key factor in the loss of genetic diversity and therefore is important in conservation efforts.

Inbreeding Depression : Inbreeding can be defined as mating of individuals related by common ancestry. There is greater probability of inbreeding occurring in smaller populations. The most important consequence of inbreeding is *inbreeding depression* which may be defined as a 'decrease in the mean of a character upon inbreeding' (Lande, 1996). Inbreeding depression causes growth rate to decline, vigour and fertility to reduce, survival rate to decrease. All of these individually or in combination, will be evident in any component of fitness, under a specific environment. A reduction in heterozygosity with concomitant increase in homozygosity is one of the most detrimental genetic outcomes of inbreeding.

4.4 Loss of Species Diversity

The loss of species is a natural process. We know from fossil and historical data that all species have a definite life span. We are also aware of forces that led to the loss of species and those that allowed certain species to survive. The fossil data suggest that as much as a quarter of Earth's species become extinct each million years. The actual reasons for this loss are not known. The explanations offered thus far, range from interspecific competitions, climatic changes, accumulation of deleterious genes, inbreeding, or from impacts of asteroids or other extraterrestrial objects. Well over 95% of all species that have evolved on this Earth thus far is already extinct. In fact, extinct species outnumber living ones by a factor of thousand to one (Krishnamurthy, 2003).

A species is said to have become extinct when all its individuals are lost without leaving any progeny. Such loss of species is called *true extinction*. There are also, what are called *pseudo extinctions*—disappearance of a species when its lineage is transformed over evolutionary time or it splits into two or more separate lineages. Extinctions of the 'true' type generally occur when a natural or man-made environmental change or challenge exceeds the adaptive capacity of the individuals of a species; furthermore, there is no safe place to which the species could retreat. Species extinction without the intervention of man is often called background extinction (Raup, 1978). The background extinction rate, on average, is calculated to be 4 million years for one species (Raup 1991). This may appear to be an incredibly long time to humans but is remarkably short with reference to the nearly 4000 million years of history of life on Earth.

On Earth, the history of life has been interrupted by a series of mass extinctions. A *mass extinction* is one which is accompanied by a massive loss of biodiversity on a global scale, that affects a broad range of taxonomic groups over a very short period of geologic time (Jablonski, 1986). Though of course, mass extinctions can occur over shorter or longer durations of several million years. In all, eight extinction events have been identified and grouped into *five* major mass extinction episodes (Raup and Sepkoski, 1982) :

(i)	Ashgillian	end Ordovician
(ii)	Givetian	
(iii)	Frasnian &	late Devonian
(iv)	Famennian	
(v)	Guadalupian	
(vi)	Dzhulfian	end Permian
(vii)	Norian	end Triassic
(viii)	Maastrichtianend Cretaceous	

Most species extinctions have been due to these mass extinctions. For example, during the mass extinction of the Permian-Triassic boundary 96% of all Earth's species at that time reportedly perished.

4.4.1 Species Extinction

It was earlier remarked that species extinction is a natural process and that during history of the Earth, several mass extinction events have taken place. Natural extinctions are, however, distinct from those triggered by human intervention. Extinctions caused directly or indirectly by human beings occur at a rate that far exceeds the background extinction rate of 4 million years for one species, by a scale of 1000 to 10000 times. Species extinctions are currently underway at very high rates, on both local and global scales. Researchers believe that we are now in the opening stages of another mass extinction, the sixth extinction, triggered by human activities alone. If it continues unabated, the **sixth extinction** could easily surpass previous extinction episodes in magnitude (Given, 1996).

4.4.2 Processes responsible for Species Extinction

Two types of processes are fundamentally responsible for species extinction:

(i) Deterministic processes or Cause and Effect relationships : Such processes include glaciations, deforestation, habitat fragmentation, and so on. In these processes, some essential components of ecosystems are removed while others, lethal to the ecosystem, are added. Deterministic events are readily observed or easily detected.

(ii) Stochastic processes or chance events : *Four* types of stochastic or random processes are distinguished (Shaffer 1987).

(a) Demographic uncertainty : This results from the effect of random events on the survival and reproduction of individuals in a finite population. This phenomenon was studied in a small population of less than 100 individuals of *Astrocaryum mexicanum*, the chocho palm native to Mexico and Central America. It was observed that the probability of its survival exceeds 95% only whenthe population size comprised at least 50 individuals. It is generally accepted that greater the population size of a species, the better is its chance of survival.

(b) Environmental uncertainty : Unpredictable environmental components such as sudden changes in weather, food supply, disease incidence, sudden changes in number of competitors, predators and parasites, are known to cause species extinction. Unlike demographic uncertainty, there is no critical population size that once reached, guarantees a high level of long-term security from environmental uncertainty.

(c) **Natural catastrophes :** These are extreme cases of environmental uncertainty in the form of widespread floods, hurricanes, fire or drought. These catastrophes are usually short in duration but massive in impact.

(d) **Genetic uncertainty :** Random changes in the genome, due to a variety of reasons such as mutation, founder effects, genetic drift and inbreeding depression, contribute to genetic uncertainty. Deterministic and stochastic processes may act either independently or in concert. In the latter case, their effects compound each other.

4.4.3 IUCN Threat Categories

The IUCN Red List Categories are meant to be an easily and widely understood system for classifying species at high risk of global extinction (Fig. 4.1). This list measures the pressures acting on species, which guides and informs conservation practices, to help prevent extinctions. This is why the IUCN Red List is often referred to as a *Barometer of Life*. The general aim of the system is to provide an explicit, objective framework for the classification of the broadest range of species according to their extinction risk. However, while the Red List may focus attention on those taxa at the highest risk, it is not the only means of setting priorities for conservation measures, for their protection.Recognizing the need for coherent guidelines, the IUCN came up with "Guidelines for Application of the IUCN Red List Criteria at Regional and National Levels" (also called the *Regional Guidelines*). The IUCN calls it the "best-practice guidelines outlining the preferred practice" (IUCN, 2024).

Today, more than 163,000 species have been assessed for the *Red List*, which by itself is an incredible achievement, though the goal was to assess at least 260,000 species, and to reassess 142,000 of those (IUCN Red List strategic plan 2021-2030). Among the assessed species, 45,321 are threatened with extinction. Current gaps in the List pertain to plants, invertebrates, fungi, and freshwater and marine species. [See Box 4.1]

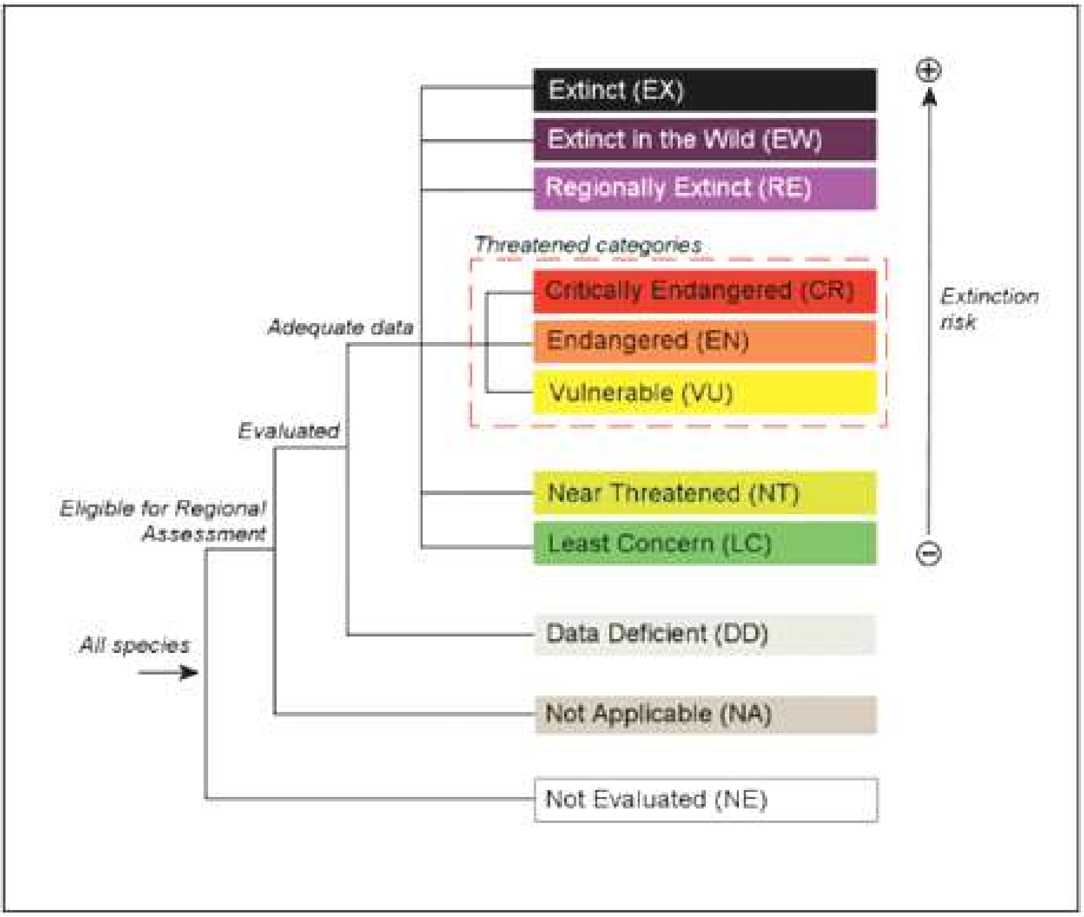

Figure 4.1 IUCN Threat Categories [Source: IUCN 2024, version 2024-1].

After a given species has been thoroughly evaluated, it is placed into one of several categories. In addition, three of the categories (CR, EN, and VU) are confined within the broader attribute of "threatened" (Fig. 4.1).The different categories of species status are defined below.

1. **Extinct (EX) :** A taxon is considered extinct when there is no reasonable doubt that the last individual has died.
2. **Extinct in the Wild (EW) :** A taxon is extinct in the wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.
3. **Regionally extinct (RE) :** A taxon is regionally extinct (RE) when there is no reasonable doubt that the last individual potentially capable of reproduction within the region has died or disappeared from the region

or, in the case of a former visiting taxon, individuals no longer visit the region.

Threatened :

4. **Critically Endangered (CR) :** those species that are at an extremely high risk of extinction due to rapid population declines of 80 to more than 90 percent over the previous 10 years (or three generations); a current population size of fewer than 50 individuals, or other factors.

5. **Endangered (EN) :** species that possess a very high risk of extinction as a result of rapid population declines of 50 to more than 70 percent over the previous 10 years (or three generations); a current population size of fewer than 250 individuals, or other factors

6. **Vulnerable (VU) :** species that are at a very high risk of extinction as a result of rapid population declines of 30 to more than 50 percent over the previous 10 years (or three generations); a current population size of fewer than 1,000 individuals, or other factors

   Rare (R) : Taxa with small populations, those that are not endangered or vulnerable at present but are at risk—are included under this category.

7. **Near Threatened (NT) :** A taxon is near threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely qualify for a threatened category in the near future.

8. **Least Concern (LC) :** A taxon is of least concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

9. **Data Deficient (DD) :** A taxon is data deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and / or population status.

A taxon falls under the *not evaluated* (NE) category when it was originally proposed under a threat category, but eventually was not discussed or evaluated against any threat criteria for whatever reason—including uncertainty about taxonomic or wild status. In short, it is a category used to include any of the ca. 1.9 million species described by science but not assessed by the IUCN.

It is important to understand, however, that a species cannot be classified by using one criterion alone; it is essential for the scientist doing the assessment to consider all five criteria when determining the status of the species.

BOX 4.1 Taxonomic gaps in the IUCN Red Data List

Plants – The IUCN Red List includes over 71,000 plant species, representing ~ 17% of the world's known plants. IUCN continues to pursue a range of assessment projects, including engaging with national Red List efforts. Examples include :

The *Plants for People initiative* focuses on assessing priority plant species in each of the following groups : crop wild relatives; medicinal plants; timber trees; and palms.

The *Global Tree Assessment* aims to assess the conservation status of every known tree species.

Freshwater species – The freshwater realm is incredibly species rich, supporting over 10% of all known species and 30% of vertebrates, despite covering less than 1% of the Earth's surface. It also hosts habitats and species of great value to human communities in terms of provision of livelihoods and ecosystem services. However, this realm is facing unprecedented levels of threat, with freshwater populations declining faster than those of any other biome. IUCN is working towards raising awareness of the importance and plight of freshwater species, and increasing their representation on The IUCN Red List, through assessment of the following freshwater taxonomic groups: decapods (crabs, crayfishes, shrimps); fishes; molluscs; odonates (dragonflies and damselflies); and selected aquatic plants.

Marine species – The marine realm is still poorly covered in The IUCN Red List, comprising less than 15% of the species assessed. IUCN has identified priority taxonomic groups of marine fish, invertebrates, plants (mangroves and sea-grasses) and macro-algae (seaweeds). If these priority groups can be assessed, the number of marine species on the IUCN Red List will be increased more than six-fold. For further details about the Global Marine Species Assessment, see the Global Marine Species Assessment website.

Reptiles – With the severe degradation of land across the globe, exacerbated by the impacts of global climate change, arid and semi-arid systems are expanding. At present, arid ecosystems are poorly covered by the species groups assessed so far and are also increasingly becoming degraded in most parts of the world. In 2022, the first comprehensive assessment of all reptile species was completed, which has helped towards filling this gap. Completion of the global reptile assessments means the IUCN Red List now includes assessments for all terrestrial vertebrates. Work is now underway to reassess this group, with the aim of calculating a Red List Index for reptiles.

***Invertebrates* –** The largest taxonomic group in the animal kingdom, it is estimated that around 97% of all animals are invertebrates. But invertebrates currently form only 30% of all animal assessments on The IUCN Red List. To improve representation of this important group, IUCN has prioritized specific taxonomic groups for assessment, including comprehensive assessments for bumblebees, monarch butterflies, swallowtail butterflies, freshwater crustaceans, dragonflies, velvet worms, giant clams, abalones, sea urchins, and selected families of spiders, scorpions, and grasshoppers.

***Fungi* –** Although fungi are one of the world's most bio-diverse groups, they are also the most under-represented taxa on The IUCN Red List, with fewer than 794 species assessments currently published. Fungi are vital components of ecosystems, are essential for nutrient recycling, and bring a wide range of benefits to human lives. To improve representation of fungi on the Red List, IUCN is currently focusing on assessing a range of fungi groups, including selected groups of lichens, mushrooms, rusts, smuts, truffles, chytrids, slime moulds, and mildews. For further information on fungi assessments, see The Global Fungal Red List Initiative website.

As more species are included on the IUCN Red List and the biases in the data are reduced, The IUCN Red List will provide a more solid basis for conducting global and regional analyses. In addition, these data will provide the basis for the indicators needed to measure progress towards the achievement of the Convention on Biological Diversity (CBD) Kunming-Montreal Global Biodiversity Framework (GBF) 2030 Targets and beyond, as well as the United Nations Sustainable Development Goals (SDGs), particularly Goal 15.

4.4.4 Census of Threatened Species

In the IUCN Red List 2024, version 1, summary statistics has been provided on each category of threatened species in all major taxonomic groups globally, continent and country-wise. Selected excerpts from this table will provide a clear idea on the status of different taxa.

Table 4.2. Number of threatened species in major groups, vis-à-vis the number of evaluated species among those described (Adapted from IUCN Red List 2024, ver.1)

	Estimated no. of described species	No. of species evaluated	P.C. of described species evaluated	No. of threatened Species	P.C. of extant species threatened
Vertebrates	75,665	63,470	84 %	11,336	21%
Invertebrates	1,490,254	27,752	2.0 %	6,322	Insufficient data
Plants & Red Algae					
Red algae	7,523	78	1.0%	9	Insufficient data
Green algae	13.960	17	0.1%	0	-
Bryophytes	21.925	327	1.5%	181	-
Pteridophytes	11,800	821	7.0%	321	-
Gymnosperms	1,113	1059	95.0%	451	43%
Angiosperms	369,000	68,704	19.0%	26,367	-
Fungi	156,313	794	0.5%	328	-
Protists-Brown algae	4,683	18	0.4%	6	-

Each year, the IUCN brings out such lists of threatened species belonging to different taxa at the global, continental and national levels. One can inspect the data from their website and understand the decadal trend of species at threat and the extent of their vulnerability. Such region and taxa-based specific information is indispensible for conservation efforts.

Table 4.3. The threatened categories in the major groups. Critically endangered-CR, Endangered-EN, Vulnerable-VU. (Adapted from IUCN Red List 2024-1).

Major Groups	**CR**	**EN**	**VU**
Mammals	235	546	557
Birds	232	405	717
Reptiles	430	789	625
Amphibians	799	1263	811

Major Groups	CR	EN	VU
Fishes	867	1396	1,664
Insects	435	994	986
Molluscs	745	642	1,064
Other invertebrates	324	391	741
PLANTS	5,915	11,477	9.937
FUNGI & PROTISTS	49	106	179
TOTAL	**10,031**	**18.009**	**17,281**

Table 4.4. The number of threatened species in India, across the major taxonomic groups. (Adapted from IUCN Red List 2024-1).

Mammals	98
Birds	88
Reptiles	106
Amphibians	139
Fishes	333
Molluscs	7
Other invertebrates	135
PLANTS	637

Table 4.5. The different categories of threatened species of plants in India. EX-extinct, EW- extinct in the wild, CR (PE)- Critically endangered (possibly extinct), CR (PEW) – Critically endangered (possibly extinct in the wild). CR-Critically endangered, EN- Endangered, VU- Vulnerable. (Adapted from IUCN Red List 2024-1).

EX	3
EW	2
CR (PE)	4
CR (PEW)	0
CR	150
EN	270
VU	217

For more information about national Red Lists published by countries across the world, one may consult the National Red List website (https://www.nationalredlist.org).

4.5 Loss of Ecosystem Diversity

Loss of Ecosystem Diversity may be considered the ultimate cause for loss of both species and genetic diversities. This has been substantiated by fossil data as well as information presently available. Both deterministic and stochastic processes described as responsible for species extinctions, are also responsible for loss of ecosystem diversity. This section delineates the threat factors affecting ecosystems in general, the magnitude of loss estimated for the major ecosystems of the world, and the major causes for such loss.

4.5.1 Factors Affecting Ecosystem Degradation and Loss

The various mechanisms involved in the loss of ecosystem diversity fall into five major categories : overkill, habitat destruction, impacts of introduced animals and weeds that later become invasive, pollution, and secondary losses.

Overkill refers to the uncontrolled organised collection (for scientific and industrial purposes) and killing of plants.

Habitat destruction can be brought about by a host of factors such as agriculture, housing, construction of roads and dams, industrial development, gravel and sand quarrying, wetland draining and filling, slash-and-burn (shifting) cultivation, desertification, tourism and so on.

Introduced animals, pests and invasive weeds impact ecosystems by displacing local taxa which adversely affects among others, community structure, biogeochemistry, fire regimes, erosion, geomorphology, hydrological cycle. At the same time, changes in the water table, trampling and overgrazing by animals, herbivory, unwanted competition between the introduced organisms and native ones, predation, diseases, disappearance of symbionts, pollinators and dispersers are some of the other changes introduced directly or indirectly by exotic invasive organisms.

Pollution can be caused by a number of factors, mostly anthropogenic. Land, water and air may all become polluted, affecting significantly different components of the ecosystem.

Secondary losses maybe induced by a combination of two or more of the aforesaid factors.

The single most important reason for loss or damage to ecosystems is habitat fragmentation. Fragmentation is defined as an unnatural separation of extensive areas of habitats into spatially segregated fragments that are too limited to maintain their different species for an infinite future. Most often it results in erosion of biodiversity. This fact was noted as early as 1855 by de Candolle, who found that breakup of a landmass into smaller units necessarily led to the extinction or local extermination of one or more species (Browne, 1983). Based on the forces in operation, fragmentation can be divided into five categories: Regressive, Enveloping, Divisive, Intrusive, and Encroaching. Fragmentation of larger habitats may lead to the creation of artificial terrestrial islands.

Such fragmented pieces of land experience microclimatic changes, with temperature and light markedly different from those that existed in the large tracts of habitat before fragmentation. Fragmentation promotes migration and colonisation of alien species. Such colonisation is often substantial and continuous, profoundly affecting the survival of native species. There is considerable evidence that the number of species in a fragmented habitat decrease over time, although the probable rates at which it happens could vary. In fact, actual data on rain forests show that forest fragments have lower species richness and fewer populations compared with continuous undisturbed forests, as may be expected.

4.6 Loss of Agrobiodiversity

Agrobiodiversity refers to the variety and variability of plants, animals, and microorganisms used for food and agriculture. It includes crop varieties, livestock breeds, and wild species that support agricultural systems. Most often, agrobiodiversity is equated with richness in crop varieties, i.e., the more the number of varieties within a crop species, the greater the agrobiodiversity of that crop species. Agrobiodiversity richness is also valued for the economic benefit derived from it. Loss of agrobiodiversity has narrowed species richness on a global level. Of the 400, 000 odd plant species reported on Earth at a conservative estimate, only ca 300, 000 have been documented. Of the latter, just 10% are edible (i.e., 30, 000 species) and among these species, 7000 have been either cultivated or collected by humans for food, feed or other agricultural purposes at one time or the other.

A mere 200 among them constitute major domesticates. And among them, only 30 are of supreme importance – of which just four are primary staple foods: rice (26%), wheat (23%), maize (7%) and potato (3%). These four crops alone account for approximately 25-28% of all 6.2 million accessionsof crops stored ex situ (WIEWS 1996). Furthermore, most of the money spent on genetic resources activities is expended on these four crops.

Besides the *narrowing down of species richness, a decrease in varietal diversity* in agrobiodiversity has also been noted. As 75% of the area under rice cultivation which once accommodated 30, 000 rice varieties, only 10 varieties are sown today. It must be understood that every new breeding activity adversely narrows the genetic base of the source variety. On the other hand, incorporation of new and favourable traits with introduced genes, serves to broaden the genetic base of the variety. Loss of genetically coded information from the agricultural field is on the rise, due to the rapid disappearance of traditional varieties and land races.

SAQ I.

1. What is genetic diversity and why is it important?
2. List six primary factors responsible for biodiversity loss.
3. What role does human population growth play in biodiversity loss?
4. Select the correct answer :

(a) What is the primary cause of habitat destruction?

(i) Climate change
(ii) Overfishing
(iii) Urbanization
(iv) Invasive species

(b) Which IUCN category indicates a species is 'vulnerable'?

(i) Critically Endangered
(ii) Endangered
(iii) Extinct in the Wild
(iv) High risk of endangerment in the wild

(c) Which of the following is NOT a factor responsible for biodiversity loss?

(i) Habitat destruction
(ii) Climate change

(iii) Overexploitation
(iv) Genetic diversity

(d) What percentage of all assessed species are threatened with extinction according to the IUCN Red List?

(i) 10%
(ii) 20%
(iii) 28%
(iv) 35%

(e) What role does human population growth play in biodiversity loss?

(i) Reduces genetic diversity
(ii) Increases demand for resources leading to habitat destruction and overexploitation
(iii) Stabilizes ecosystems
(iv) Reduces pollution

(f) Which combination of factors is most likely to exacerbate biodiversity loss in tropical rainforests?

(i) Climate change and invasive species
(ii) Urbanization and overexploitation
(iii) Pollution and habitat destruction
(iv) Human population growth and agrobiodiversity loss

g. How does agrobiodiversity contribute to the resilience of agricultural systems in the face of climate change?

(i) By increasing genetic diversity within crop species
(ii) By reducing the need for chemical fertilizers
(iii) By enhancing the pollination process
(iv) By decreasing water usage in irrigation

5. Match the two columns :

Column A	Column B
(a) Ecosystem services disrupted by pollution	(i) Increased resilience, improved soil health
(b) Factors leading to overexploitation	(ii) High market demand, lack of regulation

(c) Examples of invasive species impacts	(iii) Loss of species, altered ecological processes
(d) Results of habitat destruction	(iv) Outcompetition, disease transmission
(e) Climate change effects on biodiversity	(v) Shifts in species distribution, habitat alteration
(f) Agrobiodiversity benefits	(vi) Reduced water quality, loss of aquatic specie

6. State whether the statements are 'True' or 'False'.

(a) The number of species today threatened with extinction represents about 28% of all assessed species.

(b) A census of threatened species is crucial for prioritizing conservation efforts.

(c) Those species which are widespread and abundant are categorized in the Red List as 'not threatened.'

(d) High species diversity contributes to ecosystem stability and resilience.

(e) Some invasive species can alter habitats by changing soil composition, water availability, or fire regimes, making them unsuitable for native species.

4.7 Present status and Projected scenario for Biodiversity Loss

Global biodiversity loss is taking place at an unprecedented rate as a complex response to several anthropogenic changes. The magnitude of this loss is so great and so strongly linked to ecosystem processes and society's use of biodiversity resources, that it is now considered an important global change in its own right. According to the IUCN Red List, more than 46,300 species are threatened with extinction, which is about 28% of all assessed species. Amphibians, mammals, conifers, birds, sharks, cycads and reef corals are among the most affected groups.

The causes and mechanisms of biodiversity loss and impoverishment have already been detailed in this chapter. However, in conclusion, attention is drawn to six fundamental issues that jeopardize implementation of policies, laws and management practices put forward by various governments and organisations (UNEP, 1995; WRI/IUCN/UNEP 1992). They are:

(a) High rates of human population growth and utilization of biodiversity;

(b) Increasingly greater specialisation of traded products of agriculture and / forestry, leading to a very narrow spectrum of used products;

(c) Failure of economic systems and policies to adequately value biodiversity resources;

(d) Inequity in ownership and access to bioresources, including the benefits from their use and conservation;

(e) Inadequate knowledge and inefficient use of biodiversity information; and

(f) Poor or misused legal and institutional systems that promote an unsustainable use of biodiversity.

If current trends continue, biodiversity loss is projected to accelerate. Climate change, habitat destruction, and overexploitation are expected to drive many species to extinction. Conservation efforts and sustainable practices are crucial to mitigate these impacts.

4.8 Summary

Loss of biodiversity refers to the decline in the variety of life forms at genetic, species, and ecosystem levels. This loss has serious implications for the health of the planet and human well-being. Several factors are responsible for loss of biodiversity. The primary factors include: habitat destruction climate change, overexploitation, pollution, invasive species, and human population growth.

Genetic diversity involves the variety of genetic characteristics within a species, which is crucial for adaptability and survival. Loss of genetic diversity can reduce a species' ability to adapt to environmental changes and resist diseases. *Species diversity* is the variety of species within a particular ecosystem. High species diversity contributes to ecosystem stability and resilience. However, many species are threatened with extinction due to human activities. *Ecosystem diversity* embraces the variety of ecosystems within a region. It includes different habitats, biotic communities, and ecological processes. Healthy ecosystems provide essential services such as air and water purification, pollination, and climate regulation. *Agrobiodiversity* refers to the variety and variability of plants, animals, and microorganisms used for food and agriculture. It includes crop varieties, livestock breeds, and wild species that support agricultural systems. Agrobiodiversity is vital for food security and sustainable agriculture. The IUCN categorizes species in their *Red List* based on the risk of extinction of threatened species. Generally there are nine categories of threat of evaluated species in the list. A census of threatened species involves assessing population sizes and distributions to determine conservation status. This information is crucial for prioritizing conservation efforts.

Currently, biodiversity loss is accelerating. Over 46,300 species are threatened with extinction, representing about 28% of all assessed species. If current trends continue, biodiversity loss is expected to worsen, driven by habitat destruction, climate change, and overexploitation. Conservation efforts are crucial to mitigate these impacts and protect biodiversity.

4.9 Terminal Questions

1. Explain the importance of genetic diversity and its role in the adaptability and survival of species.
2. Discuss the significance of species diversity in ecosystem stability and resilience.
3. Briefly explain the purpose of the IUCN Red List and its role in biodiversity conservation.
4. Evaluate the current status of biodiversity loss and the projected scenarios if current trends continue.

4.10 Answer Key

SAQ I.

1. Genetic diversity refers to the variety of genetic characteristics within a species. It is important because it allows species to adapt to changing environments and resist diseases.
2. Habitat destruction, climate change, overexploitation, pollution, invasive species, and human population growth.
3. Human population growth increases the demand for resources, leading to habitat destruction and overexploitation, which contribute to biodiversity loss.

4. Select the correct answer:

   (a) (iii); (b) (iv); (c) (iv); (d) (iii); (e) (ii); (f) (iii); (g) (i)

5. Match the two columns : (a) (vi); (b) (ii); (c) (iv); (d) (iii); (e) (v); (f) (i)

6. (a) True; (b) True; (c) False; (d) True; (e) True.

Terminal Questions

1. Genetic diversity refers to the variety of genetic characteristics within a species. It is crucial for the adaptability and survival of species because it allows them to adapt to changing environments, resist diseases, and avoid inbreeding depression. Higher genetic diversity increases the chances of individuals within a species to survive and reproduce in the face of environmental changes, such as climate fluctuations or the introduction of new pathogens.

2. Species diversity is the variety of species within an ecosystem. It is significant because diverse ecosystems are generally more stable and resilient to disturbances. High species diversity ensures that different species can fulfill various ecological roles, such as pollination, nutrient cycling, and predation. This redundancy means that if one species is lost, others can fill its role, maintaining the overall functionality of the ecosystem. Additionally, diverse ecosystems are better equipped to recover from environmental changes and disturbances.

3. The IUCN Red List categorizes species based on their risk of extinction. Its purpose is to provide comprehensive, scientifically-based information on the conservation status of species. It serves as a critical tool for informing and catalyzing action for biodiversity conservation and policy change. By highlighting species at risk, the Red List helps prioritize conservation efforts, guide research, and raise awareness about the urgency of protecting biodiversity.

4. The current status of biodiversity loss is alarming, with more than 46,300 species threatened with extinction, representing about 28% of all assessed species. Groups such as amphibians, mammals, conifers, birds, sharks, and reef corals are among the most affected. If current trends continue, biodiversity loss is projected to accelerate due to factors like climate change, habitat destruction, and overexploitation. Many species may become extinct, and

ecosystems may lose their functionality, impacting ecosystem services and human well-being. Conservation efforts and sustainable practices are essential to mitigate these impacts and protect biodiversity.

4.11 References and Further Reading

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Unit – 5 ❑ Management of Plant Biodiversity

Structure

5.1 Objectives

From this unit, the reader is expected to have an idea on

- Organisations involved in management of biodiversity;
- The workings of organisations like IUCN, UNEP, UNESCO, WWF, NBPGR;
- Different legislations and conventions on biodiversity in the country and abroad, and
- Organizations that are engaged in financing biodiversity management.

5.2 Introduction

There is an ever-growing demand for bioresources by humankind. It is now fully realised that such increasing demands can no longer be met by tapping theas yet unexploited bioresources or by trade-offs between goods and services. Any nation can increase food supply by converting forestlands to agriculture but in doing so it restricts the supply of goods and services rendered by forests, which are of equal if not of greater importance. The projected climatic changes also worsen the act of balancing supply and the demand for bioresources. It is worth noting, that different governments have already made an important, even if unnoticed, pledge toward conservation and management of bioresources and biodiversity by signing the *World Charter for Nature*, which was adopted by the General Assembly of the United Nations, as far back as 1982. This Charter recognises that humanity is part of nature that every form of life is unique and warrants respect, and that continued benefits from nature will depend upon the management and maintenance of essential ecological processes. The goal of *biodiversity management* in other words, is to strike an optimal balance between biodiversity conservation, advancing sustainable living for humankind and benefit sharing. However, for management practices to succeed: (i) the social, political, economic and cultural contexts within which management objectives are pursued should be properly understood by policy-makers and managers. (ii) Proper tools and methods should be selected to attain the aforesaid objectives. Moreover, an integrated, predictive and adaptive approach to biodiversity management requires three basic types of information.

First, we need reliable and site-specific baseline information on all aspects of biodiversity. Second, we require a concrete idea about how value generation (in term of goods and services) in specific ecosystems will respond to changing environments. Third, we need information on integrated regional models, which incorporate the biophysical, economic and technological changes. The scientific community must immediately step in to mobilise all its knowledge in a manner that can increase awareness, provide information and enable capacity-building at local, regional and national levels, along with informed policy changes that can better manage the Earth's biodiversity. There are international organisations such as the Global Environment Facility, Green Climate Fund and World Heritage Fund who are ready to fund management of biodiversity.

5.3 Organizations associated with Biodiversity Management

Biodiversity management can be brought about effectively through committed organisations at the national and international levels (both governmental and nongovernmental) which frame policies and methodologies for execution. They also collect/collate vital data, store and distribute them to the needy. In addition, multilateral and national treatises, conventions and legal systems help in the effective management of biodiversity. Biodiversity information and knowledge are made available to anyone interested through well-organised databases. Biodiversity management requires skills in interdisciplinary areas such as Biology, Economics, Anthropology, Engineering, Forestry, Agriculture, Oceanography, Sociology, Management Science, Geography, Geology, Climate Science and Computer skills.

5.3.1 IUCN

IUCN stands for *International Union for Conservation of Nature and Natural Resources*. It is a membership Union uniquely composed of both government and civil society organisations. It provides public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together. Created in 1948, IUCN has evolved into the world's largest and most diverse environmental network. It harnesses the experience, resources and reach of its more than 1, 300 member-organisations and the input of 14, 500 experts. It is the global authority on the status of the natural world and the measures needed to safeguard it. Its experts are organised into six Commissions dedicated to species survival, environmental law, protected areas, social and economic policy, ecosystem management, and education and communication. IUCN provides a neutral forum in which governments, non-governmental organisations, scientists, businesses, local communities, indigenous peoples' groups, faith-based organisations and others can work together to forge and implement solutions to environmental challenges.

The IUCN is famous the world over for its regular publication of the Red List of Threatened Species. Initiated in 1964, the Red List of Threatened Species has evolved to become the world's most comprehensive information source, an inventory, on the global conservation status and extinction risk of animal, fungi and plant species. The Red List is a critical indicator of the health of the world's biodiversity. Far more than a list of species and their status, it is a powerful tool to inform and catalyze action for biodiversity conservation and policy change, critical to protecting the natural resources we need to survive. It provides information about range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions. The IUCN Red List Categories and Criteria are intended to be an easily and widely understood system for classifying species at high risk of global extinction. It divides species into nine categories: *Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct*. We will go into the details of the Red List categories in the following chapter.

While the Red List assesses the risk of extinction that individual species, *their conservation status on the road to recovery* remains largely unknown. To address this lacuna, at the behest of the World Conservation Congress (WCC) held at Jeju, South Korea in 2012, the IUCN comes out (optionally from 2020) with a Green Status of Species. The extent of species recovery is judged against three yardsticks: (a) *fully recovered* – if it is present in all parts of its range, even those habitats that may not be occupied at present but were inhabited prior to human impacts or disruption; AND (b) *are viable*, i.e., not threatened with extinction in all parts of its range; AND (c) is *performing its ecological functions* in all parts of the range. These factors contribute towards a 'green score' ranging from 0 to 100%, which shows how far a species exists from a fully recovered state. The IUCN Green Status of Species complements the Red List by providing a tool for assessing the recovery of species' populations and measuring their conservation success.

IUCN's expertise and extensive network provide a solid foundation for a large and diverse portfolio of conservation projects around the world. Combining the latest science with the traditional knowledge of local communities, these projects work to reverse habitat loss, restore ecosystems and improve people's well-being. In the IUCN Programme for 2017–2020 conserving nature and biodiversity is linked to sustainable development and poverty reduction. The IUCN Programme 2017–2020 identifies three priority areas:

(i) Valuing and conserving nature.

(ii) Promoting and supporting effective and equitable governance of natural resources.

(iii) Deploying Nature Based Solutions to address societal challenges including climate change, food security and economic and social development.

IUCN congresses have produced several key international environmental agreements including the Convention on Biological Diversity (CBD), the *Convention on International Trade in Endangered Speciesof Wild Fauna and Flora* (CITES), the *World Heritage Convention*, and the *Ramsar Convention on Wetlands*. IUCN continues to support these conventions as they grow stronger and evolve so that they can respond to emerging challenges. IUCN's Member organisations are represented by the IUCN Council – the governing body. Headquartered in Switzerland, the IUCN Secretariat comprises around 900 staff in more than 60 countries. (IUCN, 2018).

5.3.2 UNEP

UNEP stands for *United Nations Environment Programme*. It is a UN agency engaged in the coordination of intergovernmental measures for monitoring and protecting the environment, achieving sustainable development and resolving biodiversity issues. It has a threefold mandate:

(i) to create awareness on global environmental problems.

(ii) to build consensus on actions addressed towards these problems.

(iii) to promote and support such action programmes.

UNEP was formed subsequent to the UN Human Environment Conference at Stockholm in 1972, initially with an Executive Body of 50 members and a voluntary fund to finance its projects. For co-coordinating all activities of UNEP, an Environmental Co-ordination Board was created. As a member of the United Nations Development Group, UNEP aims to help the world meet the 17 Sustainable Development Goals (SDGs), as a "blueprint to achieve a better and sustainable future for all." It declares

- That a "clean and healthy environment is required to attain the SDGs".
- That "efforts to counter the triple planetary crisis of climate change, nature and biodiversity loss, and pollution and waste must be ramped up in order to truly transform societies and economies, for everyone, everywhere". societies and economies for

Over the last thirty years, UNEP has increasingly focused on climate change, helping create or implement environmental treaties and institutions, such as the UN Framework Convention on Climate Change UNFCCC). In 1988, it joined the World Meteorological Organization to establish the Intergovernmental Panel on Climate

Change (IPCC), a leading authority on the science of climate change with options for adaptation and mitigation. UNEP is also one of several "Implementing Agencies" for the Global Environment Facility (GEF), the Multilateral Fund for the Implementation of the Montreal Protocol, and the International Cyanide Management Code. UNEP has taken up the following major activities:

(i) biodiversity country studies

(ii) global biodiversity assessment (GBA) projects

(iii) biodiversity data management (BDM) projects for capacity building in developing countries and improved in-country networking of biodiversity information.

UNEP operates the Earth Watch Programme and funds publication of the magazine *Earthscan*. It has held/supported several conferences, workshops and meetings. UNEP has produced several seminal publications/documents in addition to Global Biodiversity Assessment (published by Cambridge University Press, 1995). These have brought into focus the pertinent issues of biodiversity conservation and its sustainable use. UNEP is headquartered in Nairobi, Kenya.

As record temperatures and unprecedented impacts of climate change continue to affect billions of people across the planet, the United Nations and partners have announced a series of regional meetings aimed at increasing ambition in the next round of climate pledges under the Paris Agreement. To this end, in 2025, countries are required to "submit new Nationally Determined Contributions (NDCs). These plans are known as NDCs 3.0. In these NDCs, countries are encouraged to set 2035 ambitious, economy-wide emission reduction targets that align with limiting global warming to 1.5°C and increase resilience to climate impacts".

UNEP in India

- United Nations Environment Programme established a country presence in New Delhi on 16 May, 2016. UNEP's high-level missions in the country in the months of February, March, June and October 2018, have forged a legacy of environmental leadership. It went on to host one of the biggest World Environment Day ever in June 2018, where India made the bold pledge to free the country from single-use plastic by 2022. However, the goal remains to be fully realised.
- UNEP India in partnership with governments, private sectors, UN agencies, civil societies, communities, citizens, research and academic institutions

and other organizations, is working towards raising awareness and stimulating action on critical environmental issues that contribute to the Sustainable Development Goals.

- India makes an annual financial contribution (US$ 100, 000) to the General-Purpose Funds of UN Environment and to several Multilateral Environment Agreements. UNEP has been involved in a number of projects in India including the Tree Planting Programme and the Ganga Action Plan.

5.3.3 UNESCO

UNESCO stands for *United Nations Educational, Scientific and Cultural Organisation*. It was established in 1945 as a UN Agency. In 1948 it funded for theestablishment of the IUCN. UNESCO has also assisted in the creation and operationof networks such as the MIRCENS (Microbial Research Centres), Biosphere Reservesand other protected areas, and marine research stations. MIRCENs are the outcomeof a joint effort by UNESCO, UNEP and the International Cell Research Organisation.

Activities of MIRCENs typically include collection, maintenance, testing and distribution of microbes, and training of personnel.

The International Man and Biosphere Programme (MAB) were initiated by UNESCO in the early 1960s, which took final shape in 1968, and was finally launched in 1977. One hundred and ten countries were participants in the MAB. Several UNESCO-MAB documents have already been prepared, where the objectives of the network of Biosphere Reserves, their mandated characteristics and the action plans of these Reserves are detailed. Subsequently, several MAB networks were established. These include the Euro MAB, USMAB, MAB-CYTED (Ibero-American Programme), CBRN-MAB (Chinese network) and MAB-GEF (Central European network). UNESCO has also identified World Heritage Sites and listed them. A World Heritage Fund (WHF) was created and is being managed by UNESCO's World Heritage Committee; the annual budget for this fund is 2 million US dollars. UNESCO, with the help of IUCN, was instrumental in the preparation of the draft for the Rio Summit and Convention. It, along with the International Union of Biological Sciences, launched in 1991 the much-acclaimed co-operative scientific programme on biodiversity called DIVERSITAS—for studying the origin, maintenance, and loss of biodiversity among other tasks. The headquarters for UNESCO is in Paris.

5.3.4 World Wildlife Fund (WWF)

WWF stands for *Worldwide Fund for Nature and Natural Resources*. It was established in 1961 and is headquartered in Gland, Switzerland. WWF International has several affiliated national units. The Indian unit was established in 1969 at the time of the XII General Assembly of the IUCN, held in New Delhi. The WWF International is controlled by a Board of International Trustees, while the national units are managed by separate national teams. For example, the Indian unit has a Board of 8 trustees, with its headquarters in Mumbai. It has a network of 18 State and Divisional Units. WWF has initiated several specific conservation programmes in more than 24 countries, with importance given to endangered fauna and flora. The logo of WWF is the Giant Panda, as designed by Gerald Watterson.

WWF-India has three missions to stop the degradation of the planet's natural environment and build a future in which humans live in harmony with nature, by:

- Conserving the world's biological diversity
- Ensuring that the use of renewable natural resources is sustainable
- Promoting the reduction of pollution and wasteful consumption.
- In order to conserve India's ecological security, WWF-India has adopted the following steps:
- Ensuring conservation of the country's biodiversity, major ecosystems and critical landscapes.
- Minimizing wasteful consumption and promotion of sustainable and judicious use of natural resources by all segments of society.
- Promoting the active involvement of rural and traditional communities in the sustainable management and conservation of natural resources.
- Working towards reduction in the impact of climate change.
- Minimizing pollution, reducing the use of toxic chemicals and ensuring improved management of toxic waste.
- Enhancing active participation of all sections of society in nature conservation and environmental protection through environmental education, awareness and capacity-building.
- Ensuring that environmental principles are integrated into development planning, policy and practices.

- Promoting environmental governance through legislation, policy and advocacy.

5.3.5 NBPGR

In India, initially, centralized plant introduction agency was established in 1946 at the Indian Council of Agricultural Research (ICAR), New Delhi. This unit was expanded in 1956 as "Plant Introduction and Exploration Organization" in the Botany Division of Indian Agricultural Research Institute (IARI). It was further expanded in 1961, as an independent "Division of Plant Introduction". In August 1976, on the recommendation of the Government of India, this division upgraded to an independent institute as the "National Bureau of Plant Introduction," later renamed as "*National Bureau of Plant Genetic Resources* (NBPGR)" in January 1977. NBPGR is the nodal agency for activities and services related to plant genetic resources. It was established with the mandate to plan, conduct, promote, and coordinate all activities, including collection, conservation, exchange, quarantine, evaluation, documentation, and utilization of plant genetic resources.

The establishment of the Bureau coincided with the advent of the Green Revolution. One of its earlier goals was to realize the perceived effects of the Green Revolution on agrobiodiversity. It was in accordance with the international developments in the form of establishment of the International Board for Plant Genetic Resources (IBPGR), Rome, in 1974 (now renamed as *International Plant Genetic Resources Institute*). The NBPGR played a pivotal role in the improvement of various cropplants and diversification and development of agriculture in India through germplasmintroduction from various institutes/organizations located in foreign countries andgermplasm collection from within the country and abroad and their conservation.

The National Bureau of Plant Genetic Resources (NBPGR) has its headquarters at New Delhi. The Bureau draws guidelines from the Crop Science Division of ICAR, Institute Management Committee, Research Advisory Committee, Institute Research Council and Germplasm Advisory Committees. The Bureau has five Divisions, three units and an experimental farm at its headquarters in New Delhi. There are 10 Regional Stations located in different phyto-geographical zones of the country. They are :

(i) Shimla (Himachal Pradesh)

(ii) Jodhpur (Rajasthan)

(iii) Thrissur (Kerala)

(iv) Akola (Maharashtra)

(v) Shillong (Meghalaya)

(vi) Bhowali (Uttarakhand)

(vii) Cuttack (Orissa)

(viii) Hyderabad (Andhra Pradesh)

(ix) Ranchi (Jharkhand)

(x) Srinagar (Jammu & Kashmir)

The different activities of NBPGR include :

- Introduction and supplement of the required germplasm from other countries.
- Exploration and collection of valuable germplasm.
- Maintaining proper inspection and quarantine measures.
- Testing, multiplication and proper maintenance of germplasm.
- Publication of exchange and collection list.
- Maintenance of the record of introduced plants.
- Supply of germplasm to scientists or any institution, on written request.
- Improvement of medicinal and aromatic plants.

5.4 Methodologies for Plant Biodiversity Regulations and Practices

Several methodologies are involved in effective management of biodiversity. Let us look at a few of them.

Mitigation Hierarchy : This framework aims to mitigate impacts on biodiversity through a sequential process: avoid, minimize, rehabilitate, and offset. It is applied to manage the ecological effects of infrastructure and development projects. [biodiversityinfrastructure.org]

Good Practice Guidance : Organizations like the Chartered Institute of Ecology and Environmental Management (CIEEM) provide guidance for habitats and species, emphasizing standardized survey methods, impact assessments, and monitoring protocols to inform planning and development. [cieem.net]

Legal and Policy Frameworks : Best practices in biodiversity conservation law include threat-based and target-based laws, transparency, inclusive decision-making, and regular evaluation. Mechanisms such as protected areas, species recovery plans, and the integration of indigenous knowledge are vital. [cambridge.org]

SAQ I.

1. What is the main objective of the World Wide Fund for Nature (WWF)?
2. How does the Mitigation Hierarchy contribute to biodiversity conservation?
3. What role does the National Bureau of Plant Genetic Resources (NBPGR) play in India's agricultural sector?
4. What is the function of the Red List? How does it differ from the Green List?
5. *Select the correct answer :*

(a) Which organization is known for publishing the Red List of Threatened Species?

(i) WWF
(ii) IUCN
(iii) UNEP
(iv) UNESCO

(b) What is the primary focus of the National Bureau of Plant Genetic Resources (NBPGR)?

(i) Wildlife conservation
(ii) Marine biodiversity
(iii) Plant genetic resource conservation
(iv) Climate change research

(c) Which methodology involves a sequential process of avoid, minimize, rehabilitate, and offset to manage biodiversity impacts?

(i) Ecosystem Services Valuation
(ii) Mitigation Hierarchy
(iii) Adaptive Management
(iv) Conservation Triage

6. *State whether the following statements are 'True' or 'False' ?*

(a) The IUCN comprises solely of governmental organizations.

(b) UNESCO's Man and the Biosphere Programme designates Biosphere Reserves to promote sustainable development.

(c) The Mitigation Hierarchy framework is applied to manage the ecological effects of infrastructure and development projects.

(d) NBPGR primarily focuses on marine biodiversity conservation.

(e) The IUCN Red List is a critical indicator of the health of world's biodiversity.

7. *Match each organization with its key activity.*

Organization	Activity
1. IUCN	(i) Plant genetic resources conservation
2. WWF	(ii) Biosphere Reserves
3. UNESCO	(iii) Wildlife conservation
4. UNEP	(iv) Global environmental policy
5. NBPGR	(v) Red List of Threatened Species.

8. *Fill in the blanks by selecting the correct word provided within parenthesis.*

(a) Rising ocean temperatures cause coral ________.

(b) Loss of _____ ice-habitats threatens species like seals and polar bears, which depend on ice for hunting and breeding.

(c) Some ________ species can alter habitats.

(d) Introduced _________ can significantly reduce native prey populations.

(e) The variety and variability of plants, animals and microbes used for food and agriculture is termed __________.

(agrobiodiversity, bleaching, predators, invasive, native, polar, endangered)

5.5 Key Organizations Financing Biodiversity Management

While biodiversity management is crucial for maintaining ecological balance and ensuring the sustainability of our planet's natural resources, being able to finance such efforts is crucial. Several organizations play pivotal roles in financing and supporting biodiversity conservation efforts globally. You have already come across the names of such bodies from our previous discussions and the work they are entrusted with. Let us quickly go through them.

The Global Environment Facility (GEF) : Established in 1991, it is a multilateral financial mechanism that provides grants to developing countries for projects benefiting the global environment and promoting sustainable livelihoods. As the financial mechanism for the Convention on Biological Diversity (CBD), the GEF funds projects aimed at conserving biodiversity, ensuring sustainable use, and restoring natural ecosystems. [thegef.org]

Global Biodiversity Framework Fund (GBFF) : Launched in August 2023 during the Seventh GEF Assembly in Vancouver, Canada, the GBFF was ratified by 186 countries. The fund aims to help countries achieve the goals and targets of the Kunming-Montreal Global Biodiversity Framework, focusing on strengthening national-level biodiversity management, planning, policy, governance, and financial approaches.

The World Heritage Fund (WHF) supports conservation of World Heritage Sites, many of which are biodiversity-rich areas.

The Green Climate Fund (GCF), the world's largest climate-focused fund, was created in 2010 at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP 16) in Cancun, Mexico. With its headquarters in Incheon, South Korea, it has been operational since 2015. The GCFis designed to assist developing countries inmitigation of greenhouse gas emissions (climate change mitigation);enhance resilience and adaptation to climate change (climate adaptation); supportsustainable development and safeguard biodiversity as part of climate resilience. It undertakesfinancing under the UNFCCC and the Paris Agreement; mobilizes funds from developed nations and private sectors to support climate actions in developing countries; and prioritizessupport for Least Developed Countries (LDCs), Small Island Developing States (SIDS), and African nations. Its mega funding projects includeecosystem-based adaptations (e.g., reforestation, wetland restoration); climate-resilient agriculture; renewable energy and low-carbon transport; and Nature-based Solutions (NbS) to climate adaptation and biodiversity preservation. However, it is not strictly a biodiversity fund.Countries and organizations can access GCF funding throughAccredited Entities (AEs) such as the UNEP, World Bank, NGOs, and development banks; and throughdirect access entities like national institutions and local organizations in developing countries. While the Green Climate

Fund focuses primarily onclimate action (mitigation and adaptation) and *indirectly* supports biodiversity through ecosystem-based solutions, the GEF *directly* funds biodiversity conservation projects as part of its core mandate under the Convention on Biological Diversity (CBD)

There are several other bilateral and multilateral aid agencies like the World Bank, European Union, USAID, and regional development banks to finance biodiversity and sustainable development initiatives. Together, these funds aim to mobilize resources, strengthen policies, and implement strategies to halt biodiversity loss and promote sustainable development.

SAQ II.

1. *Choose the correct answer :*

(a) Which organization serves as the financial mechanism for the Convention on Biological Diversity (CBD)?

(i) World Wildlife Fund (WWF)
(ii) Global Environment Facility (GEF)
(iii) United Nations Environment Programme (UNEP)
(iv) Global Biodiversity Framework Fund (GBFF)

(b) When was the Global Biodiversity Framework Fund (GBFF) launched?

(i) 2010
(ii) 2015
(iii) 2023
(iv) 2025

5.6 Summary

Several prominent organizations play crucial roles in biodiversity management, each contributing uniquely to the conservation and sustainable use of biological diversity. The United Nations Environment Programme (UNEP) is the leading global environmental authority that sets the global environmental agenda and promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system. It plays a pivotal role in developing international environmental agreements and provides guidance on best practices for biodiversity conservation. The International Union for Conservation of Nature (IUCN) established in 1948, is a membership union comprising over 1,400 governmental and non-governmental organizations. It harnesses the expertise of more than 17,000 experts to provide knowledge and tools for nature conservation and sustainable development. The IUCN is renowned for its Red List of Threatened Species, which assesses the conservation status of species worldwide. The World Wide Fund for Nature (WWF) founded in 1961, is an international non-governmental organization dedicated to wilderness preservation and the reduction of human impact on the environment. It focuses on various areas, including the conservation of species and their habitats, climate change mitigation, and sustainable resource use. The United Nations Educational, Scientific and Cultural Organization (UNESCO) seek to build peace through international cooperation in education, science, and culture. In biodiversity management, UNESCO's *Man and the Biosphere Programme* designates biosphere reserves to promote sustainable development based on local community efforts and sound science. The National Bureau of Plant Genetic Resources (NBPGR) based in India is responsible for the collection, conservation, characterisation, and evaluation of plant genetic resources. It ensures the availability of diverse plant genetic material to breeders and researchers, supporting food and agricultural security.

Effective plant biodiversity management involves several methodologies. One of them is the Mitigation Hierarchy framework that aims to mitigate impacts on biodiversity through a sequential process – avoid, minimize, rehabilitate, and offset. It is applied to manage the ecological effects of infrastructure and development projects. Organizations like the Chartered Institute of Ecology and Environmental Management (CIEEM) provide guidance for habitats and species, emphasizing standardized survey methods, impact assessments, and monitoring protocols to inform planning and development. Pertaining to the biodiversity conservation laws, the best practices include threat-based and target-based laws, transparency, inclusive decision-making, and regular evaluation. Mechanisms such as protected areas, species recovery plans, and the integration of indigenous knowledge are also vital. These organizations and methodologies collectively contribute to the global effort to conserve plant biodiversity, ensuring sustainable ecosystems for future generations.

Organisations such as the Global Environment Facility (GEF), World Heritage Fund (WHF) and Global Biodiversity Framework Fund (GBFF) are instrumental in providing financial resources to support biodiversity conservation worldwide.

5.7 Terminal Questions

(a) Describe the role of UNEP in shaping international biodiversity policies.

(b) Explain the importance of plant genetic resources conservation and the role of NBPGR.

(c) Discuss how biosphere reserves under UNESCO's MAB Programme balance conservation and development.

(d) Discuss the role of the Global Environment Facility (GEF) in biodiversity conservation.

(e) Explain the significance of the Global Biodiversity Framework Fund (GBFF) in achieving global biodiversity targets.

5.8 Answer key

SAQ I.

1. The WWF aims to preserve wilderness areas and reduce human impact on the environment through various conservation initiatives.
2. It provides a structured approach to managing biodiversity impacts by sequentially avoiding, minimizing, rehabilitating, and offsetting negative effects of development projects.
3. NBPGR collects, conserves, and evaluates plant genetic resources, ensuring diverse genetic material is available for breeding and research to support agricultural security.
4. See Section 5.3.1.
5. (a) (ii); (b) (iii); (c) (ii)
6. (a) False; (b) True; (c) True; (d) False. (e) True
7. Matching each organization with its key activity.

   Ans. (1) (v); (2) (iii); (3) (ii); (4) (iv); (5) (i)
8. Fill in the blanks by selecting the correct word provided within parenthesis.

   (a) bleaching; (b) polar; (c) invasive; (d) predators; (e) agrobiodiversity.

SAQ II.

1. (a) (ii); (b) (iii)

Terminal Questions

(a) UNEP leads global environmental efforts, coordinates treaties like the CBD, promotes capacity-building, and fosters biodiversity mainstreaming.

(b) Plant genetic resources ensure agricultural diversity and resilience to climate change. NBPGR conserves seeds and germplasm, enabling breeders to develop improved crops.

(c) Biosphere reserves promote sustainable development by combining conservation with local community involvement and scientific research.

(d) The Global Environment Facility (GEF), established in 1991, serves as the financial mechanism for the Convention on Biological Diversity (CBD). It provides grants to developing countries to implement projects aimed at conserving biodiversity, promoting sustainable use, and restoring natural ecosystems. Through its funding, the GEF supports various initiatives, including the establishment of protected areas, sustainable land management practices, and the conservation of endangered species.

(e) Launched in August 2023, the Global Biodiversity Framework Fund (GBFF) was established to scale up financing for the implementation of the Kunming-Montreal Global Biodiversity Framework. Ratified by 186 countries, the GBFF focuses on strengthening national-level biodiversity management, planning, policy, governance, and financial approaches. By providing targeted funding, the GBFF aims to assist countries in achieving global biodiversity goals and targets, thereby contributing to the conservation and sustainable use of biological diversity worldwide.

5.9 References and Further Reading

References and Further Reading

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Unit–6 ❑ Biodiversity Legislation and Conventions, Information Management, Communication

Structure

6.1 Objectives

Studying the topics of biodiversity legislation, conventions, and related areas can yield several valuable learning outcomes. Here are the key objectives and expected learning outcomes:

- Students will be able to understand, identify and explain the role of key international biodiversity conventions.
- To understand the national and international legal frameworks that governs biodiversity conservation and sustainable use.
- To realise how various conservation approaches are factored in at the local, national and international levels.
- Students will appreciate the value of biodiversity and ecosystem services and the role of conservation in maintaining these services.
- To be able to appreciate the interconnectedness of different ecosystems which need to be taken into account while following up with conservation goals.
- To become aware of the impact of human activities in global and local biodiversity issues. biodiversity.
- To gain a concrete idea about management and utilisation of biological information, and the importance of data management in conservation.
- Students will understand how to investigate and analyse biodiversity-related information accessed from various sources.
- To recognize the roles of different institutions, libraries, periodicals, databases and other repositories in biodiversity information management and conservation efforts.
- To enhance critical thinking skills while trying to evaluate different conservation strategies and their effectiveness.
- Students will be able to develop informed policies and strategies for preserving our planet's natural heritage, and effectively communicate them to different advocacy groups with common or overlapping goals.

6.2 Introduction

Biodiversity legislation and conventions are crucial for the conservation and sustainable use of the world's biological diversity. These international agreements and national laws aim to protect ecosystems, species, and genetic resources, ensuring their survival for future generations. International biodiversity laws encompass a range of treaties and agreements designed to safeguard global biodiversity. Key among these are the Convention on Biological Diversity (CBD), which promotes the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from genetic resources. Adopted at the Earth Summit in Rio de Janeiro in 1992, it is a comprehensive global agreement addressing all aspects of biodiversity. It sets out commitments for maintaining ecological balance while pursuing economic development. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) established in 1973, aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. It provides varying degrees of protection to over 38,000 species through a system of permits and certificates. The Ramsar Convention, adopted in 1971, focuses on the conservation and sustainable use of wetlands. Wetlands are vital ecosystems that support a rich diversity of life and provide essential services such as water purification and flood control. The Bonn Convention, also known as the Convention on the Conservation of Migratory Species (CMS) of Wild Animals, aims to conserve terrestrial, marine, and avian migratory species throughout their range. It encourages international cooperation to protect these species and their habitats. The World Heritage Convention, adopted in 1972, seeks to identify and protect cultural and natural heritage sites of outstanding universal value. These sites are recognized for their exceptional importance to humanity and are preserved for future generations. The International Tropical Timber Agreement (ITTA) and International Tropical Timber Organization (ITTO) promote the sustainable management of tropical forests and the trade of tropical timber. They aim to ensure that timber production does not lead to the degradation of tropical forests and that it benefits local communities and economies. India has enacted several laws to protect its rich biodiversity, including the Biological Diversity Act, 2002 amended in 2023, aims to conserve biological diversity, ensure sustainable use of its components, and ensure the fair and equitable sharing of benefits arising from the use of genetic resources.

Effective management of biological information is essential for biodiversity conservation. This involves the collection, storage, and dissemination of data on species, ecosystems, and genetic resources. Libraries, periodicals, and databases play a crucial role in this process by providing access to valuable information and research. Libraries, periodicals, and databases are vital resources for biodiversity research and conservation. They provide access to scientific literature, research findings, and data on species and ecosystems. These resources supplemented with huge data repositories, policymakers, different advocacy groups like citizen-science, today work round the clock to save our planet threatened with biodiversity loss and climate change.

6.3 Biodiversity Legislation and Conventions

Primitive humans have always depended greatly on the various elements of biodiversity; in fact they had developed an unwritten code for the sustainable use of biodiversity. Such codes exist even today in several tribal societies throughout the world. During the evolution of human society and civilisation, these unwritten codes were replaced by legislation. A few decades ago, however, Environmental Law emerged as a distinct branch of law, which started to look into various legislations relating to environment with a view to monitor and ensure environmental justice.

Initially, biodiversity laws were a part of agriculture and/or forestry laws; they dealt specifically with regulations pertaining to exploitation of wild species and establishment of protected areas. Only slowly did they evolve as specialized biodiversity laws, gradually extending their ambit to planning and land-use legislations. Today, biodiversity laws provide framework for the establishment of procedures and institutions destined to facilitate and encourage biodiversity conservation and management programmes, to make biodiversity a public service, and to promote better public awareness of biodiversity.

6.3.1 International Biodiversity Laws

International laws have two aspects : a public and a private one. In the public sphere, international laws govern the activities and relationships between nations, although the principle of state sovereignty reigns supreme. Consequently, adherence to international laws by nations is subject to their consent. In the private sphere, the law operates within the context of existing public laws, and seeks to control the activities and relationships of individuals and non-governmental organisations.

Evidently, treaties have become the backbone of international laws.Very recent developments inInternational Laws have resulted in treaties laying down general rules that the contracting nations should absolutely commit themselves to. Implementation of the treaties would need to :

> Treaties are contracts providing for benefits to both the contracting nations. Therefore, if one nation fails to comply with their treaty commitments, the other can retaliate by refusing to discharge its own obligations.

(i) Establish appropriate institutions such as Conferences of Nations and Secretariats, to review implementation of the contents of the treaties, encourage and promote cooperation between nations, and provide a forum where cases of non-compliance are discussed and solutions reached.

(ii) Underscore the obligation of contracting nations to provide periodic reports on the actions taken by each nation in implementing the contents of the treatise.

(iii) Empower the conference or Secretariat to adopt specific recommendations relating to the treaty, and,

(iv) Allow for admission of non-governmental organisations as observers at meetings of the Conference.

There are *four* sources of international laws :

(i) International conventions,

(ii) International customs,

(iii) General principles of law and,

(iv) Decisions of the Judiciary and directives of the most appropriate authority such as the International Court of Justice Statute 1948 (UNEP, 1995).

6.3.2 Biological Diversity Act of India

The Biological Diversity Act (BDA) was formulated after India became signatory to the CBD. The draft legislation was developed through an intensive consultation process involving all stakeholders such as the Central Government, State Governments, institutions of local self-government, scientific and technical institutions, experts, non-governmental institutions, industry, etc. The act was passed by the Parliament in December 2002. The objectives of the act are 'to provide for conservation of biological diversity, sustainable use of its components and equitable sharing of the benefits arising out of the use of biological resources and for matters connected therewith or incidental thereto'.

Salient Provisions: Some of the salient provisions made in the BDA for regulation of access to biological diversity, its conservation and sustainable use are:

(i) Conservation and sustainable use of biological diversity.

(ii) Conservation and development of areas important from the standpoint of biological diversity by declaring them as biological diversity heritage sites.

(iii) Protection and rehabilitation of threatened species.

(iv) To respect and protect knowledge of local communities related to biodiversity.

(v) Regulation of access to biological resources of the country with the purpose of securing equitable share in benefits arising out of the natural resources and its associated knowledge.

(vi) To secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information related to the use of biological resources.

(vii) Involvement of institutions of self-government in the broad scheme of the implementation of the act through constitution of committees.

The Act envisages a *three-tier structure* to regulate access to the biological resources, comprising of

- National Biodiversity Authority (NBA),
- State Biodiversity Boards (SBB) and
- Biodiversity Management Committees (BMC) at the local level

The National Biodiversity Authority (NBA) was established in 2003 to implement India's Biological Diversity Act (2002). The NBA is a Statutory, Autonomous Body and it performs facilitative, regulatory and advisory function for the Government of India on issues of conservation, sustainable use of biological resources and fair and equitable sharing of benefits arising out of the use of biological resources. India has updated its 2002 Biological Diversity Act (BDA) by passing the Biological Diversity (Amendment) Act, 2023 during the 2023 Monsoon Session of Parliament. The amendment seeks to (i) reduce the pressure on wild medicinal plants by encouraging cultivation of medicinal plants; (ii) encourage Indian system of medicine; (iii) facilitate fast-tracking of research, patent application process, transfer of research results while utilising the biological resources available in India without compromising the objectives of United Nation Convention on Biological Diversity and its Nagoya Protocol. The modifications are of great importance as they influence research and innovation across sectors reliant on biodiversity such as pharmaceuticals, agriculture, cosmetics, and traditional medicine, among others. Furthermore, they bolster domestic endeavours in this domain. These changes affect a range of sectors, from domestic and international biotech and pharmaceutical corporations harnessing biological resources to traditional medicine realms encompassing AYUSH disciplines, research and bio-surveying entities, indigenous communities with time-honoured knowledge, and IPR sectors with a keen focus on biological assets. The **State Biodiversity Boards** (SBBs) focus on advising the State Governments, subject to any guidelines issued by the Central Government, on matters relating to the conservation of biodiversity, sustainable use of its components and equitable sharing of the benefits arising out of the utilization of biological resources. The SSBs also regulate, by granting of approvals or otherwise requests for commercial utilization or bio-survey and bio-utilization of any biological resource by Indians.

The local level **Biodiversity Management Committees** (BMCs) are responsible for promoting conservation, sustainable use and documentation of biological diversity including preservation of habitats, conservation of landraces, folk varieties and cultivars, domesticated stocks and breeds of animals and microorganisms and chronicling of knowledge relating to biological diversity. Since its establishment, NBA has supported creation of SBBs in 26 States and, facilitated establishment of around 32, 796 BMCs. One of the key mandates of BMCs is to prepare a Biodiversity Register, which documents the elements of biodiversity in the areas, and issues pertaining to its sustainable utilization and befit sharing; the traditional knowledge associated with it.

6.3.3 Convention on Biological Diversity (CBD)

Also called the Rio or Earth Summit, the *Convention on Biological Diversity* **(CBD)** is a major landmark in biodiversity management, regulation and utilisation.The CBD is the international legal instrument for "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”. This convention was the result of very intense political interest in biodiversity andseveral years of intense bio diplomacy. Preparations for CBD were initiated by UNEPin 1987 with the formation of an Ad hoc Working Group of Experts met in 1988, followed by a meeting in 1991 of the Intergovernmental Negotiating Committee fora CBD. The CBD was adopted during the Earth Summit (UNCED) in Rio de Janeiro,Brazil in 1992, along with establishment ofthe *Global Environmental Facility* (GEF). The Convention came into force on 29th December 1993. This was followed by the first meeting of the contracting countriesin the Bahamas, Nov-Dec, 1994. India was the first country to sign the Convention and ratify it on 18th February, 1994.

Presently, the CBD has been ratified by 196 nations. The Secretariat of the

Convention on Biological Diversity (SCBD) is based in Montreal, Canada. The Executive Secretary is the head of the Secretariat. The CBD's governing body is the *Conference of the Parties* (COP). This ultimate authority of all governments (or Parties) that have ratified the treaty, meets every two years to review progress, set priorities and commit to work plans.

Its main function is to assist governments in the implementation of the CBD and its programmes of work, to organize meetings, draft documents, coordinate with other international organizations, collect and disseminate information. Its overall objective importantly, is to encourage actions, which will lead to a sustainable future. The CBD covers biodiversity at all levels: ecosystems, species and genetic resources. It also covers biotechnology, following the *Cartagena Protocol on Biosafety*. In fact, it covers all possible domains that are directly or indirectly related to biodiversity and its role in development, ranging from science, politics and education to agriculture, business, culture and much more.

However, there was (and still is) serious disagreement between countries over biodiversity utilisation and conservation. Developed countries felt (and many still feel) that conservation of biodiversity, wherever it may be located in the world, is a common concern of humankind, while developing countries tended to show a strong 'country driven approach' with reference to the use of biodiversity for their overall economic developments. During the past years, the developed countries (industrialized) have developed new medicines, biotechnology produces, crops, etc. using the raw materials of tropical species, but without giving any return of due profits earned out of them. Thus, the countries in which the wild tropical species were originally found did not receive fair compensation from the developed countries for the use of their bioresources. [https://www.un.org/en/observances/biological-diversity-day/convention]

Box 6.1

The Nagoya Protocol on Access and Benefit-sharing (ABS) of the Convention on Biological Diversity (CBD) is a fundamental international agreement that plays a crucial role in the protection and equitable utilization of plant genetic resources. Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilization (the Protocol) is a global agreement that implements the access and benefit-sharing obligations of the Convention on Biological Diversity (CBD). The Nagoya Protocol was adopted by the CBD in Nagoya, Japan in October 2010. It came into force on 12 October 2014. The Protocol applies to genetic resources that are covered by the CBD, and to the benefits arising from their utilization. It also covers traditional knowledge (TK) associated with genetic resources that are covered by the CBD and the benefits arising from its utilization. The Protocol sets out core obligations for its contracting Parties to take measures in relation to access to genetic resources, benefit-sharing and compliance. It aims to create greater legal certainty and transparency for both providers and users of genetic resources by :

Establishing more predictable conditions for access to genetic resources.

Helping to ensure benefit-sharing when genetic resources leave the country providing the genetic resources

By helping to ensure benefit-sharing, the Nagoya Protocol creates incentives to conserve and sustainably use genetic resources and therefore enhances the contribution of biodiversity to development and human well-being.

The Nagoya Protocol addresses traditional knowledge associated with genetic resources with provisions on access, benefit-sharing and compliance. It also addresses genetic resources where indigenous and local communities have the established right to grant access to them. Contracting Parties are to take measures to ensure these communities' prior informed consent, and fair and equitable benefit-sharing, keeping in mind community laws and procedures as well as customary use and exchange.

6.3.4 CITES

CITES stands for the Convention on International Trade in Endangered Species of Wild Fauna and Flora. It is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species. The necessity for controlling international trade in endangered species, although recognised as early as 1911, could not be realised in practice for a long time–not until CITES came into force.

CITES materialized from extensive lobbying by IUCN for international trade controls in species that are prioritized for conservation. CITES was drafted following resolutions adopted at a meeting of members of IUCN in 1963. The text of the Convention was finally agreed to at a meeting of representatives of 80 countries in Washington DC, USA, on 3 March 1973, and was therefore known in those days as the 'Washington Convention.' CITES actually came into force from 1 July 1975. For many years, CITES has been among the conservation agreements with the largest membership, with now 184 Parties.

Why was CITES needed?

Widespread information about the endangered status of many prominent species, such as the tiger and elephants, might make the need for such a convention seem obvious. But at the time when the ideas for CITES were first formed, in the 1960s, international discussion of the regulation of wildlife trade for conservation purposes was something relatively new. With hindsight, the need for CITES is clear. Annually, international wildlife trade is estimated to be worth billions of dollars and to include hundreds of millions of plant and animal specimens. The trade is diverse, ranging from live animals and plants to a vast array of wildlife products derived from them, including food products, exotic leather goods, wooden musical instruments, timber, tourist curios and medicines. Levels of exploitation of some animal and plant species are high and the trade in them, together with other factors, such as habitat loss, is capable of heavily depleting their populations and even bringing some species close to extinction. Many wildlife species in trade are not endangered, but the existence of an agreement to ensure the sustainability of the trade is important in order to safeguard these resources for the future.

Because the trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. CITES was conceived in the spirit of such cooperation. Today, it accords varying degrees of protection to more than 40,000 species of animals and plants, whether they are traded as *live specimens, fur coats or dried herbs*. All the legal provisions of CITES apply not only to whole live or dead specimens of listed species, but also to their readily recognisable parts and derivatives; however, a small number of exceptions are listed. The role of CITES, therefore, is to provide the nations of the world a legal framework for combating the illegal trade in endangered taxa.

Another organisation, called TRAFFIC (Trade Record Analysis of Flora and Fauna in Commerce) monitors international trade of species. The unit was established in 1991 in the WWF-India headquarters in New Delhi.

6.3.5 Ramsar Convention

Also called the Convention on Wetlands of International Importance, the Ramsar Convention is an International treaty drawn up in 1971 at the city of Ramsar in Iran, and it came into force in December 1975. This convention expects its contracting nations to promote the judicial use of wetlands and their resources situated in their territory; it also requires the contracting partiers to designate certain wetlands for inclusion on a list of wetlands of international importance. Such listed wetlands of international importance are called the Ramsar Sites. The contracting nations are required to make national wetland inventories, establish nature reserves on wetlands and provide adequately for their maintenance.

> **Wetlands** are vital for human survival. They are among the world's most productive environments and are a cradle of biodiversity, invaluable for survival of innumerable species of plants and animals. They provide humanity with a host of "ecosystem services"-- freshwater supply, food and building materials, and biodiversity to flood control, groundwater recharge, and climate change mitigation.

Yet, the wetland area continues to shrink and their quality continues to decline in most regions of the world. Consequently, the ecosystem services that wetlands provide to people are compromised.

The major parameter for a wetland to qualify for inclusion in the international list is the presence in it of rare, vulnerable, endangered or endemic plants/animals. The site must be nominated by a contracting country, meet at least one of nine criteria and the site must submit itself to scientific review. A 'Wetlands Conservation Fund' has been established to assist countries in implementing the objectives of the Ramsar Convention. Funding is provided only to those countries that have contracted for wetland conservation activities relating to any one of the following fields: improvement of management of Ramsar Sites, designation of new Ramsar Sites, promoting wise use of wetlands, training personnel in wetland management and organizing promotional activities such as seminars, workshops and educational programmes.

As of November 2023, there are 172 contracting parties and over 2,000 designated sites covering over 200,000,000 hectares (490,000,000 acres). Every contracting country has at least one Ramsar site, and 31 of the contracting countries have only one site. The country with the most sites is the United Kingdom with 170. There are 89 Ramsar sites in India as of February 2025, the highest number in South Asia. It encompasses diverse ecosystems including freshwater lakes, marshes, mangroves, and high-altitude lakes. These sites play a critical role in supporting biodiversity, providing habitat for many species of flora and fauna. The surface-area covered by Ramsar Sites in India is more than 13 lakh hectares. Tamil Nadu has the highest number of 18 Ramsar Sites in India. West Bengal has two Ramsar sites: the East Calcutta wetlands and the Sunderban wetlands.

Box 6.2

The International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty) was adopted by the 31 Session of the Conference of the Food and Agriculture Organization, United Nations, on 3 November 2001. The Treaty came into force on 29 June 2004. The objectives of the treaty (referred to as the Plant Treaty 2004), are the conservation and sustainable use of all plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security. The Treaty aims at:

recognizing the enormous contribution of farmers to the diversity of crops that feed the world;

establishing a global system to provide farmers, plant breeders and scientists with access to plant genetic materials;

ensuring that recipients share benefits they derive from the use of these genetic materials.

The Treaty's truly innovative solution to access and benefit sharing, the *Multilateral System*, puts 64 of our most important crops–crops that together account for 80 percent of the food we derive from plants–into an easily accessible global pool of genetic resources that is freely available to potential users in the Treaty's ratifying nations for some uses.

[Source; https://www.fao.org/plant-treaty/en/]

6.3.6 The Bonn Convention

The Convention on the Conservation of Migratory Species of Wild Animals (also known as **CMS** or the **Bonn Convention**, not to be confused with the Bonn Agreement) aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the UNEP, associated with the conservation of wildlife and habitats on a global scale. The Convention was signed in 1979 in Bonn (hence the name) and came into force in 1983. From that time, its membership has grown steadily to 130 Parties from Africa, Central and South America, Asia, Europe and Oceania. The Convention states that the Parties :

(a) Should promote, cooperate in and support research relating to migratory species.

(b) Shall endeavour to provide immediate protection for migratory species.

(c) Shall endeavour to conclude agreements covering the conservation and management of migratory species.

Till now, seven Agreements have been concluded under the auspices of CMS. They address :

- Populations of European Bats
- Cetaceans of the Mediterranean Sea, Black Sea and Contiguous Atlantic Area
- Small Cetaceans of the Baltic and North Seas
- Seals in the Wadden Sea
- African-Eurasian Migratory Water birds
- Albatrosses and Petrels
- Gorillas and their Habitats

The Memoranda of Understanding (MOU) concluded till now, aims to conserve Siberian Cranes, Slender-billed Curlews, Marine Turtles of the Atlantic Coast of Africa, Marine Turtles of the Indian Ocean and South-East Asia, Middle-European Population of the Great Bustard, Bukhara Deer, Aquatic Warbler, West-African Populations of the African Elephant, Saiga Antelope, Cetaceans of Pacific Island States, Dugongs, Mediterranean Monk Seal, Ruddy-headed Goose, Grassland Birds. In addition, the CMS Secretariat has launched an Action Plan for the *Central Asian Flyway*, one of the world's most vital routes for migratory birds, and an Action Plan for the conservation and restoration of the Sahelo-Saharan antelopes, while initiatives to develop agreements or MOU are ongoing with regard to raptors, migratory sharks, and western African aquatic mammals.

6.3.7 The World Heritage Convention

The World Heritage Convention (WHC) is one of the most important global conservation instruments created in 1972. The primary mission of the Convention is to identify and protect the world's natural and cultural heritage considered to be of Outstanding Universal Value. It embodies a visionary idea – that some places are so important that their protection is not only the responsibility of a single nation, but is also the duty of the international community as a whole; and not only for this generation, but for all those to come. The implementation of the World Heritage Convention is facilitated through the operational guidelines, which define the procedures for new inscriptions, site protection, danger-listings, and the provision for international assistance under the World Heritage Fund. The Convention is governed by the World Heritage Committee supported by the UNESCO World Heritage Centre, the secretariat for the Convention, and three technical advisory bodies to the Committee: IUCN, ICOMOS, ICCROM. IUCN is the Advisory Body on natural heritage. It monitors listed sites and evaluates sites nominated to the World Heritage List, in accordance with the relevant natural criteria for selection.

6.3.8 ITTA and ITTO

ITTA stands for *International Tropical Timber Agreement*. It came into force on 1st April 1985. The contracting parties entered into the agreement recognising the importance of, and need for, proper and effective conservation and development of timber forests and concomitantly ensuring optimum utilisation of such forests in a sustainable manner and maintenance of ecological balance. Tropical timber reforestation and afforestation are encouraged at national and international levels and more than 66 projects and 35 pilot studies on these aspects have been approved and supported. ITTO (International Tropical Timber Organisation) has published guidelines for sustainable forest management of tropical forests and conservation of biodiversity in such forests (ITTO 1990, 1992, 1993, 1998a, b).

SAQ I.

(a) When and where was the CBD adopted? What are its main goals?

(b) What type of ecosystems does the Ramsar Convention focus on?

(c) What does the Bonn Convention aim to protect? How do they operate?

(d) What is the purpose of the World Heritage Convention?

(e) What do International Tropical Timber Agreement (ITTA) and International Tropical Timber Organization (ITTO) promote?

6.4 Biodiversity Information Management and Communication

"Biodiversity information" comprises all types of information systems that allow management of biodiversity data. These data involve information on a multitude of living organisms, their physiological and biological characteristics, with a description of the ecosystems where they are observed. One key aspect in such systems is correct identification of these life forms, to allow subsequent studies of their habitats, determine spatio-temporal correlations among species, and therefore derive new facts about our planet. Easy access to updated and comprehensive information on biodiversity is crucial for research, decision-making, policy advice and monitoring of the biodiversity status and the effectiveness of conservation measures. Construction of comprehensive data baseson the basis of such information systems derived from local, regional and international bioresources data, is a fundamental prerequisite in biodiversity science and its practitioners. Related concepts including those on biomes, ecosystems, floras and faunas, hot spots, genetic resources, alien taxa, are all part of this information system. Hence a strong effort for the collection, documentation, management and distribution of biodiversity information is needed so that effective decisions on managing bioresources can be made. Such information is also required for enacting national and international legislation and laws. Naturally, biodiversity information management researchers/technicians need to muster several skills involved in data capturing, analysis and presentation. The discipline of 'biodiversity informatics' has cropped up to address such needs.The use of biodiversity information involves basically three kinds of motivations :

- public policy—to comply with laws, rules, legislation, regulations and/or treaties;
- private sector—to advance commercial interests such as ecotourism, bioprospecting and biotechnological applications among others;
- public interest and cultural motivations—to advance conservation efforts and sustainable management of bioresources.

The important activities here include *data collection* from the real world, *datastorage, analysis of organised and integrated data* (with mathematical models if required)—to obtain useful and pertinent information, derive knowledge from such information through further analysis; to interpret, understand and finally arrive at wise, judicious and ethical aspects for effective biodiversity management initiatives.

There are many biodiversity-related initiatives at the national level that are closely linked to the BDM project. These include Biodiversity Country Studies, National Biodiversity Strategies and Action Plans (NBSAP), National Environmental Action Plans (NEAP), National Conservation Strategies (NCS), National Sustainable Developmental Strategies, National Tropical Forest Action Plans (TFAP), etc. The BDM Newsletter 'BDM UPDATE' provides complete information on relevant issues and events.

Box 6.3. ***Biodiversity Management Information System* (BIOMIS)**

The National Biodiversity Authority, Government of India, with the help of National Informatics Centre of the Ministry of Communications & Information Technology, has created a *Biodiversity Management Information System* (BIOMIS), which has among its objectives :

Development of web basedapplication to create a database of biodiversity register information for the state concerned.

Biodiversity details to be captured from local bodies like Municipalities, Corporations and Panchayat areas.

The created database to be used for searching and locating specific biodiversity information pertaining to any local body or state.

Local public or researchers to benefit from this database from the readily available information.

They can subscribe for this facility through state biodiversity boards and get the information at their finger-tips.

The Scope of BIOMIS is to --

- Develop a web portal to provide information related to biodiversity details to public, and those involved in the BPR activities.
- To introduce m-Governance and related services with Responsive Web Design (RWD) technology to facilitate anywhere and any-device service delivery mechanism.
- Develop a system to provide facility for online reporting of new findings.

6.4.1 Libraries

Collections of both published and unpublished literature constitute one of the main sources of information which can be shared across platforms. Most libraries are regional or national, but several international libraries exist. Some of the most important among them are situated at the *Asian Institute of Technology, International Centre for Living Aquatic Resources Management, National Library of Agriculture* (USA), *National History Museum* (UK), *Royal Botanic Gardens Kew and Edinburgh* (UK), *Smithsonian Institution* (USA and Panama) and the *IUCN*. These libraries can provide vital information on biodiversity.

6.4.2 Periodicals

Several periodicals contain articles on biodiversity. The names of the most important appear in Ulrich's International Periodicals Directory. In addition, several newsletters are available. Some of the important periodicals are :

- *Biodiversity Letters*
- *Biological Conservation*
- *Conservation Biology*
- *Ecology*
- *Oikos*
- *Oecologia*
- *Journal of Biogeography*
- *Journal of Ecology*
- *AMBIO*
- *Annual Review of Ecology and Systematics*
- *Ecography*
- *Trends in Ecology and Evolution?*
- *Biodiversity and Conservation*
- *Biotropica*
- *Biodiversity*
- *Threatened Plants Newsletter*
- *Journal of Intellectual Property Rights*
- *BDM Updates*

6.4.3 Data Management and Databases

Biodiversity data is information about the plants, animals, and other organisms that make up the natural world. This data is collected by scientists, government agencies, and other organizations, and it is used to study the distribution, abundance, and characteristics of species. The key components of biodiversity data management comprise *data collection*—field surveys, remote sensing and through citizen science; *data storage*—repositories, databases, cloud services; *data standardization*—using common formats (e.g., Darwin Core); *data sharing*—open-access platforms, APIs, data portals; and *data analysis*—mapping, modelling and AI applications.

We learn from Biodiversity Data Management (BDM) :

- The diversity of life on Earth and the factors that influence it.

- How the data helps us inform conservation efforts – by understanding which species are at risk, where they are found, conservationists can develop strategies to protect and preserve these species and their habitats. This data can also be used to monitor the success of conservation efforts with suitable adjustments as needed.
- We derive support for research on the relationships between species.
- This data can be used to study the impacts of climate change, habitat loss, and other factors on species and their ecosystems, which are all invaluable in our conservation efforts.
- The data is also valuable for policymakers. By understanding the distribution and abundance of species, policymakers can make informed decisions about land use, resource management, and other issues that affect the natural world.
- This data can also be used to inform the development of policies and regulations that protect species and their habitats.

However, BDM faces several challenges are challenges, such as the lack of standardized formats, existence of gaps in data as well as biases, limited funds for long-term monitoring and restricted access to proprietary data.

All nations are now fully aware of their responsibilities towards biodiversity wealth and conservation, the need to efficiently manage such information and related data. In addition, individuals, local communities, industries, NGOs and other institutions have also realised that to make proper decisions and manage biodiversity, they need to develop databases and their own information system frameworks. The need for effective organisation, management and use of such data and information on biodiversity is already reflected in many international agreements and legislations such as the CBD 1993 and its *Nagoya Protocol* on access and benefit sharing 2010 (Nagoya Protocol 2010), *CITES*, the International Treaty on Plant Genetic resources for Food and Agriculture (*Plant Treaty* 2004) and so on. For data management and information exchange on biodiversity, the UNEP and World Conservation Monitoring Centre together designed and submitted to *Global Environment Facility* (GEF) the project proposal on "Biodiversity Data Management (BDM) capacitation in developing countries and networking biodiversity information". The BDM is a UNEP/GEF project funded by GEF to the tune of US $4 million. This project commenced in June 1994. The Bahamas, Egypt, Poland, Chile, Ghana, Thailand, China, Kenya, Costa Rica and Papua New Guinea were the ten countries that participated in the first phase of this project. The overall objective of BDM is to enhance the capacity building of developing countries in biodiversity data management relating to the implementation of the Convention on Biological Diversity. It decides to conduct a national "institutional survey" which will report on the existing national capacity; prepare a "national plan" for the management and application of biodiversity data, develop a series of "basic guidelines" to support efficient information management; and a "resource inventory" of available methods and technologies which can be drawn upon to assist data management. The *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES) established in Panama City on April 21, 2012, is an independent intergovernmental body committed to strengthening the role of science in public decision-making on biodiversity and ecosystem services, for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.India is one of its founding members. It is not a United Nations body. However, at the request of the IPBES Plenary and with the authorization of the UNEP Governing Council in 2013, the United Nations Environment Programme (UNEP) provides secretariat services to IPBES. At present it has almost 150 member States. A large number of NGOs, organizations, conventions and civil society groupings also participate in the formal IPBES process as observers, with several thousand individual stakeholders, ranging from scientific experts to representatives of academic and research institutions, local communities and the private sector, contributing to and benefiting from its work (www.ipbes.net).

Let us briefly have a look at some Biodiversity Data Repositories.

A. *Global Biodiversity Information Facility* (GBIF) – a global open-access biodiversity data platform that aggregates species occurrence records from multiple sources. It gathers data from museums, universities, citizen science projects, and government agencies.

B. *Encyclopedia of Life* (EOL) – a digital database that provides comprehensive species information, including descriptions, images, and taxonomy. While GBIF focuses on raw occurrence data, EOL provides curated species profiles with multimedia content.

C. *Ocean Biodiversity Information System* (OBIS) – focuses mainly on marine biodiversity data, including species distributions and ocean ecosystem monitoring. It contributes to marine conservation by providing data for marine protected areas, fisheries management, and climate change studies.

D. *Barcode of Life Data System* (BOLD) – a repository for DNA bar-coded data, helping to identify species using genetic sequences. It helps in species identification, especially for cryptic or morphologically similar species.

> Environmental DNA (eDNA) is an emerging technology that provides a novel source material for researchers and conservationists to monitor biodiversity and record alien & invasive species from the water and organic sediments that they leave behind in the environment

E. *eBioAtlas* is an ambitious partnership between *Nature Metrics* and *IUCN* to rapidly create a global atlas of life in the world's river basins and wetlands using cutting-edge eDNA technology. It intends to provide a comprehensive picture of biodiversity in each location, mobilising local stakeholders and citizen scientists to fill in critical knowledge gaps to support conservation efforts and inform global policy to reverse the loss of biodiversity. The IUCN is supposed to recruit and work with a network of global and local implementing partners to collect the environmental DNA (eDNA) samples. While the NatureMetrics will analyse the samples to identify the range of fish, vertebrates, and mammals present at each location and add the data to the eBioAtlas database. To maximize impact, the database will be freely available to non-commercial users and will be designed to interface with the IUCN Red List and other national and global environmental databases including the Global Biodiversity Information Facility (GBIF). Implementing partners would then identify local projects while stakeholders would assist with sampling. *Fauna & Flora International (FFI)* was the first implementing partner for eBioAtlas. They have been carrying out eDNA testing in Liberia and Guinea since 2019 and wanted to spread to more survey sites in Africa, to contribute data to the eBioAtlas (https://ebioatlas.org/).

> *NatureMetrics* is an award-winning technology start-up who uses cutting-edge genetic techniques to monitor biodiversity. They hope to uncover multiple species from complex environmental samples in low-cost and repeatable ways. By surveying everything from bats to bacteria, they help understand the ways and means to protect and build natural capital through activities such as farming, energy generation and forestry.

F. *The Catalogue of Life* is an assembly of expert-based global species checklists with the aim to build a comprehensive catalogue of all known species of organisms on Earth. Continuous progress is made towards completion, but for now, it probably includes just over 80% of the world's known species. The Catalogue of Life estimates 2.3 million extant species on the planet recognised by taxonomists at present time. This means that for many groups it continues to be deficient, and users may notice that many species are still missing from the Catalogue. (https://www.catalogueoflife.org/)

The role of Citizen Science Platforms

Citizen science platforms play a crucial role in biodiversity data collection and management by engaging the public in observing and recording species occurrences. One citizen science platform is *iNaturalist* –where users can upload and identify species observations. It supports biodiversity research by crowdsourcing species observations that contribute to biodiversity databases like GBIF. Platforms like Observation.org enable naturalists, citizen scientists, and biologists to collect, validate, and share biodiversity observations globally. These platforms often provide mobile applications, such as *ObsIdentify*, to facilitate data collection in the field. The aggregated data contribute to large biodiversity databases – valuable for research, conservation strategies and designing policies. By involving the public, these platforms increase data coverage and promote awareness and education about biodiversity conservation.

World Conservation monitoring Centre (WCMC) is based in Cambridge, UK, UNEP-WCMC is a collaboration between the United Nations Environment Programme and the UK non-profit organization, WCMC.

Box 6.4 *Digital Sequence Information (DSI) on genetic resources*

The Conference of the Parties (COP) to the CBD and the COP serving as the meeting of the Parties to the Nagoya Protocol, first addressed the issue of digital sequence information (DSI) on genetic resources at their respective meetings held in December 2016.

In December 2022, at its 15 meeting, the COP decided to establish a multilateral mechanism for benefit-sharing from the use of DSI on genetic resources. The COP also established the Ad Hoc Open-ended Working Group on Benefit-sharing from the Use of DSI on Genetic Resources to undertake further development of the multilateral mechanism (decision 15/9). Digital sequence information on genetic resources was also included in Goal C and Target 13 of the Kunming-Montreal Global Biodiversity Framework.

Other Databases on Biodiversity :

Hundreds of databases on biodiversity have now been created throughout the world and some of them are listed here :

(i) IOPI World Plant Checklist

(ii) BIMS (Biodiversity Information Management System): A relational database for monitoring the conservation status of species, wildlife habitats and protected areas.

(iii) BRAHMS (Botanical Research and Herbarium Management System): A database on botanical collection system.

(iv) ENVIS (Environmental Information System, India)

(v) Abstract of Tropical Agriculture (ORBIT).

(vi) Agricola (DIMDI, Data-star/Dialog)

(vii) AGRIS International (DIMDI, Data-star/Dialog)

(viii) Biological and Agricultural Index (BRS)

(ix) BIOSIS Previews (DIMDI, Data-star/Dialog)

(x) CAB Abstracts (DIMDI, Data-star/Dialog)

Of the available databases worldwide (as of 1995 the number was 7500), 75% are related to biological sciences, of which more than 60% are bibliographic or directory type and the rest are numerical, textual, image or multimedia.

SAQ II.

(a) In which year was the Biological Diversity Act first enacted in India?

(b) What is the primary purpose of the Global Biodiversity Information Facility (GBIF)?

(c) What is IPBES? How does it differ from the CBD?

(d) Choose the correct answer.

1. The Biological Diversity Act in India aims to :

   (a) Regulate international trade in wildlife
   (b) Conserve biological diversity and ensure fair sharing of benefits
   (c) Protect World Heritage Sites
   (d) Promote sustainable agriculture practices

2. Which international organization provides free and open access to biodiversity data, facilitating research and formulating policies?
   (a) International Union for Conservation of Nature (IUCN)
   (b) Global Biodiversity Information Facility (GBIF)
   (c) World Wide Fund for Nature (WWF)
   (d) United Nations Environment Programme (UNEP).

(e) Match the biodiversity data repository with its key feature :

Repository		Key Feature
1. Observation.org	(i)	Global repository for eDNA-based biodiversity data
2. eBioAtlas	(ii)	Citizen science platform for collecting and sharing biodiversity observations
3. GBIF	(iii)	Aggregator of scientific data on biodiversity
4. OBIS	(iv)	Digital database with comprehensive species information: descriptions, images and taxonomy.
5. BOLD	(v)	Repository for DNA barcoding data, helping to identify species using genetic sequences
6. EOL	(vi)	Marine biodiversity data, including species distributions and ocean ecosystem monitoring
7. iNaturalist	(vii)	A citizen-science platform, where users can upload and identify species observations.

(f) State whether the following statements are 'True' or 'False'.

1. The eBioAtlasprogramme utilizes environmental DNA (eDNA) to gather biodiversity data at scale, supporting conservation efforts and informing global biodiversity policy.
2. The Nagoya Protocol is a legally binding agreement under the CBD that focuses on access to genetic resources and the fair and equitable sharing of benefits.
3. The Catalogue of Life is an online database that provides an index of known species of animals, plants, fungi, and microorganisms, aiming to catalogue all known species on Earth.

6.5 Summary

Realizing the paramount importance of biodiversity and bioresources, international and national organizations work round the clock for the successful management of the earth's biodiversity. A plethora of biodiversity legislation has been framed for the purpose and conventions regularly held to examine the problems and prospects, and enact rules to promote the sustainable use of the natural resources. They include international agreements and national laws that aim to safeguard ecosystems, species, and genetic resources. The international biodiversity laws comprise various treaties and agreements that strive to preserve global biodiversity. They are designed to protect ecosystems, species, and genetic resources worldwide.

The Convention on Biological Diversity (CBD) for instance, adopted in 1992 at the Earth Summit, promotes the conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of benefits arising from genetic resources. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) established in 1973, aims to ensure that international trade in specimens of wild animals and plants does not jeopardize their survival. It regulates trade through a system of permits and certificates. The Ramsar Conventionadopted in 1971, focuses on the conservation and sustainable use of wetlands–freshwater lakes, marshes, mangroves, and high-altitude lakes. They are vital ecosystems providing essential services such as water purification and flood control and provide habitats for many species of flora and fauna. As of February 2025, India has 89 Ramsar sites. The World Heritage Conventionseeks to identify and protect cultural and natural heritage sites of outstanding universal value, ensuring their preservation for future generations. There are 43 World Heritage Sites in India. Out of these, 35 are cultural, seven are natural, and one, the Kanchenjunga National Park, is of mixed type—listed for both cultural and natural attributes. The Bonn Convention aims to conserve migratory species of wild animals by encouraging international cooperation to protect these species and their habitats. The International Tropical Timber Agreement (ITTA) and International Tropical Timber Organization (ITTO) agreements promote the sustainable management of tropical forests and the trade of tropical timber, to ensure that timber production benefits local communities and economies without degrading forests. The Biological Diversity Act of 2002 and the Biological Diversity (Amendment) Act of 2023 are the main acts that govern biological diversity in India. They aim to conserve biological diversity, ensure

sustainable use of its components, and ensure fair and equitable sharing of benefits arising from the use of genetic resources. Effective management of biological information involves collecting, storing, and disseminating data on species, ecosystems, and genetic resources. It is crucial for biodiversity conservation. Libraries, periodicals, and databases provide access to scientific literature, research findings, and data on species and ecosystems. They support the work of scientists, policymakers, and conservationists in protecting biodiversity. Presently, bioinformatics revolution is fully capable of enabling biodiversity researchers to communicate efficiently with each other, thus providing a common language for progress

6.6 Terminal Questions

(a) What is the main goal of biodiversity legislation?

(b) What is the role of international biodiversity laws?

(c) What is the primary objective of CITES? How does CITES work?

(d) Why is biological information management important?

(e) How do libraries, periodicals, and databases contribute to biodiversity conservation?

(f) What is the objective of India's Biological Diversity Act, 2002?

(g) What are the main protocols under the CBD?

(h) Name five key components of biodiversity data management?

6.7 Answer key

SAQ I

(a) The CBD was adopted in 1992 at the Earth Summit in Rio de Janeiro, Brazil. Its main goals are to promote the conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of benefits arising from genetic resources.

(b) The Ramsar Convention focuses on the conservation and sustainable use of wetlands.

(c) The Bonn Convention or CMS aims to protect migratory species of wild animals and their habitats. They operate through agreements and memorandums of understanding (MoUs) between countries that share migratory routes

(d) The purpose of the World Heritage Convention is to identify and protect cultural and natural heritage sites of outstanding universal value.

(e) The ITTA and ITTO promote the sustainable management of tropical forests and the trade of tropical timber.

SAQ II

(a) 2002

(b) GBIF aims to provide free and open access to biodiversity data worldwide, supporting research, monitoring, and management of species, including alien and invasive species.

(c) IPBES is a global scientific body that provides policymakers with biodiversity assessments and conservation strategies. IPBES is a scientific advisory body, while CBD is a legally binding treaty.

(d) MCQ. 1. (b); 2. (b);

(e) 1 - (ii), 2 - (i), 3 - (iii), 4 – (vi), 5 – (v), 6 – (iv), 7 – (vii).

(f) True or False. 1. True ; 2. True; 3. True.

Terminal Questions

(a) The main goal of biodiversity legislation is to protect and conserve biological diversity, ensure the sustainable use of its components, and promote the fair and equitable sharing of benefits arising from genetic resources.

(b) International biodiversity laws establish global frameworks and agreements to safeguard ecosystems, species, and genetic resources through collaborative efforts and binding commitments among countries.

(c) The primary objective of CITES is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. It uses three appendices to classify species based on their level of protection: Appendix I (most endangered), Appendix II (controlled trade), and Appendix III (protected in certain countries).

(d) Biological information management is important for the effective collection, storage, and dissemination of data on species, ecosystems, and genetic resources, supporting biodiversity conservation efforts.

(e) Libraries, periodicals, and databases provide access to scientific literature, research findings, and data on species and ecosystems, supporting the work of scientists, policymakers, and conservationists in protecting biodiversity.

(f) The objective of the Biological Diversity Act, 2002, is to conserve biological diversity, ensure sustainable use of its components, and ensure fair and equitable sharing of benefits arising from the use of genetic resources.

(g) The Cartagena Protocol (2003) which tries to focus on biosafety and the safe handling of genetically modified organisms (GMOs). The Nagoya Protocol (2014) which seeks to ensure fair and equitable sharing of benefits from genetic resources.

(h) Data collection, Data storage, Data standardization, Data sharing, Data Analysis.

6.8 References and Further Reading

Reference

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Unit – 7 ❑ Conservation of Biodiversity—Genetic, Species and Ecosystem

Structure

7.1 Objectives

Understanding genetic, species, and ecosystem biodiversity allows us to

- assess the health and stability of ecosystems,
- identify potential threats to biodiversity, and
- develop effective conservation strategies to protect the variety of life on Earth, and the
- functioning of healthy ecosystems;
- A diverse gene pool within a species, a range of different species within an ecosystem, and a variety of ecosystem types all contribute to resilience and adaptability in the face of different calamities, such as climate change or disease outbreaks.

7.2 Introduction

The Earth’s biodiversity is the result of close to 4 billion years of evolution. It includes not only the world’s species with their unique evolutionary histories, but also genetic variability within and among populations of species and the distribution of species across habitats, ecosystems, landscapes, even whole continents or oceans. We usually explore biodiversity at three levels: genetic diversity, species diversity and ecosystem diversity. These three levels work together to create the complexity of life on Earth.

Genetic diversity is the variety of genes within a species. Each individual within a species has their own particular genetic composition. Almost always, a species comprises different populations, each with their unique genetic characteristics. Even, no two individuals within a population are ever genetically identical, barring clones or identical twins. However, not all groups of organisms have the same degree of genetic diversity. Those of relative recent ancestry are genetically more similar than those whose common ancestor dates long back in evolutionary time. The latter,in particular with great genetic diversity, are invaluable genetic resource. Thus, several species of carnivorous marsupials in Australia called dasyurids are endangered and at least one of them, the Tasmanian tiger, has gone extinct, since Europeans arrived in Australia. Loss of even one species of dasyurids such as the spotted-tailed quoll (*Dasyurus maculatus*) or a numbat, the banded anteater (*Myrmecobius fasciatus*), would entail loss of a substantial genetic resource. Several species of dasyurids in Australia are in fact endangered. The most efficient way to counteract loss of genetic diversity is to maintain large and well-connected populations. Small and isolated populations rapidly lose genetic variation resulting in lower adaptive capacity, loss of resilience and weak potential for long-term survival.

Species diversity refers to the variety of species that exist in a habitat or a region. Some habitats, such as rainforests and coral reefs, harbour many species. Others, such as salt flats or a polluted stream, have fewer. Endemic species are those that exist nowhere else.Charles Darwin's reflections on species diversity underlay one of the most far-reaching theories in the history of ideas: the theory of evolution by natural selection. His travels to the far-flung islands, archipelagos, rain forests revealed species diversity in all its forms and changed our thinking of our own position in Nature for all time to come. Like Darwin, we often equate biodiversity with the number and novelty of the species present. Each species has a unique history – they are the result of descent with modification (Darwin 1859) withthe history of the lineage that they represent. Some taxa are of particular interest due to their evolutionary relationships. In the Galapagos, Darwin's finches are closely related species that are a living testimony of evolutionary diversification in full play. For us, the chimpanzees, gorillas, and orangutans have special value as "kin". On another scale, closely related beetles remind us of that South America and Africa were once the same land mass, their common heritage still evident after ca. 100 million years of geographic separation.

Ecological biodiversity is the diversity of ecosystems, natural communities, and habitats. In essence, it represents the variety of ways that species interact with each other and their environment. The forests of Sunderbans differ from the forests of Neora Valley by the types of species found in both these ecosystems, as well as in temperature and rainfall. Ecosystem diversity is crucial to ecosystem integrity, which in turn enables our life support, giving us a livable climate, breathable air, and drinkable water.

But then, why do we *need to conserve*? The reasons are threefold.

(i) To create a viable population to avoid extinction of rare and endangeredspecies.

(ii) To maintain the entire genetic diversity within the populations, thus enhancingtheir ability to undergo adaptive changes leading to speciation.

(iii) To preserve ecosystem processes such as primary and secondary productivity, energy flow, nutrients flow, water balance, soil conservation, and so on.

Overall, understanding biodiversity at all levels is critical for effective conservation efforts, sustainable resource management, and maintaining the overall health of the planet. Greater biodiversity in ecosystems, species, and individuals leads to greater stability. Thus, species with high genetic diversity and many populations that are adapted to a wide variety of conditions are more likely to be able to withstand disease, disturbances, other kinds of stress, and climate change.

7.3 Conservation of Genetic Diversity

The genetic variability among individuals within a species can result from mutation, gene rearrangements, genetic polymorphism (the presence of different forms of the same gene), and isolation of gene pools, local selection pressures, habitat (environmental) complexity, landscape mosaics, and environmental gradients. Specific genetic combinations in populations result from natural selection acting on individuals in response to biotic and abiotic environments and from random, non-selective fixation of genes. Lately, studies of molecular evolution and recent laboratory techniques enable us to determine the degree or closeness of relationships within and between populations. To conserve genetic diversity, different populations of a species must be conserved.

Genetic conservation strategies are generally planned and executed at the population level, as the unit for genetic conservation is basically a population of a species. The reasons why genetic conservation is attempted at the population level are:

(i) The population, and not the species, is the ecologically and evolutionarily significant (i.e. functional) unit (ESU).

(ii) Genetic changes over generations mostly take place at the population level.

(iii) Local adaptive changes likewise occur in the population.

(iv) Geographically and genetically isolated populations offer the greatest potential for speciation.

(v) Conservation at the species level may overlook the dynamics and attributes of individual populations within it as well as their ecological functions.

(vi) Lastly, conservation at a level below the population, say at the allelic level, is impractical.

All genetic conservation strategies and actions should be compatible with the three aims of conservation mentioned in the Introduction. The first level of concern has a time-scale of a few days to a few decades and if not met, the other two goals are automatically denied. Maintenance of genetic diversity must also be planned in such a way that the population and species are able to genetically adapt and evolve in an unhindered manner. This second level of concern has a time-scale of several decades to millennia. The third level of concern, the capacity for continuing speciation, is considered the creative part of biodiversity, just as extinction is the annihilating part. The potential of a population (thereby the species) for continued speciation, need be maintained at all cost. However, its time-scale of tens of thousands of years or more makes appreciation of it difficult for humans. In any case, short-term conservation goals should be discouraged in the interest of biodiversity.

Genetic conservation has its own limitations; per se, it cannot save biodiversity. Application of genetics to conservation efforts is still in its infancy. Moreover, many genetic techniques useful in assessing genetic diversity are hardly cheap and take time to learn.

7.4 Conservation of Species Diversity

'Species' most often are at the centre of conservation strategies. Numerous legislations and conventions on conservation at the world and national levels are focused on species such as the CITES, Endangered Species Act of USA (ESA). Loss of species diversity is more obvious, easily detectable and quantifiable than either loss of genetic or habitat diversity. Even conservation approaches based on habitats or ecosystems depend on an intimate understanding of the biology of their constituent species. The design and management of bioreserves are also often based on knowledge of species-area relationships. life-history requirements of species destined for conservation in such reserves and the minimum number of individuals of a species necessary to avoid major loss of genetic diversity.

SAQ I.

(a) What factors can contribute to genetic variability among individuals?

(b) State the reasons why genetic conservation is generally attempted at the population level.

(c) What is ESU? Why is it important to consider 'populations' as ESUs?

(d) State whether the following statements are 'true' or 'false'.

(i) To conserve genetic diversity, different populations of a species must be conserved.

(ii) Geographically and genetically isolated populations have the least potential for speciation.

(iii) To avoid extinction of rare and endangered species, a viable population is a primary requisite.

(iv) Genetic conservation by itself cannot preserve biodiversity.

7.4.1 Types of species to be conserved

The first category of species: In this category, the priority is given to the threatened species (i.e., critically endangered, endangered and vulnerable species) following the International Union for Conservation of Nature and Natural Resources (also known as the IUCN Red List or Red Data List). Given (1984) proposed several highly prioritized data for selection of threatened species to be conserved.

The second category of species: In this category, the directly harvested plants which are sources of propagating materials for planting elsewhere or such plants showing genetic variation useful for breeding programme are selected. These include medicinal plants, food and storage plants, dye yielding plants, spices, ornamentals, etc.

The third category of species: This category includes Keystone species, Umbrella species, Flagship species, and so on.

A. Keystone species : Within biological communities, certain species may be important in determining the ability of large numbers of other species to persist in the community. These crucial species have been termed keystone species. They are often top predators in an ecosystem. Since they hold the ecosystem together, they are likened to a keystone in an arch; if removed, the entire structure collapses. The concept of keystone species was developed by Robert T Paine (1966). He described the role of keystone species in Mukkaw Bay in Washington. The keystone species sea stars for example (Pisaster ochraceus), eat mussels that have no other natural predators and keep their number in check. If the sea star is removed from the ecosystem, the mussel population increases uncontrollably, driving out other species. As a result, the number of other species decline drastically. Other examples of other keystone species :

(a) Caribbean Ivory tree coral (*Oculina varicosa*) : This coral is home to 300 invertebrate species. Many small-fishes live and breed here and become food for larger fishes.

(b) Sugar maple (*Acer saccharum*) : It is a keystone species of hardwood forest that brings up water from lower levels in the ground to increase the moisture of the top soil, and help other plants to thrive there. The tree provides shelter to many insects, birds and small animals.

(c) Elephants seem to serve as a keystone species in some parts Africa. The species of elephant native to Africa (*Loxodonta africana*) has two sub-species: the savanna or bush elephant (*L. africanavar. africana*) and the forest elephant (*L. africanavar. cyclotis*). They differ to some extent in form and size. The forest elephant is shorter, smaller with rounded ears, flattened forehead, longer and thinner tusks than the savanna subspecies. The forest elephant subspecies is a keystone species in some woodland in Western Africa. In these forests, elephants are the only animal large enough to break larger fruits with thick shells, as also many other smaller hard fruits. The nutlike pits inside these seeds pass through the elephant's intestine and are subsequently deposited with the animal's dung that provides a rich source of nutrients. The seeds germinate and continue to grow. More than 30% of the larger tree species in these forests depend on elephant for their seed dispersal and germination. The savanna elephants on the other hand, eat small trees and preserve the grassland. The grasses need open space so that they may get plenty of sun light for their survival. If elephants were not there, the savanna would convert to a forest.

The identification of keystone species has several important implications for conservation biology. First, as already discussed, the elimination of a keystone species from a community may precipitate the loss of many other species. Second, in order to protect a species of particular interest, it may be necessary to protect the keystone species on which it depends either directly or indirectly. Third, if the few keystone species of a community can be identified, these could be carefully protected or even encouraged if the area is disturbed by human activity.

Keystone Species-A species whose loss from an ecosystem would cause a greater than average change in other species populations or ecosystems processes; species that have a disproportionately large effect on other species in a community. [*Heywood VH, Watson RT. Global Biodiversity Assessment. UNEP*]

Protecting keystone species is a priority in conservation efforts, because if a keystone species is lost from a conservation area, numerous other species might be lost as well. Because many tropical insect species appear to be highly specialized in their feeding behaviour, subsisting on just one or a few related plant species, it is argued that the extinction of each tropical plant species potentially results in an extinction cascade, with an additional loss of 10 to 30 insect species. It is even possible that the extinction of a single plant species could eliminate hundreds of insect species.

B. Umbrella species : The term was first coined by Bruce A. Wilcox in 1984 who defined umbrella species as "one whose minimum area requirements are at least as comprehensive as the rest of the community for which protection is sought through the establishment and management of a protected area.” According to Heywood (1995) “umbrella species are those whose occupancy area or home range are large enough and whose habitat requirements are wide enough that, if they are given a sufficient large area for their protection will bring other species under that protection” (Fig. 7.1). The umbrella effect is the idea that protecting one species will help protect a large amount of co-occurring species. Thus, umbrella species are those selected for conservation, typically because protecting these species indirectly protects the many other species within the ecosystem. Species co-occur when their home ranges overlap. This is usually because they share some of the same habitat needs, like the types of temperatures they can survive in or the need to live in rocky terrain. By protecting the home range of an umbrella species, the habitats in that area will stay intact and livable for the other species that need to live there, too.

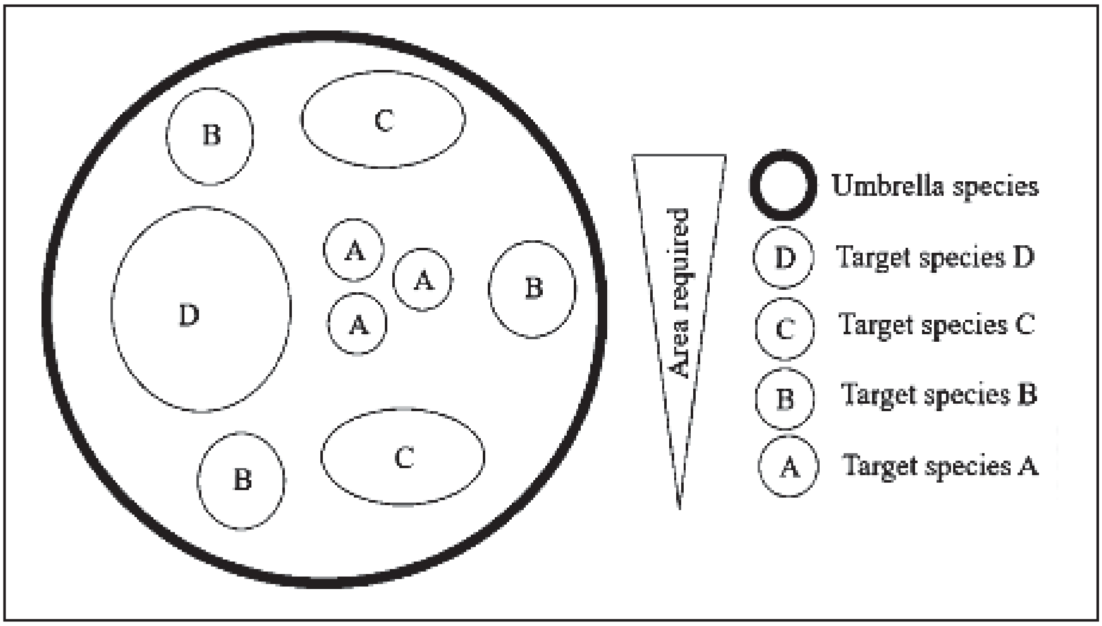

Figure 7.1. The concept of ‘umbrella species’

Examples : (i) The reserves in Klamath-Siskiyou forests of Northern California, set aside for the northern spotted owl, also protect molluscs and salamanders within that habitat. Thus, northern spotted owl and old growth trees are the umbrella species and molluscs and salamanders are within the protective boundaries of the northern spotted owl.

(ii) Tiger in India and elsewhere has served as an umbrella species. *Project Tiger* was launched to save the tiger and thereby its habitat and thus other species are also protected within its protective boundaries.

(iii) The Giant Panda in China is a well-known umbrella species. Researchers from Duke University have shown that 96% of giant panda habitat overlaps with the habitats of species that are only found in that area of China. By protecting the home ranges of the giant panda, the essential habitat for these species is also preserved.

C. Flagship species : A flagship species is a plant or animal species which is used to represent a certain environmental issue or cause. According to Simberloff (1998), "a flagship species is a species that has become a symbol and leading element of an entire conservation campaign." A flagship species is selected in conservation campaign because of its attractiveness because it has unique features and is compatible with the conservation goals and the target audience. It has been argued that flagship species can be useful for raising funds for conservation efforts that benefit all the species in the area the flagship species inhabits. For example, the polar bear above the iceberg is used as a flagship species to generate awareness about global warming. Whales have been used as flagship species, as an international symbol of a moral mandate for greater ocean conservation efforts.

D. Indicator species : Indicator species are defined as species which can provide information on ecological changes and give early warning signals regarding ecosystem processes in site-specific conditions due to their sensitive reactions to them. They are also called bioindicators. These species are known to be particularly sensitive to pollutants, human interference, ecological instability or other disturbances. Indicator species are sensitive to environmental changes (even subtle changes), are easy to observe and monitor and provide biotic data to researchers. Importantly, they reveal patterns—like reproduction rates, size, lifespan, density, and growth over time. These patterns can help assess the health of the environment and predict future changes. The Bald-Eagle in the USA was particularly susceptible to chemical pesticides, particularly DDT. The population of bald-eagle dwindled and the species was threatened. Banning use of DDT restored the population of bald-eagle and its name was later removed from the threatened list. Certain lichens are particularly sensitive to sulphur oxide pollution and have been used for biomonitoring such pollution levels,

E. Charismatic species : These species are significant from social, cultural or anthropomorphic standpoints, and/ or usually attractive.

F. Recreational species : These species are used for collection, growth, observation, popular sports—all that prioritize enjoyment. Recreational species include fish—popular game fish such as tuna, billfish, grouper, and shark; release of catches is often encouraged for conservation. Dolphins are also used for such purposes.

Once the species are identified for protection, conservation strategies can be worked out for them either through in-situ or ex-situ methods or through a judicious combination of both. Species-based approach has resulted in identification, at the national and international levels, of taxa that need conservation and which are then listed by IUCN or national agencies in Red Data Books or detailed in the IUCN Species Survival Commission (SSC).

SAQ II

(a) Define a keystone species. Why protecting them is considered important?

(b) Why is an 'umbrella species' so called?

(c) Point out the basic differences between a 'keystone species' and an 'indicator species'?

Multiple Choice Questions :

1. A species that has become a symbol and leading element of an entire conservation campaign is known as –

   (a) Umbrella species
   (b) Flagship species
   (c) Keystone species
   (d) Charismatic species

2. Which of the below is an advantage of ecosystem diversity?

   (a) There are no planned satisfactory habitat or ecosystem classification on which the protected area networks will depend.
   (b) Populations of threatened species which need urgent conservation steps are likely not be included in a network of protected areas.
   (c) It is the cheapest and most effective way of conserving both genetic and species diversities.
   (d) none of the above.

3. In kelp (large seaweeds of Laminariales) ecosystems, sea otters by preying

on sea urchins help control their populations, which in turn protect kelp forests from being overgrazed. Sea Otter is a (n) __________ species.

(a) Indicator species
(b) Flagship species
(c) Umbrella species
(d) Keystone species

7.5 Conservation of Ecosystem Diversity

Conservation of ecosystem attempts to ensure that representative areas of ecosystems or important habitat sites are maintained through a network of protected areas, through restoration of degraded ecosystems such as reforestation or say wetland restoration, or through any other controls on land use. A decision on which habitat should be selected for conservation is dictated by criteria such as species richness and degree of endemism (hot spots). Conservation potential / Threat Index (based on ecosystems), predicts how current deforestation rates would affect the conservation and establishment of protected areas. Initially, this approach was tested in 23 Indo-pacific countries and subsequently was adapted for the Indo-Pacific region and Latin America and West Indies. It was observed that engaging local communities in conservation efforts ensures sustainable management of ecosystems.

Advantages :

(i) It is argued that if ecosystems are allowed to be kept intact and materials and energy flow unhindered through the ecosystem, then conservation of species and genetic diversity is automatically done.

(ii) Ecosystem diversity conservation is the cheapest and most effective way of conserving both genetic and species diversities.

(iii) It requires no detailed knowledge of the status and distribution of its constituent species. This method is particularly useful for conserving the tropical rain forest ecosystems, whose species diversity has not yet been adequately studied or quantified.

Disadvantages :

(i) There is no planned satisfactory habitat or ecosystem classification on which the protected area networks will depend.

(ii) Another problem is that populations of threatened species which need urgent conservation steps may not be included in a network of protected areas.

(iii) Many ecosystems of the world are poorly known and understood. Also, the size, composition and complexity of an ecosystem can vary considerably in time and space. Attempts to reconcile both species- and ecosystem-based approaches are the needs of the time. It is better to identify areas or ecosystems of high diversity, especially in threatened species, and undertake efforts to conserve such areas.

7.6 Summary

Genetic Diversity refers to the variation in genes within a species. It includes differences in DNA among individuals, which can result in variations in traits such as color, size, and resistance to diseases. Genetic diversity is crucial for a population's ability to adapt to changing environments and for the overall health of the species. To conserve genetic diversity, different populations of a species must be conserved. Genetic conservation strategies are generally planned and executed at the population level, as the unit for genetic conservation is basically a population of a species.

Species Diversity is the variety of species within a particular region or ecosystem. It includes the number of different species (species richness) and the abundance of each species (species evenness). High species diversity ensures ecosystem resilience and stability. Endemic species are confined to a particular region. Thus, the Cape Floristic Region in South Africa is home to about 6,200 plant species found nowhere else in the world. Species most often is the focus of conservation strategies. Different categories of species are conserved – keystone species, umbrella species, flagship species, indicator species, charismatic and recreational species.

Ecosystem Diversity encompasses the variety of ecosystems in a given area. It includes different habitats like forests, deserts, wetlands, and oceans, each with its unique community of organisms and environmental conditions. While the African continent for example is home to tropical rain forests, alpine mountains and dry deserts and enjoys a high level of biodiversity, Antarctica, covered almost entirely by an ice sheet, has low biodiversity. Ecosystem diversity supports a wide range of services, such as water purification, climate regulation, and nutrient cycling. Conservation of ecosystem attempts to ensure that representative areas of ecosystems or important habitats remain undisturbed. This is ensured by a network of protected areas, by restoration of degraded ecosystems or through other controls over land use. Criteria such as species richness, presence of hot spots often dictate selection of ecosystems for conservation.

Understanding and preserving these three levels of biodiversity is essential for maintaining the balance and health of our planet's ecosystems.

7.7 Terminal Questions

(a) Why a population, rather than the entire species, is considered the ecologically and evolutionarily significant unit ?

(b) What is an 'umbrella species' and its characteristics?

(c) Explain in brief why is conservation of ecosystem diversity very important?

7.8 Answer key

SAQ I

(a) See Section 7.3; (b) See Section 7.3;

(c) Evolutionary Significant Units. By considering populations as ESUs, conservation efforts can better address the specific needs and characteristics of these groups, ultimately contributing to the overall health and resilience of the species

(d) 'True' or 'False'. (i) True; (ii) False; (iii) True; (iv) True

SAQ II

(a) Look up Section 7.4.1.

(b) See Section 7.4.1

(c) Keystone species have a direct and critical impact on ecosystem function and stability. Indicator species provide insight into the overall health and changes within the ecosystem but do not necessarily have a critical impact on ecosystem stability.

Multiple Choice Questions :

1. (b); 2. (c); 3. (d)

Terminal Questions

(a) Some of the reasons why a population, rather than the entire species, is considered the ESU:

(i) *Genetic Differentiation :* Populations within a species can exhibit significant genetic differences due to geographic isolation or local adaptations. These genetic differences can lead to unique evolutionary traits that are important for the species' long-term survival and adaptability.

(ii) *Local Adaptations :* Populations often adapt to their specific local environments, developing unique traits that help them thrive in those conditions. These adaptations can be crucial for the survival of the population and may not be present in other populations of the same species;

(iii) *Reproductive Isolation :* Populations can become reproductively isolated from each other, meaning they do not interbreed frequently. This isolation can lead to the development of distinct genetic and phenotypic characteristics that are important for conservation;

(iv) *Ecological Roles :* Different populations may play unique ecological roles within their habitats. Protecting these populations ensures the maintenance of ecosystem functions and biodiversity;

(v) *Conservation Priorities :* Focusing on populations allows conservationists to prioritize efforts on distinct and irreplaceable units within a species. This approach helps allocate limited resources more effectively and ensures the preservation of unique evolutionary lineages.

(b) An umbrella species is one whose conservation is expected to confer protection toa large number of co-occurring species and their habitats. By focusing conservation efforts on an umbrella species, we can indirectly protect a wide array of other species that share the same ecosystem. Their characteristics include :

- Wide Range : Umbrella species typically have large home ranges and habitat requirements, encompassing a variety of ecosystems.
- Indicator Role: They often serve as indicators of overall ecosystem health.

- Conservation Efficiency: Protecting umbrella species can streamline conservation efforts by addressing the needs of multiple species simultaneously.

(c) Conserving ecosystem diversity is critical for several reasons:

- *Biodiversity Preservation:* Ecosystem diversity supports a wide range of species, each with unique roles and contributions. By preserving diverse ecosystems, we maintain species richness and genetic diversity, which are crucial for resilience and adaptability.
- *Ecosystem Services:* Healthy ecosystems provide essential services such as water purification, air quality regulation, pollination, soil fertility, and climate regulation. These services are vital for human well-being and survival.
- *Resilience to Change:* Diverse ecosystems are more resilient to environmental changes and disturbances, such as climate change, natural disasters, and human activities. This resilience helps ecosystems recover and adapt, ensuring their long-term stability.
- *Resource Availability:* Diverse ecosystems offer a variety of resources, including food, medicine, raw materials, and genetic resources. These resources are important for livelihoods, economic activities, and scientific research.
- *Cultural and Recreational Value:* Ecosystems provide cultural, spiritual, and recreational benefits. They are integral to many indigenous cultures and communities, offering opportunities for tourism, education, and recreation.
- *Interconnectedness:* Ecosystems are interconnected, and the health of one ecosystem can impact others. Conserving ecosystem diversity helps maintain these connections and supports the overall health of the planet.

By conserving ecosystem diversity, we ensure the continued functioning of natural systems that sustain life on Earth. It is an investment in our future and the health of our planet.

7.9 References and Further Readings

Reference

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Unit – 8 ❑ Biodiversity Conservation Efforts and Sustainable Development

Structure

8.1 Objectives

From this unit you will learn

- The different conservation strategies adopted to conserve biodiversity on this planet.
- Why in situ conservation is important
- Why do we need to fall back upon ex situ conservation
- The different social approaches to conservation that are still in practice over the centuries such as sacred groves and the significance of Sthalavrikshas
- How different tribal people, indigenous communities have protected their own dwelling ground, and what we can learn from them
- Different community efforts at protecting biodiversity

- That all development efforts that encroach forest lands and traditional practice of indigenous communities cannot succeed without taking the inhabitants into confidence
- Why informed prior consent of indigenous societies and their involvement/participation in the use of bioresources is now a cardinal principle at all levels, national or international.
- You can study case-histories of conflict that had arisen when traditional communities were forcefully evicted by the state or corporations to clear land for 'development'. Lessons learnt from such conflicts help in planning for similar 'developments' in the future.
- Success stories of participatory forest management
- The contents of different biodiversity awareness programmes that are available
- The role of numerous organisations actively committed to conserving biodiversity
- The sustainable development goals of the United Nations, the measures adopted to execute them and how our country seeks to achieve these goals.

8.2 Introduction

Biodiversity is the web of life, the living fabric of our planet. It underpins human wellbeing in the present and in the future. However, biodiversity is currently in a state of sharp decline – an estimated 1,000 times the natural rate according to UNESCO 2024. Its rapid decline threatens nature and people alike. Many scientists believe due to deleterious anthropogenic changes, we are now in the midst of 'Earth's sixth mass extinction' event, comparable to the last great extinction crisis 65 million years ago. These extinctions are irreversible and pose a serious threat to our health and wellbeing. It is vital to transform people's roles, actions and relationships with biodiversity, to halt and reverse its decline. Designation and management of protected areas is the cornerstone of biodiversity conservation. However, despite an increase in the total number of protected areas in the world and other in situ conservation strategies, biodiversity continues to decline. An integrated landscape approach to conservation planning plays a key role in ensuring suitable habitats for species. UNESCO works on the conservation of biodiversity and the sustainable use of its components through UNESCO designated sites, including biosphere reserves, World Heritage sites and UNESCO Global Geoparks. In 2018, UNESCO designated sites protected over 10 million km^2, an area equivalent to the size of China. There are currently 1,157 UNESCO World Heritage sites which not only represent the most outstanding places on the planet in terms of human history and culture, but also protect some of the richest areas in terms of biological diversity. These extraordinary places, encompassing both natural and cultural treasures, play a vital role in preserving ecosystem integrity and biodiversity. Despite covering less than 1% of the Earth's surface, they harbour over 1/5 of mapped global species richness, making them a haven for an astonishing array of plant and animal life. Today there are more than 20,000 threatened species, 75,000 species of plants and 30,000 species of birds, fishes and mammals in these World Heritage Sites. These conservation instruments have adopted policies and strategies that aim to conserve these sites, while supporting the broader objectives of sustainable development. One such example is the policy on the integration of a sustainable development perspective into the processes of the World Heritage Convention. UNESCO is also the depository of the Convention on Wetlands of International Importance. Countless species of plants and animals depend on these delicate habitats for survival. However, many protected areas are not functioning as effectively as originally intended, due in part to limited resources to maintain these areas and/or enforce relevant legal frameworks. In addition, current protected area networks may need to be re-aligned to account for climate change. Capacity building is a key factor in the successful avoidance and reduction of land degradation and informed restoration. Capacity development needs should be addressed at three levels: national, provincial and local. There is also a need for capacity building to enable sources outside government to inform relevant departments and policies on biodiversity (e.g. through consultancies, academia and think tanks). *Ex situ* conservation through botanical gardens, arboretas, zoological gardens, captive breeding, seed banks, *in vitro* storage of germplasm at different centres -- have all gone a long way in mitigating hunger and natural calamities. Efforts to preserve biodiversity must take into account not only the physical environment, but also social and economic systems that are well connected to biodiversity and ecosystem services. Measures to improve environmental status within conservation areas, combined with landscape-scale approaches, are urgently needed if their efficiency is to be improved.

Sustainable development is a generic term that describes how to meet the needs of the present without compromising the needs of future generations, defined for the first time in the 1987 Brundtland Report, *"Our Common Future"*, published by the United Nations World Commission on Environment and Development. The Sustainable Development Goals are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. Integration of sustainable development perspective and sustainable development goals (SDGs) is imperative in all conservation practices.

The 15th Conference of the Parties to the Convention on Biological Diversity (COP15) adopted a landmark roadmap to 2030 which includes area-based targets such as designating 30% of the Earth's land surface a protected area and restoring 30% of the planet's degraded terrestrial, inland water, coastal and marine ecosystems by 2030. UNESCO will be contributing to implementation of the *Kunming–Montreal Global Biodiversity Framework*, as the agreement is known, through its own networks of designated areas–738 biosphere reserves, 177 UNESCO Global Geoparks and 218 natural World Heritage sites. They already cover a cumulative area equivalent to more than 6% of the land surface of the Earth.

8.3 Types or Methods of Biodiversity Conservation

Biodiversity conservation involves protecting and maintaining the variety of life on Earth. Withclimate change and its associated adverse to cataclysmic impact, biodiversity loss and species extinction is increasing at a very fast rate. Biodiversity conservation is therefore imperative at different levels throughout our planet. It includes *in-situ* and *ex-situ* conservation which is being practiced for many years. Technological advancements including remote sensing, different conservation technologies, biotechnology to protect endangered species or enhance resilience are also in place for quite some time. Legal and different policy measures including international treaties and agreements already exist for close to three decades. The United Nation is playing a proactive role in this regard. Public awareness and educational programmes involving communities and indigenous population has definitely increased awareness and involvement. Continuous research and regular monitoring has exposed gaps in our knowledge. But much still remains to be done. It is feared that if we do not act more resolutely and faster, biodiversity loss will easily outpace all our good intentions. Let us not forget that climate change continues to exacerbate biodiversity depletion much faster than we could even imagine.

8.3.1 *In situ* Conservation

- Protected Areas : Establishing national parks, wildlife sanctuaries, and biosphere reserves to safeguard habitats.
- Habitat Restoration : Restoring degraded habitats, such as wetlands or forests, to support biodiversity.
- Sustainable Practices : Promoting sustainable agriculture, forestry, and fishing to minimize environmental impact.

It involves the conservation of species, ecosystem in their natural habitat where both wild and domesticated taxa can be conserved through a network of protected areas. According to the IUCN guidelines for Protected Area Management Categories, a protected area can be defined as “an area of land and/or sea specially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means”.

Box 8.1 Kunming-Montreal Global Biodiversity Framework (GBF)

The GBFis an international agreementadopted in December 2022 at the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity. It supports the achievement of the Sustainable Development Goals and builds on the Convention’s previous Strategic Plans to set out an ambitious path, to reach the global vision of a world living in harmony with nature by 2050.Among the Framework’s key elements are 4 goals for 2050 and 23 targets for 2030. Here are some key points:

A. Targets for 2030:

- *30×30 Deal :* Conserve and manage 30% of terrestrial, inland water, and coastal and marine areas.
- *Restoration :* Restore 30% of degraded ecosystems.
- *Species protection :* Stop the extinction of known species and reduce the extinction risk and rate by tenfold.
- *Pollution reduction :* Reduce pollution risks and negative impacts by 2030.
- *Sustainable management :* Sustainably manage areas under agriculture, aquaculture, fisheries, and forestry.
- *Climate change :* Tackle climate change through nature-based solutions.
- *Invasive species :* Reduce the rate of introduction and establishment of invasive alien species by at least 50%.
- *Wild species :* Secure the safe, legal, and sustainable use and trade of wild species.
- *Urban spaces :* Green up urban spaces.

B. Goals for 2050:

- *Ecosystem and species health :* Halting human-induced species extinction.
- *Sustainable use of biodiversity :* Ensuring the sustainable use of biodiversity.
- *Equitable sharing of benefits :* Equitably sharing the benefits arising from the utilization of genetic resources.
- *Implementation and finance :* Closing the biodiversity finance gap.

Financial Commitments

- *USD 200 billion per year :* Aim to channel this amount to conservation initiatives from public and private sources.
- *USD 500 billion/year reduction in harmful subsidies :* Countries committed to identifying and eliminating harmful subsidies by 2030. [https://www.cbd.int/conferences/2021-2022/cop-15/documents]

8.3.1.1 Categories of Nature Reserve

There are various types of protected areas with different degrees of protection and purposes. According to IUCN categories (2006), there are 6550 National parks and about 40,000 smaller protected areas. The various categories of Nature Reserves are mentioned below:

Category Ia - Strict Nature Reserve : These are often home to dense native ecosystems that are protected from human disturbance outside of scientific study, environmental monitoring and education. In some cases they are of spiritual value to local communities.

Category Ib - Wilderness Area : In this category, the areas are generally larger and are protected in a slightly less stringent manner than that of strict nature reserves. Human visitation is limited, often allowing such persons who are willing to travel of their own accord, either by foot, by ski by boat or any other means. The Serengeti National Park of Tanzania is an example of Wilderness Area.

Category II - National Park : It displays similar characteristics to that of Wilderness Areas with reference to size. The main purpose of this category is to protect functioning ecosystems. Human visitation is more lenient than that of strict nature reserve and wilderness areas. National parks are managed in such a way that they contribute to local economies through promoting educational and recreational tourism.

Category III - Natural Monument or Feature : These are comparatively smaller areas that are specifically assigned to protect a natural monument and its surrounding habitat. The protected area of this category encompasses natural, geological or geomorphological features, culturally-influenced natural features, and natural cultural sites and so on.

Category IV - Habitat/Species Management Area : They refer to more specific areas of conservation with regard to an identifiable species or habitat, which needs continuous protection rather than that of a natural feature. Habitat or species management areas may be present as a fraction of a wider protected area which needs varying levels of active protection such as prevention of poaching, creation of artificial habitats, halting natural succession, supplementary feeding practices and so on. For example, Galapagos is managed under this category to preserve the island's native flora and fauna.

Category V - Protected landscape/Seascape : In this category, the area covers entire bodies of land and ocean with a clearer management plan relevant to Nature conservation, but is more likely to include a range of for-profit activities. The basic principle is to protect regions that have built up a distinct character in view of their ecological, biological, cultural or scenic value.

Category VI - Protected Area with sustainable use of natural resources : This category may be principally suitable to huge areas that already have lowlevel of human activities in which local communities and their traditional practices have had little permanent influence on the environmental condition of the region.

8.3.1.2 Objectives of Nature Reserves

Objectives : Four primary objectives for preservation of Nature Reserves are:

1. To preserve large and functioning ecosystems with an objective of providingadequate conditions to the resources so that the ecosystems can be sustainedfor a long time.
2. To preserve biodiversity with an objective of conserving maximum possible number of species.
3. To protect those species which are especially threatened.
4. To perpetuate plants for continuing and sustainable harvest.

In addition, McNeely *et al*. (1987) lists some other objectives, such as

(i) To maintain and promote genetic diversity;

(ii) To manage Wild Life;

(iii) To conserve soil and water;

(iv) To protect social and cultural heritage;

(v) To serve the requirements of education and research;

(vi) To serve as sites of recreation and tourism

(vii) To maintain scenic beauty and aesthetic integrity.

(viii) To promote integrated development within the reserve and between the reserves.

(ix) To promote options for the future.

8.3.1.3 Biosphere Reserves and National Park

Design of Biosphere Reserves /National Park

According to Given (1996) six important issues are to be seriously considered while designing such Reserves, and these are very crucial to the success of the Reserve. These include: (i) Reserve size; (ii) Spatial and Temporal heterogeneity and dynamics; (iii) Ideal Geographic Context; (iv) Connection of different reserves; (v) Natural Landscape elements and (vi) Creation of zones within a Reserve. Let us elaborate on these issues.

(i) Reserve size : The reserves should be large enough so that they can cater to a viable population of species and ecosystem functions in a sustainable manner. Large Reserves have no edge effects; hence they can minimize the impact of external factors and also can accommodate perturbations more effectively. A global survey showed that ~76% of the World's important Nature Reserves are less than 100,000 ha in area. Only 3.5% exceeded a million hectare.

(ii) Spatial and temporal heterogeneity and dynamics : Nature is dynamic and undergoes changes over time; hence heterogenous reserves are better than homogenous ones. Such spatially heterogenous reserves better accommodate the biotic and abiotic disturbances and at the same time promote the occurrence of metapopulations of a species.

(iii) Ideal geographic context : The context refers to the shape and location of the reserves. There are guidelines for setting up a reserve. The context of the reserve must be considered individually for every potential reserve. The shape of the reserve is predetermined if it includes natural features like lake, riverbank or mountain top. If the shape is not predetermined, the best shape is circular, because it is compact and has the smallest amount of edge effect. Generally, one large and several small areas are better than one large area.

(iv) Connections of different reserves : Reserves are made contiguous through corridors, i.e. strips of areas similar to reserves that connect two or more reserves for maintaining overall integrity of the physical environment. The corridors allow easy movement of species and become species-rich as high proportion of species from both communities inhabit or utilize the area. The corridors also help to reduce erosion and increase aesthetic value of landscape.

(v) Natural landscape element : These include valleys, ridges, slopes, canyons, drainage basins, streams, etc. The various diversities of landscape enhance the value of a reserve. Any modification of natural landscape elements makes the reserve inferior.

(vi) Creation of zones within a reserve : Any Nature Reserve should have three district zones namely, a central core zone, buffer zone and manipulation or transition zone (Fig. 8.1).

(a) Core zone : It comprises of legally protected ecosystem with suitable habitats and landscape elements where no human activity is allowed.

(b) Buffer zone : Next to the core zone, a buffer zone is created which helps to absorb edge effects—such as changes in temperature, relative humidity and light; more exposure to wind; increased leaf fall; decreased population size of the species; elevated levels of tree mortality etc. ln this zone, limited human activity is permitted. There are different kinds of buffer zones, of which ‘extension buffering’ and ‘socio-buffering’ are the important ones.

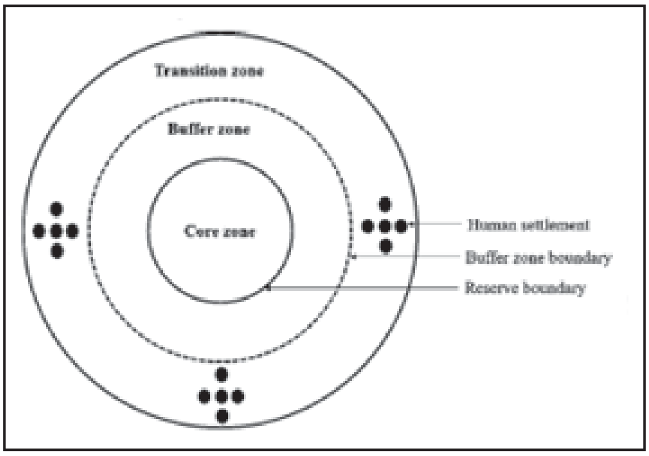

Fig. 8.1. Zones of biosphere reserve

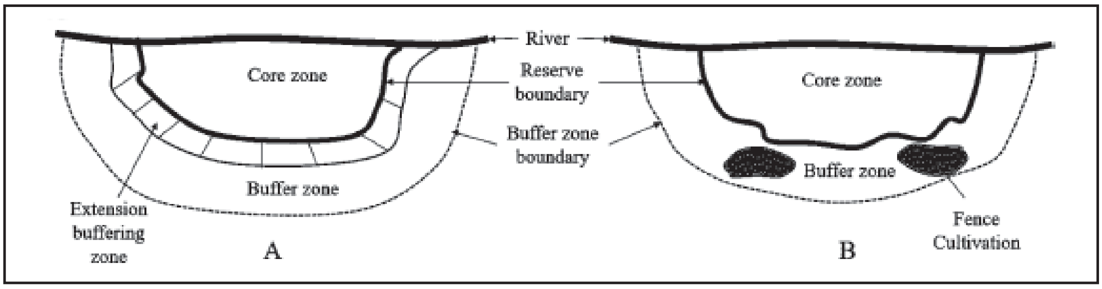

Fig 8.2. A. Extension buffering. B. Socio-buffering

Extension buffering (Fig. 8.2):

It extends habitats of the core area into the buffer zone so that much larger populations, especially of extremely rare species can survive.

Socio-buffering (Fig. 8.2): It permits several human activities like production of crops, harvesting of bioresources, so that the traditional use of bioresources of core area by the people native to the reserve can be minimized.

(c) Manipulation or Transition zone : It is the outermost area or peripheral zone where several human activities such as cropping, recreation, forestry, and settlements are allowed in cooperation with the Reserve management and local people. This zone is also known as the “region of cooperation” because it emphasizes the importance of collaboration to achieve the biosphere reserve's goals – to restore degraded areas to their natural form.

A total of 18 biosphere Reserves have been designated by the Ministry of

Environment, Forests and Climate Change, Government of India on August 25, 2011 (Fig. 8.1). The purpose of the formation of the biosphere reserve is to conserve in situ all forms of life, along with its support system, in its totality, so that it could serve as a referral system for monitoring and evaluating changes in natural ecosystems. The first biosphere reserve of the world was established in 1979, since then the network of biosphere reserves has increased across the world

Box 8. Man and Biosphere Programme (MAB).

In 1971, UNESCO launched a global programme to formalize the scientific interaction between man and his natural environment. This programme is called the Man and the Biosphere **Programme** (MAB). Some 120 countries have joined in by establishing 669 biosphere reserves, including 16 transboundary reserves connected by the World Network of Biosphere Reserves. The MAB is aimed at conserving the ecology and environment which is essential to the very survival of many rare and dying species of flora and fauna. India, with its rich treasure trove of biodiversity, is geographically ideal for establishing, cultivating and maintaining a variety of biosphere reserves.

Biosphere Reserves of India

According to UNESCO, *"Biosphere reserves are areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. They are internationally recognized, nominated by national governments and remain under sovereign jurisdiction of the states where they are located"*. The Ministry of Environment, Forest and Climate Change, Government of India defines Biosphere Reserves thus – *"Biosphere Reserves (BRs) are representative parts of natural and cultural landscapes extending over large area of terrestrial or coastal/marine ecosystems or a combination thereof and representative examples of bio-geographic zones/province"*. Of the 18 Biosphere Reserves in the country, 10 are part of the *World Network of Biosphere Reserves*, set up under the auspices of the UNESCO *Man and Biosphere (MAB) Programme*.

The Nilgiri Biosphere Reserve in the Nilgiri Mountains of the Western Ghats was the first to be set up in 1986. It is the largest protected forest in India. The name "Nilgiri" derives from the Sanskrit words "Neelam" (blue) and "giri" (mountain), inspired by the Kurinji shrub (Strobilantheskunthiana), also known as Neelam Kurinji, which blooms once every 12 years. The Panna National Park in Madhya Pradesh was declared a Biosphere Reserve last, in 2011. The Gulf of Mannar Biosphere Reserve in Tamil Nadu, which covers an area of 10,500 km^2 of ocean, 21 islands and the adjoining coastline, is the largest Biosphere Reserve in the country. The smallest area-wise, is the Dibru-Saikhowa National Park located in Dibrugarh and Tinsukia districts of Assam with an area of 765 km^2.

Twelve of the 18 biosphere reserves in India constitute a part of the *World Network of Biosphere Reserves* (Tab. 8.1), based on the UNESCO Man and the Biosphere Programme list. Ten Indian popular *National parks and Sanctuaries* have been listed in Table 8.2.

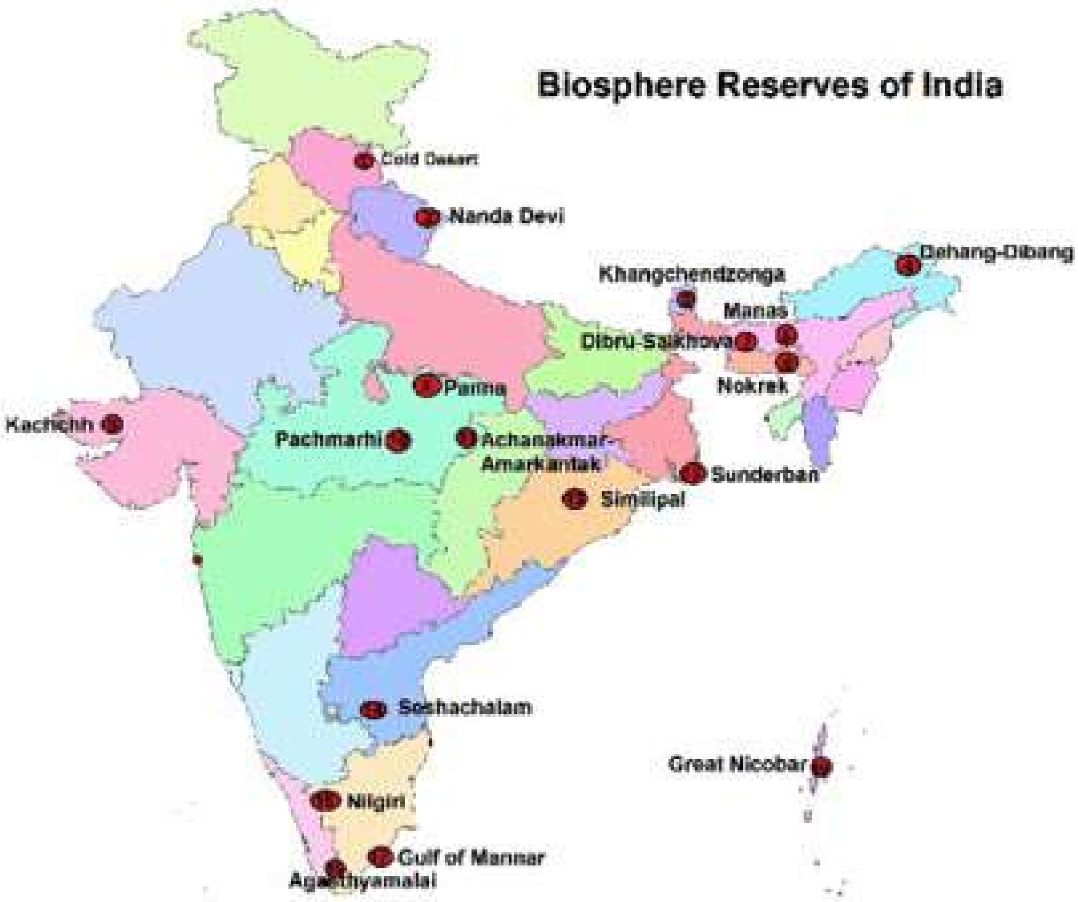

Fig. 8.1 Biosphere Reserves of India.(1) Cold Desert, Himachal Pradesh, (2) Nanda Devi, Uttrakhand, (3) Khangchendzonga, Sikkim, (4) Dehang-Debang, Arunachal Pradesh, (5) Manas, Assam, (6) Dibru-Saikhowa, Assam, (7) Nokrek, Meghalaya, (8) Panna, Madhya Pradesh, (9) Pachmarhi, Madhya Pradesh, (10) Achanakmar-Amarkantak, Madhya Pradesh-Chattisgarh, (11) Kachchh, Gujarat, (12) Similipal, Odisha, (13) Sundarban, West Bengal, (14) Seshachalam, Andhra Pradesh (15) Agasthyamala, Karnataka-Tamil Nadu-Kerala, (16) Nilgiri, Tamil Nadu-Kerala, (17) Gulf of Mannar, Tamil Nadu, (18) Great Nicobar, Andaman & Nicobar Island.

Bonn Challenge : The Government of Germany and the IUCN launched the Bonn Challenge in 2011. It is a global initiative aiming to restore 350 million hectares of degraded land by 2030. It was meant to address the issues caused by deforestation and degradation; to improve the ecological and social functions of degraded landscapes; build resilience to ecological and societal changes; and to meet the goals of the Rio Conventions and the 1992 Earth Summit

Table 8.1 World Network of Biosphere Reserves

	Name	States/ UT	Year
1	Nilgiri Biosphere Reserve	Tamil Nadu, Kerala & Karnataka	2000
2	Gulf of Mannar Biosphere Reserve	Tamil Nadu	2001
3	Sundarbans Biosphere Reserve	West Bengal	2001
4	Nanda Devi Biosphere Reserve	Uttarakhand	2004
5	Nokrek Biosphere Reserve	Meghalaya	2009
6	Pachmarhi Biosphere Reserve	Madhya Pradesh	2009
7	Simlipal Biosphere Reserve	Odisha	2009
8	Great Nicobar Biosphere Reserve	Andaman & Nicobar Islands	2013
9	Achanakmar-Amarkantak Biosphere Reserve	Chhattisgarh, Madhya Pradesh	2012
10	Agasthyamalai Biosphere Reserve	Kerala and Tamil Nadu	2016
11	Khangchendzonga National Park	Sikkim	2018
12	Panna Biosphere Reserve	Madhya Pradesh	2020

Table 8.2. Ten Indian popular National Parks

Name	Location
Corbett National Park	Uttar Pradesh
Kanha National Park	Madhya Pradesh
Gir National Park	Gujarat
Sultanpur Lake Bird Sanctuary	Haryana
Dachigam Sanctuary	Jammu and Kashmir
Simlipal	Orissa

Name	Location
Desert National Park	Rajasthan
Annamalai	Tamil Nadu
Bandipur National Park	Karnataka
Bir Molibagh Sanctuary	Punjab

8.3.1.4 On-farm Conservation

On-farm conservation is an important type of in-situ conservation for maintenance of traditional crop varieties by farmers. The local crop varieties maintained 'on-farm' are called landraces which have developed over time by adaptation to the natural and cultural environment in which they live. Landraces are genetically and physically more diverse than formal breeds. The term 'traditional variety' is often applied to plant landraces. Though landrace populations are morphologically highly variable, they are each identifiable and possess a certain genetic integrity. Farmers often tend to give them local names. A landrace has particular properties and each has a reputation for adaptation to particular soil type. All components of landrace population are adapted to local climatic condition, cultural practices and disease and pests (Harlan, 1975).

Landraces are not only derived from ancestral stock, but also *de novo* from modern plant cultivars by undirected breeding. On-farm conservation ensures the protection and preservation of ancient landraces and wild species for the future.

8.3.1.5 Home Garden Conservation

Home Garden Conservation involves the smaller-scale conservation of plants grown in home, kitchen gardens or back yard gardens. Generally, vegetables, fruit plants or ornamental plants are grown in home garden. This method often provides conservation of indigenous germplasm in the form of landraces, obsolete cultivars and rare species. Several reports on Home Garden Conservation of landraces are available. Hawkes (1983) reported 45 cultivated species and 25 wild medicinal plants that are conserved in gardens of a village in Central Java. Alcorn (1984) reported that the Huastec Indians in Mexico maintain several home gardens where 300 species are grown. In Cuba, farmers manage several larger gardens called *Conucos*, which form the place for local cultivars of crops.

8.3.1.6 Advantages and Disadvantages of *in situ* conservation

Let us quickly examine the disadvantages and advantages of in situ conservation, which would be apparent from the foregoing discussion.

A. *Advantages of in situ conservation*

1. It allows for easy conservation of a diverse range of wild relatives.
2. It offers a possibility for conservation of multiple target taxa within a single reserve.
3. It protects entire ecosystems, ensuring the survival of interdependent species.
4. It allows for the maintenance of natural variation within populations.
5. It provides easy access for genetic and evolutionary studies.
6. It is an appropriate method for conservation of recalcitrant species.
7. It promotes a balance between conservation and human needs.
8. It allows for the preservation of cultural heritage.
9. It is often more cost-effective than ex-situ conservation.
10. It is a dynamic conservation method in relation to environmental changes, pests and diseases.

B. *Disadvantages of in situ conservation*.

1. Continued habitat destruction and degradation pose a significant threat.
2. This type of conservation is vulnerable to natural and anthropogenic disasters, e.g., climate change, fire, vandalism, urban development and air pollution. It is a formidable challenge to contain such disasters.
3. Poaching and illegal hunting can undermine efforts.
4. It requires high level of active supervision and monitoring.
5. Only a limited amount genetic diversity can be conserved in any one reserve.
6. An appropriate management regime remains poorly understood for some species.
7. *In this* method, materials are not easily available for utilization.
8. In-situ conservation can be a slow process, especially for species with low reproductive rates, i.e., recovery of populations are slow.

In conclusion, *in situ* conservation is a crucial strategy for protecting biodiversity, but it requires careful planning, monitoring, and addressing various challenges to ensure its success.

8.4 *Ex situ* Conservation

Ex-situ conservation can be followed for both wild plants and domesticated crops. While the first section under this heading is concerned mainly with domesticated crops, all subsequent sections are applicable to both wild and domesticated taxa.

8.4.1. Germplasm collections

It refers to the collection of domesticated taxa and their relatives in the form of plants, seeds, tubers and other propagules through in vivo methods or in the form of single cells to parts of whole plants through in vitro method. In this technique, assemblages of genotypes or populations are maintained as research materials for plant breeders, taxonomists, evolutionists, etc. The first systematic seed germplasm collections were made from all over the world by Nicolai Vavilov-a Russian geneticist and botanist in 1920s and 1930s, through botanic-agronomic expeditions. He set up one of the first seed banks in Leningrad (now St. Petersburg) which is now known as "the Vavilov Institute of Plant Industry". Inspired by the concept of Vavilov, several seed bank projects have been undertaken and as a result there are now about 6.2 million accessions or samples of 80 different crop plants stored in 750 gene banks and related facilities in 131 countries (Food and Agricultural Organisation, 2010). The *"Millennium Seed Bank Project"* is the largest seed bank (100 times bigger than *"Svalbard Global Seed Vault"*) established at the Wellcome Trust Millennium Building, in the grounds of Wakehurst place in West Sussex near London. The aim of this centre is to store every plant species possible, of which l0% collection have already been done in 2009, and hopefully next 25% collection was to be achieved by 2020. This Centre also distributes seeds to other key locations around the world.

The "Svalbard Global Seed Vault" (was made inside a Sandstone mountain in a tunnel on frozen Norwegian island of Spitzbergen–about 1370 km from North pole, which is operated by the 'Global Crop Diversity Trust'. The permanent frost in the area keeps the vault below the freezing point of water and the one-meter thick steel-reinforced concrete walled seed containers make the area resistant against all sorts of catastrophes such as nuclear war and world war. The seed bank has also been established in the Australian Botanic Gardens, Mount Annan in collaboration with the Millennium seed bank since 2003 for conservation of native Australian flora, specially the threatened species.

In India, seed banks were created to store native varieties of seed after the *'Beej Bachao Andolan'* (means, Save the Seeds Movement) started in the late 1980s in Uttarakhand, led by Vijay Jardhari. Other important seed banks in the world are the United States National Seed Storage Laboratory at Fort Collins, Colorado; The Izmir Centre, Turkey; The Royal Botanic Gardens, Kew, U.K.; The Iberian Gene Bank, Madrid, Spain, and many others.

8.4.2 Seed Banks

Seed bank is the most effective method of ex-situ conservation for reproductively propagated plants. Seed banks allow the storage of genetic diversity of whole plant populations. A seed bank can be defined as a *collection of seeds stored in a viable state for planting in case seed reserves elsewhere are destroyed*. It is a form of gene bank. Seeds are shed from the plants and are deposited on the floor of forest soil year after year. Hence soil is considered to be the natural seed or gene bank, where majority of seeds germinate to produce new plants. Thus, conservation of seed germplasm is one of the best methods of ex-situ conservation.

Seeds can be categorised into two types based on their retention of viability in storage.

(i) Orthodox or Conventional or Desiccation tolerant seeds : Such seeds can be stored in a seed bank for a long time without substantial loss of vitality and without genetic change. According to Roberts (1975) orthodox seeds can be defined as "Seeds for which the viability period increases in a logarithmic manner as one reduces the storage temperature and the moisture content of the same". Most of the orthodox seeds are either from tropical pioneer species where dormancy is enforced by hot and dry climate or temperate species where dormancy is enforced by cold winters.

Seeds may be viable for thousands of years. One notable example of a long-lived orthodox seed that has grown into a viable plant in 2005 was a Judean date Palm seed (cultivar of Phoenix dactylifera) about 2000 years old, excavated from Herod the Great's palace in Israel. In 2012, Russian scientists had regenerated the plant Silenestenophylla from a 32,000-year-old seed collected from a burrow 124 feet under the Siberian permafrost along with 800,000 other seeds.

(ii) Recalcitrant Seeds or Unorthodox Seeds : Seeds that do not survive drying and freezing (temperature < 10°C) during *ex-situ* conservation are called *recalcitrant seeds*. Thus, recalcitrant seeds cannot be stored for long period, because they soon lose their viability. The common examples of such plants that produce recalcitrant seeds are Mango/ Jackfruit, Avocado, Citrus, Coffee, Tea, Cocoa, Coconut, Rubber, Maple, Oak, Cinnamon, Chestnut, and so on. Most climax species produce recalcitrant seeds. About 20% of the World's total plants produce recalcitrant seeds which have no natural dormancy and cannot survive if not allowed to germinate immediately. The recalcitrant seeds have a moisture content of 12 to 31% and any further reduction in moisture content renders them non-viable. A decrease in moisture content of recalcitrant seeds infringes viability. Therefore, they must be replanted on a continuous basis to replenish seed stocks.

Maintenance of Seed banks : Preservation of the orthodox seed for future use is a long process, it involves : Cleaning, X-ray analysis, Drying, Packaging and storage, and Germination monitoring.

- ***Cleaning :*** Cleaned seeds are collected from the field. In some cases, seeds are collected while they are in fruits; the seeds must be taken from the fruit undamaged. This reduces bulk and risk of diseases. The seeds are often liberated from fruits by hand.
- **X-ray analysis :** A few seeds are taken at random and treated with X-ray. This is done to check the number of empty seeds and those with hidden insect larvae inside.

Later, the X-ray treated seeds are thrown away as they may be genetically damaged. By this method, the percentage of viable seeds may be determined.

Drying, packaging and storage of seeds : Drying and freezing of seeds often increases the time that the seeds will remain viable. There are three different methods of seed storage

(i) *Short-term storage :* It is a general practice for common farmers. ln this technique, seeds are stored for one to few years by sun drying and are kept in sealed containers at 5°C temperature or at room temperature.

(ii) *Mid-term storage :* In this technique, orthodox seeds can be stored for 5 to 25 years at 0 to 5°C and with their moisture content maintained between 2 to 5%. The seeds are preserved in airtight sealed containers. According to FAO (1975) the recommended conditions for medium-term seed storage are 1-6°C.

(iii) *Long-term storage :* According to FAO (1975) the recommended temperatures for seed storage are -18°C or less with the seed moisture contents between 2-5%. Seeds can be stored for very long periods at sub-zero temperature, if previously dried to 5 to 8% moisture content. Even orthodox seeds can be stored up to 100 or more years if stored at -10° to -20°C temperature. The storage of seeds in liquid nitrogen (-196°C) give better and problem-free results. The life of the seeds is roughly doubled for every 5°C drop in temperature. Similarly, the life of seeds will be doubled with each 17 % decrease in moisture content. If these two factors are judiciously reduced there will be several fold increase in seed life span. Koopowitz and Kaye (1990) have shown that when temperature drops by 5°C and water content decreases by 1%, the seed lives become four times longer.

Germination monitoring : A few seeds at random are tested for viability once they are frozen. If seeds do not germinate, they are either dead or dormant. Generally, the Tetrazolium test is performed to distinguish between dead and dormant seeds. A few seeds are tested every five to ten years to check germination.

8.4.3 'Test tube' Gene Banks

This is the place where germplasms of vegetative propagules such as tubers, bulbs, corms, rhizomes, roots, tree cuttings, etc., of vegetatively propagated plants are conserved. Many plants especially short-lived shrubs or trees do not produce seeds and thus propagated vegetatively from propagules. These plants are conserved in an appropriate place through the maintenance of their propagules under proper environments.

8.4.4 Field Gene Banks

This method involves planting of plant species for the purpose of *ex-situ* conservation of genes. Here, germplasm of important crops are conserved to provide for breeding, reintroduction and research. More land area, adequate soil and appropriate weather are the basic requirements for field gene banks. It is useful in conservation of perennial species, which is very important in agriculture and forestry. The *International Bureau of Plant Genetic Resources* (IBPGR), Rome, had initially established 23 field gene banks for germplasms of domesticated and wild relatives of domesticated crops. At present 50 institutions are involved in IBPGR's activity and more than 100 species are being conserved globally in field gene banks. By this method, ~ 42,000 varieties of rice have been conserved in the Central Rice

Research Institute of Cuttack, Orissa. According to IBPGR (1991), there are *five operational procedures for characterization and documentation of germplasm resources in a field gene bank.* These are :

(i) Establishing the Origin of the plant materials,

(ii) Characterization of Mature plants,

(iii) Preliminary Evaluation of Development of plants and their Character Expression,

(iv) Further Evaluation on the Mechanism of Reactions in plants against physical stress, pathogen and predators,

(v) Management Data on Handling of genetic resource, its distribution, regeneration and maintenance.

8.4.5 DNA Banks

A DNA bank is a 'gene library' where samples of DNA extract are stored and maintained. The DNA samples are categorised into three types: (i) DNA libraries, (ii) total genomic DNA, and (iii) individual cloned DNA fragments. Several international network of DNA banks have been established for conservation of DNA. The National Institute of Agrobiological Sciences (NIAS) DNA Bank was set up in 1994 as a Section of Ministry of Agriculture, Forestry and Fisheries (MAFF) Genebank System.

Purpose of DNA Banks

- DNA banks serve a variety of purposes, primarily focused on scientific research and conservation. The key objectives in conservation are inpreserving genetic diversity, especially in endangered species.By storing DNA samples, scientists can :
  - *Create genetic backups :* In case populations decline or go extinct.
  - *Study genetic variation :* Within and between populations.
  - *Develop breeding programmes :* To restore populations.

A few well known DNA Banks are :

The European Nucleotide Archive (ENA) : A repository for DNA sequence data from all organisms.

The Millennium Seed Bank : A global seed bank that also stores DNA samples.

The Smithsonian Institution's National Museum of Natural History : A DNA bank for various animal species.

The DNA Bank provides a right to use all genomic data from diverse sources -- rice, silkworms and so on. The data from genome projects, particularly nucleotide and amino acid sequences, are collected and administered from all publicly available data base repositories. The various homology search system such as BLAST, FASTA, WAIS, SRS, with available databases have been created to enable analysis and comparison of sequence information.

The DNA Bank network was set up in 2007 by the initiation of Global Biodiversity Information Facility (GBIF), Germany. It offers a worldwide network of DNA bank databases of microorganisms, protists, plants, algae, fungi and animals which are available via a central web portal.

The Global Genome Biodiversity Network (GGBN) was launched in 2011 to make well-documented and vouchered collection that store DNA and tissue samples related to biodiversity. To drive home the importance of genetic diversity and its contribution to human well-being, the GGBN aims to

- promote establishment and operation of DNA banks worldwide, to ensure that genetic material from diverse species is preserved for future generations;
- facilitate the exchange of genetic resources among countries, fostering international collaboration and research;
- extend support to the development of policies and standards related to the management and utilization of genetic resources and ensure ethical and sustainable practices; and to
- raise awareness about the importance of genetic diversity and its contribution to human well-being.

In essence, the GGBN seeks to create a global network of DNA banks and resources that can be used to address pressing challenges such as food security, climate change, and human health. By preserving genetic diversity, the GGBN hopes to secure a sustainable future for both humans and the planet. The data would be reachable through the GGBN Data portal (http://data.ggbn.org) that links globally distributed biodiversity databases and bridges the gap between biodiversity repositories, sequence databases and research results. GGBN and DNA Bank Network have similar objectives and rules, and all partners of the DNA Bank Network are members of GGBN.

8.4.6 Pollen Banks

A Pollen Bank is a collection of pollen grains stored in a viable state for crossing and breeding of a new cultivar. Since pollen represents a male gametophyte generation, they can be germinated to produce a haploid plant where all the phenotypic characters would be expressed. Thus, pollen banks have many-fold importance. Comprehensive studies have been carried out to assess the different storage conditions that can enhance the viability of pollen grains. This storage can be conveniently grouped as *short term and long term storage method*. (Bhattacharya etal., 2017)

Short term pollen storage : It includes the effect of temperature and humidity, and pollen storage in organic solvent.

(i) *Effect of temperature and humidity :* In general, low temperature and low relative humidity favour pollen germination in most taxa. However, a large number of pollens can be stored for a limited period of time by manipulating the storage temperature and humidity. Pollens are stored in appropriate containers like glass or plastic vials for an extended period of time. Such containers in turn are stored in desiccators with dehydrating agents to control humidity. Tricellular pollen of grasses requires sophisticated environmental conditions even for a short period of time.

(ii) *Storage in organic solvent :* Pollen grains stored in non-polar organic solvents like benzene, diethyl ether and cyclohexane retain viability and show very little leaching of phospholipids, sugars and amino acids. On the other hand, extensive leaching of substance and loss of viability are seen in polar solvents. Insect pollinated species such as *Camelia japonica*, *Ginkgo biloba*, *Juglansregia*, *Malus pumilus* stored in organic solvent at 4°C for 35-40 days exhibited normal viability.

Long term pollen storage : Storage of pollen at temperatures above 0°C slows down its metabolism, resulting in gradual decrease and finally, total loss of viability. Thus, for long-term preservation, cryogenic technique seems to be more promising. Some of the methods of long term preservation of pollen are described below:

(i) *Storage at sub-zero temperature :* Using a storage temperature of -10°C to -34°C, the longevity of bicellular pollen (desiccation tolerant) and pollen with originally low content of moisture have been extended between one to three years.

(ii) *Freezing or vacuum drying (Lyophilization) :* The desiccation-tolerant pollen can be preserved for a long period of time by the freeze or vacuum drying method.

Freeze-drying involves the rapid freezing of pollen to sub-zero temperature of -60°C or -80°C using inert gas like helium or nitrogen followed by the gradual removal of water under vacuum sublimation. In *vacuum drying*, the pollen grains are directly exposed to a vacuum with simultaneous cooling. The moisture is then withdrawn by evaporative cooling. In a number of species, freeze drying followed by lyophilization showed better result.

(iii) *Cryopreservation by deep-freezing :* Long term preservation can be done by ultra-low temperature, ranging between -180°C and -196°C (in liquid nitrogen). Several agronomically important grass (Poaceae) species have been stored through cryopreservation for long periods (one to 12 years). Examples include *Zeamays, Triticum aestivum*, etc.

8.4.7 In-vitro Germplasm Conservation

In vitro method of germplasm conservation is mostly appropriate for vegetatively propagated crops as also for recalcitrant seeds. The vegetatively propagated crops are preserved *in vitro* in variety of forms including isolated protoplasts, cells from suspension or callus cultures, meristem tips, somatic embryos, shoot tips or propagules at various stages of development. This tissue culture-based method is mainly utilized for conservation of somaclonal and gametoclonal variations in cultures, plant material from endangered species, plants of medicinal value, storage of pollen, for production of disease-free plants and genetically engineered materials.

Methods for *In Vitro* Germplasm Conservation : There are two main approaches to in vitro germplasm conservation: slow growth techniques and cryopreservation.

1. *Slow growth techniques :* This is a simple and economic method which can be used in all species where shoot tip or nodal explants are available. It is possible to maintain the healthy growth of stocks which must be sub-cultured every 4-6 weeks. Thus, it is labour-intensive as well in addition to a risk of contamination by pathogen. Genetic changes can also take place.

2. *Cryopreservation :* In general, cryopreservation (Greek kryosdenotes frost) means preservation in the frozen state. In practice, materials are preserved at a very low temperature, for example, over solid CO_2 (–79°C), in deep freezers (–80°C), in vapour phase of N2 (–150°C) or in liquid N_2 (–196°C). Actually, cryopreservation is the process of freezing living material to preserve it at or near the temperature of liquid nitrogen, –196°C (–320°F). This method is also called

freeze preservation and at this very low temperature, the cells stay in a completely inactive state where physical and cellular metabolic processes are halted and they are free of contamination by pathogens, but genetic drift can occur. Thus, plant tissues/organs/cells can be stored at very low temperature for indefinite period which can be recovered and grown again to regenerate a whole plant whenever required. Two major factors have to be considered before freezing of specimens: (a) the degree of freeze tolerance displayed by a given genotype to reduce temperature, and (b) the formation of ice crystals within the cells.

8.4.8 Botanic Gardens

Although a satisfactory definition is still wanting, a *botanic garden* can be broadly defined as *a place of collection of living plants grown for educational, recreational, economic, medicinal or scientific purposes*. A botanic garden is the most important form of *ex-situ* conservation of plants. There are more than 1600 Botanic Gardens and Arboreta throughout the world and these receive over l50 million visitors a year. Many of these gardens have *seed bank* facilities too,

The function of botanic gardens most widely known is to assemble and maintain a diversity of plant species in the open or in greenhouses for reference and study. Botanic gardens conduct or facilitate research in diverse aspects of plant science, particularly in taxonomy. Some plant species that have disappeared in the wild or survive as a single population, are found preserved in Botanic Gardens through ex-situ conservation. The *Botanic Gardens Conservation Institute* (BCCI) was set up in 1987 for collection and making available information on plant conservation. A few plants preserved in different Botanic Gardens may be mentioned. *Tambourissatetragonia* earlier represented by two surviving specimens are now propagated through tissue culture in Kew Botanic Gardens, U.K. *Limonium tuberculatum* had disappeared from the wild but a dozen populations still survive in the Botanic Garden of Canary Island, Spain. Similarly, a few populations of *Ramosmania heterophylla* are conserved in the Botanic Garden of Mauritius. Endangered plantsin the wild such as *Ginkgo biloba*, *Frankliniaalatamaha*, *Encephalartos woodii*, *Swietenia humilis*, *Dracaena draco* and others have been perpetuated in this manner.

There are many kinds of botanic gardens and arboreta :

(i) *Traditional, state supported gardens*, with associated herbarium and laboratories (e.g.. Acharya Jagadish Chandra Bose Indian Botanic Garden, Berlin Botanic Garden, Kew Botanic Garden);

(ii) *Municipal or civic supported*, sometimes with associated herbarium and laboratories, normally open to the public (e.g. Gothenberg, Glasgow, Nantes);

(iii) *University gardens* with an associated herbarium and laboratories usually open to the public (e.g. Calcutta university Garden, Cambridge, Berkeley, Hamburg, Montpellier);

(iv) *Private*, often *with some state support*, with an associated herbarium and laboratories, invariably open to public (e.g. Missouri Botanical Garden, Fairchild Tropical garden at Miami);

(v) *Private, without state support*, usually lacking a herbarium or laboratory (e.g. Les Cedres, Maurimurta);

(vi) *Government/State arboreta* with an associated herbarium and laboratories: (e.g. US National Arboretum) or without herbarium (e.g. Westonbirt);

(vii) *University arboreta* with an associated herbarium and laboratories (e.g. Arnold Arboretum);

(viii) *Private arboreta*, with or without herbarium or laboratories (e.g. Hilliers, Morton arboretum, Bickelhaupt);

(ix) *Botanical-zoological gardens/parks* (e.g. Hongkong, Wilhelma Stuttgart);

(x) *Agrobotanical gardens* (e.g. Botanical garden of the Agri-Horticultural Society of India, Godollo arboretum, Hungary).

8.4.9 Captive breeding in zoos

Ex situ conservation can also prevent immediate extinction of animals by captive breeding. If needed, all surviving animals out in the wild can be brought into captivity. The Californian condor (*Gymnogyps californicanus*) and black-footed ferret (*Mustela nigripes*) were saved from extinction in this way. Other success stories include golden lion tamarin (*Leontopithecusrosalia*), the Arabian oryx (*Oryx leucoryx*), the Red wolf (*Canis rufus*), the Przewalski's horse (*Equus ferusprzewalskii*), Amur leopard (*Panthera pardusorientalis*) and so on. Captive breeding aims to retain maximum genetic variation in the threatened population. In order toutilise the entire available gene pool, all individuals of a species in zoos around the world are treated as a single population. Information on their birth, death, mating and parentage are recorded, and those under-represented are encouraged to mate. The number in captivity should be brought to the minimum viable number and the sex ratio ideally kept at 1:1. However, inbreeding depression is a problem as also contamination of captive populations by genes of domestic animals, or interbreeding among races that are distinct in the wild. Thus, European bison carries genes of domestic cattle, while zoo populations of tigers and lions are mixtures of subspecies. Retention of genetic integrity is important in captive breeding. The ultimate objective is to re-introduce the animals in the wild—which has to be executed very carefully.

SAQ I

1. What is the importance of a 'pollen bank'?
2. With concrete examples show how Botanic Gardens play a definitive role in conservation of threatened species?

3. Multiple Choice Questions (MCQs)

(a) Which of the following is an example of in-situ conservation?

(i) Zoo
(ii) National Park
(iii) Botanical Garden
(iv) Seed Bank

(b) What is the primary goal of biodiversity conservation?

(i) To increase human population
(ii) To ensure the survival of species and maintain ecosystem balance
(iii) To eliminate invasive species
(iv) To promote urbanization

(c) Which of the following conservation strategies involves the storage of genetic material for future use?

(i) Biosphere Reserves
(ii) Gene Banks
(iii) Wildlife Sanctuaries
(iv) Ecotourism

8.4.10 Advantages and Disadvantages of *Ex-situ* Conservation

Let us now list the advantages and disadvantages of *ex-situ* conservation.

■ **Advantages of *Ex-situ* conservation**

1. Greater diversity of target taxa can be conserved as seeds.
2. Easy access for characterization and evaluation.

3. Feasible for medium and long-term secure storage and disease resistance.
4. Little maintenance costs once material is conserved.
5. Easy access for plant breeding.

■ **Disadvantages of *Ex-situ* conservation**

1. Genetic diversity may be lost with each generation cycle.
2. Restricted to a single target taxon per accession.
3. Problem of storing recalcitrant seeds;
4. It freezes evolutionary development.

8.5 Ecosystem or Habitat Restoration

The ecological restoration is crudely defined as “making nature” (Jackson, 1992), while the *Society of Ecological Restoration* described it as “the process of intentionally altering a site to establish a defined, indigenous, historical ecosystem”. The purpose of this process is to mimic the structure, diversity, function and dynamics of the specified ecosystem. This process is now fast growing and is a promising an exhilarating field of conservation.

8.6 Social approaches to Conservation

Biodiversity conservation is amultifaceted effortthat requires scientific methods, grassroots movements, government policies, and global awareness campaigns. While scientific approaches provide structured solutions,social movements and awareness campaigns engage the public in conservation efforts, ensuring a more sustainable future for all species.

Loss, as well as conservation of diversity, is an issue of great social concern, since the intrinsic value of biodiversity is rooted in a sociocultural system. However, many people in this market-driven consumerist society are yet to fully comprehend the intimate relationship between biodiversity and society at large. This is evident from the OTA Report (1987)*, ‘Social and political processes influencing how biological diversity is perceived and valued are the least well understood and, in the long run, (constitute) the most important factors affecting success of on-site diversity maintenance’. In fact, sociologists, anthropologists and historians have to develop very important descriptions of social factors affecting biodiversity maintenance at specific sites. It is also important to remember that science alone cannot protect biodiversity. Society and social and cultural values must be summoned for the conservation and protection of nature and its bioresources.

Let us now briefly examine in this section, how different society and cultures practices the cult of biodiversity in their daily lives followed by a discussion in the *Section 8.7* about the different approaches to educate people about the value of biodiversity and approaches taken to raise public awareness on the issue.

8.6.1 Sacred Groves

Certain social taboos and cultural practices of indigenous communities and rural folks have preserved bioresources for hundreds of years. It is because their local history, folk traditions, livelihood and survival ethos are integral to sustenance of nature in its primal form. Their traditional culture accumulated over centuries, is deeply ingrained in the ethos of these people. This has contributed hugely to the retention of biodiversity in their dwelling place and vicinity.

One such cultural practice or social taboo, particularly in certain tribal communities in India and a few other parts of the world -- is the practice of protection of patches of forest-land with temples in their vicinity. These people believe that the ruling deity of this temple or other place of worship is the custodian or protector of everything that lives in that forest, its entire flora and fauna. The deity may be gods or goddesses or even totems such as a slab of stone, a hero stone, sati stone or trident. Therefore, to these people, destruction of any part of the biota in that forest area is sacrilege. Since sanctity was ascribed to the plants of such groves and since spiritual beings were believed to reside in such places, ordinary human activities were voluntarily precluded. Such activities included tree-felling, gathering of wood/fuel, plants and their parts, hunting, fishing, grazing by domestic animals, ploughing, planting and harvesting. Touching plants (and animals associated with them) in these sacred groves has been forbidden to all except the temple priest. Even to him, it is restricted to his offering to the deity. The tribal doctor, often the temple priest, is granted access to certain plants and/or minerals found in that area because the presiding deity is believed to cure ailments of people

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Endnote. * U.S. Congress, Office of Technology Assessment, *Technologies To Maintain Biological Diversity*, OTA-F-330 (Washington, DC: U.S. Government Printing Office, March 1987].

under its protection through them. Sometimes, gardens with local floristic elements were specially created near existing temples and declared sacred, to ensure their protection and conservation. Responsibility for protecting groves and enforcing rules were assumed by the local community since the grove was an integral part of their society. Local autonomy was accorded to management of these groves, although a representative of the province / king of that region were often a part of the temple committees associated with the grove, as indicated in local epigraphical records. This ensured the conservation and preservation of the local vegetation for posterity. Mention of sacred groves and gardens dedicated to the worship of a presiding deity are mentioned in ancient Greek, Latin American and Indian literary works or epigraphical records or inscriptions in copper plates. There are several references to sacred groves in the Old Testament too. Sacred groves are known by several names in India depending on the place. Commonly they were called *Nandanvanasin* ancient or medieval literature.

Epigraphical records are inscriptions, or written records, that are studied as part of epigraphy, the study of written matter on durable materials such as wood, stone, metal, shell and so on. The word *epigraphy* is derived from the Greek roots: *epi* meaning “on” or “upon” and *graphie* meaning “to write”.

Local names such as *Devban* in Himachal Pradesh, *Sarna* in Jharkhand, *Devgudis* in Chhattisgarh, *Kan* in Karnataka and parts of Maharashtra, *Devarakaduin* northern Karnataka and Goa, *Kavus* in Kerala, *Deorai* in Madhya Pradesh, *Orans* in Rajasthan, *Koilkaduin* Tamil Nadu, *Garamthan/Harithan* in West Bengal have also been recorded. There are reports of sacred groves in the Near East, Europe, North and Sub-Saharan Africa, India, S.E. Asia, Oceania, China, Japan, Siberia and the Americas. In India, several thousands of sacred groves and temple-gardens of various sizes (from clumps of trees to areas of several hundred hectares) almost always of diverse floristic composition have been reported in all biogeographical regions – whether of evergreen forests or desert/ arid areas.There have been different estimates of the total number of sacred groves varying from 14,000 to 100 000 in our country. About 4215 sacred groves covering an area of 39,063 hectares are estimated to be distributed in India. Groves are reported in areas from the highest mountain peaks to sea level. The largest sacred grove is at Mawflong, in Meghalaya. Most sacred groves have been reported from Maharashtra.

The importance of sacred groves in preserving rare or threatened species would be evident from the fact that *Ginkgo biloba*, the 'living fossil', is presently found in one of the largest 'semi- natural' populations at Tian Mu Shan, near the Kaishan Buddhist temple in China. Floristically, such groves even today contain taxa lost/ endangered in adjacent regions. Several endemics are today reported only from such groves, for example *Dipterocarpus indicus*, *Myristicafatua*, *Pinangadicksonii*, *Manilkara hexandra*, and so on.

Sacred groves, wherever still present, should be preserved and restored for several reasons, including their value as historical evidence for the relationship of human beings to nature.Sacred groves come under the fold of Other Effective Area Based Conservation Measures (OECMs) – a new approach to conservation, which is included in the Convention on Biological Diversity.

8.6.2 *Sthalavrikshas*

Sthalavrikshas in Sanskrit means 'temple trees'. In India, every temple whether Hindu, Jain or Buddhist, had and still has a specific tree taxon cultivated very near to the sanctum sanctorum, the place where the presiding deity / idol is erected. That particular tree is designated the *temple tree or sthalavriksha* for that temple. The idea simply is that the people of the village close to the temple ought to be concerned about protection of trees in general, symbolized by selecting an appropriate tree to express their concern. This is yet another form of expression of people's regard for nature, nature-worship and expression of social concern for the conservation of plants. Ancient Tamils, for example, believed that Gods resided in trees and by worshipping trees they worshipped God. Moreover, different Gods resided in different types of trees and hence they planted the specific temple tree in temples meant for specific Gods. As many as 65 temple trees are recorded in Tamil Nadu alone, each at specific temple sites. (Krishnamurthy,2003).

8.6.3 People's Movements for Biodiversity Conservation

After the 1970s, a large number of environmental movements have cropped up in our country. Biodiversity conservation *per se* was not the specific objective of these movements. But protection of local ecosystems was almost always their goal, which in turn led to conservation of biodiversity. Several reasons may be ascribed to the emergence of such movements, such as —

For endnote : OECM is a geographically defined area other than a protected area. "governed and managed in ways that achieve positive and sustained long-term outcomes for the in-situ conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values."

(i) For exerting control over natural resources;

(ii) In protest against wrong/detrimental developmental policies of the government;

(iii) Environmental destruction and degradation

(iv) Different socioeconomic reasons,

(v) The spread of environmental awareness and media reports.

The emergence of environmental movements has not been restricted to any particular part of the country; rather the whole country has witnessed such movements. Now, let us discuss some of the important movements.

8.6.3.1 Bishnoi Movement

Amrita Devi Beniwal, a common woman-folk of the Bishnoi community in Marwar (Jodhpur), Rajasthan, started this movement. In 1730, the then Maharaja of Jodhpur, Abhay Singh, is believed to have ordered the felling of Khejarli trees (*Prosopis cineraria*), to burn lime for the construction of his new palace. Amrita Devi could not bear to witness to felling of the trees which were considered sacred to the Bishnoi community. She hugged the trees and urged other villagers to follow her, when the king’s men arrived to cut the trees. In response, they killed her, her three daughters and a total of 363 Bishnoi villagers–the infamous Khejarli massacre. The Bishnoi tree martyrs were influenced by the teachings of Guru Maharaj Jambaji, who had founded the Bishnoi faith in 1485 and set forth principles forbidding harm to trees and animals. According to legend, the king who came to know about the events rushed to the village and apologized, and ordered his men to stop the logging operations. Soon afterwards, the Maharajah designated the Bishnoi state as a protected area, forbidding harm to trees and animals. This legislation is still in force today in that region. Amrita Devi is acknowledged a martyr, a founder of this movement and her bravery is commemorated by the Bishnoi community each year. The Government of India instituted the *Amrita Devi Bishnoi National Award* for individuals or rural communities that have shown extraordinary courage and dedication in protecting wildlife. The Bishnoi Movement in turn inspired the Chipko Movement, our subject of discussion in the following section.

8.6.3.2 Chipko Movement

‘Chipko’ means ‘to hug’ or to embrace in affection. The *Chipko Movement* is a success story in environmental conservation and the credit for it goes to the women of Reni village of the Alakananda catchment area in the Uttarakhand region of the Himalayas. It was prompted by an order issued in the 1960s by the Government of India to cut trees in these foothills, on a large scale. This led to severe floods in 1970 which swept away 6 bridges, 16 footbridges and over 600 houses, in addition to destroying crops over hundreds of hectares, and affecting no less than 100 villages in the area. The *Chipko Andolan* was born when the women of the village sought to save the forests in this extremely sensitive catchment area by marching to the trees chanting slogans and hugging the trees when contractors were about to cut them. Evidently, they drew inspiration from the Bishnoi Movement. To the people the local forests were 'myka' (mother's house). No harm can befall them. The contractors were forced to abandon their felling operations.

The same story was repeated in 1975 when 200 women in Gopeshwar, Chamoli district, waged a war against the cutting of oak trees by the district administration. The womenfolk of Bhyundar village in the lower reaches of the famous *Valley of Flowers* also went on the warpath with their 'Chipko'. In 1980, women of Dungri-Paitoli villages in the Chamoli region of Uttarakhand also resorted to the Chipko agitation to save their forests. The action was replicated in the 1980s in Bached village of Gopeshwar by 200 women, who prevented the felling of 1600 trees. The local women argued that even dead trees should not be removed, as the lumbering practices would invite soil erosion. The mother organisation of the Chipko movement was the Dasholi Gram Swarajya Mandal (DGSM) led by Mr. Chandi Prasad Bhat and Mr. Sunderlal Bahuguna. Chipko was only one of the Andolans. The DGSM educated the villages about the importance of forests and their conservation through lectures, ecodevelopment camps, tree plantation programmes, construction of simple water distribution schemes, and setting up microhydel projects with locally available technologies.

The Chipko movement has had six demands-

1. Complete stoppage of commercial cutting of trees;
2. On the basis of minimum needs of the people, a reorganization of traditional rights should take place;
3. Arid forest should be made green with people's participation and increased tree cultivation;
4. Village committees should be formed to manage forests;
5. Forest related home-based industries should be developed and the raw

materials, money and the techniques for these should be made available; and

6. Finally, depending on local conditions and requirements, local varieties should be given priority in afforestation programmes.

8.6.3.3 Narmada Bachao Andolan

The most popular movement in the environmental history of India is the movement in the Narmada River Valley. The Narmada is the largest west-flowing river on the Indian peninsula. More than 21 million people lived in the valley, mostly in villages. Many tribal groups, such as the Bhils and the Gonds, occupied 12 forested uplands. In the year 1985, Medha Patkar, Baba Amte, along with adivasis, farmers, environmentalists and human rights activists, had organized a social movement against a number of large dams being built across the Narmada River. Baba Amte, famous for his campaign against leprosy, had published a booklet called Cry O Beloved Narmada in 1989 to protest against the construction of the dam. In 1994, Indo-Canadian filmmaker and writer Ali Kazimi produced a film with the name *Narmada : A Valley Rises*. It documented the five-week *Sangharsh Yatra* of 1991 and the film went on to win several awards. In 1996, veteran documentary filmmaker, Anand Patwardhan, made an award-winning documentary: *A Narmada Diary*. In this way the story of the struggle of people affected, reached far and wide.

The movement first started as a protest for not providing proper rehabilitation and resettlement for the people who have been displaced by the construction of *Sardar Sarovar Dam*. Later on, the movement turned its focus on the preservation of the environment and the ecosystems of the valley. Environmentalists and researchers mobilized public attention to the vast biodiversity destroyed by flooding, as also the misery of the displaced people. Activists also demanded that height of the dam be reduced to 88 m from 130 m as proposed. In the face of widespread protest the World Bank withdrew from the project. The environmental issue was taken up by the judiciary. In October 2000, the Supreme Court gave a judgment approving the construction of the Sardar Sarovar Dam with a condition that height of the dam could be raised to 90 metres. It also ordered payment of compensation to families affected by the project. The Andolan activists faced state repression, including arrests, police brutality, and legal harassment.

The project was largely financed by the state governments with the aid of market borrowings. The project is expected to be fully completed by 2025. Medha

Patkar and others continue to fight for proper rehabilitation of the displaced people in Madhya Pradesh as also to receive the promised compensation by the Narmada Tribunal.

8.6.3.4 Appiko Movement

The *Appiko Movement* took place in the Uttara Kanada district of Karnataka in the Western Ghats, popularly called the 'forest district' for its extremely rich forest wealth. During colonial rule, the rich forest resources were plundered. After independence, the government too continued to fell trees for revenue. Sadly, the Forest Department continued with the colonial forest policy. Vast tracts of tropical forests were converted into monoculture of teak and eucalyptus plantations. A group of youth wrote in protest to the forest officials in Balegadde village, against moves to establish teak plantations, and urged them to stop clearing the natural forest. But this appeal was ignored. Then the villagers decided to launch a movement. They invited Sunderlal Bahuguna, the architect of Chipko movement and gathered local people to take up an oath to protect the forest trees by embracing them. In September 1983, when the axe-men entered the Kalase forests, the people embraced the trees to thwart felling of trees. This launched the 'Appiko' movement. This movement succeeded in its threefold objective, to

- Protect the existing forest cover;
- Regenerate trees in the denuded land, and
- To utilize the forest wealth, keeping in mind conservation of the natural resources.

The Appiko movement did create awareness among the villagers throughout the Western Ghats about the ecological danger to their forest abode, the main source of their sustenance, posed by commercial and industrial interests.

8.6.3.5 Silent Valley Movement

In the year 1978, the *Kerala Sastra Sahitya Parishad* (KSSP) an NGO, and the poet-activist Sughathakumari played an important role to protect the Silent Valley, the moist evergreen forest from being destroyed by a hydroelectric project. The Kerala State Electricity Board (KSEB) had proposed a construct a hydroelectric dam across the Kunthipuzha River that runs across the Silent Valley. In February 1973, the Planning Commission approved the project at a cost of about Rs 25 crores. Many feared that the project would submerge 8.3 km^2 of virgin moist evergreen forest. Several NGOs also had strongly opposed the project and urged the government to abandon it. In January 1981, bowing to unrelenting public pressure, Prime Minister Indira Gandhi declared that Silent Valley will be protected. In June 1983, the Centre re-examined the issue through a Commission chaired by Prof. MGK Menon. In November 1983, the Silent Valley Hydroelectric Project ultimately had to be called off. In 1985, Prime Minister Rajiv Gandhi formally inaugurated the *Silent Valley National Park*.

8.6.4 Participatory Forest Management

In the year 1972, an enterprising young Forest Officer, Ajit Kumar Banerjee, initiated the *participatory forest management* (PFM) concept in the Arabari village of West Bengal. Soon, the novel concept became popular, and spread to the other states of the country. It marked a significant turning point in the history of forest conservation, a model to be emulated, not only in India but in other countries of Asia. The essential feature of PFM is that the State and Society become partners in the management of forest resources. The State continues to own the resources but the benefits such as the non-timber forest products, are shared with the entire community. In this way, the entire community develops a stake in the preservation of forests. This ensures conservation and sustainable use. Clearly, forest degradation can be reversed through PFM efforts and it has been a success story for several forest tracts all over India, over the last 25 years.

8.7 Biodiversity Awareness Programmes

Public awareness about the value of biodiversity is still inadequate. Lately, some awareness programmes have indeed been taken up on related issues such as forest and land degradation, pollution, but they are grossly inadequate. The problem is compounded by incomplete knowledge or sheer ignorance and indifference at all levels. Development has its benefits, but the way it simultaneously leads to serious loss of biodiversity, has to be taken into account. Issues related to environment have often been branded as antidevelopment. The wisdom lies in maintaining a proper balance between our needs and the delicate ecological balance easily disrupted or lost through ‘development’ activities. Widespread ignorance or misconceptions about biodiversity may be attributed to several reasons.

(i) Our courses in science, technology and economics have so far failed to integrate knowledge about biodiversity in their curricula.

(ii) Our planners, decision-makers, politicians and administrators have not been trained to integrate biodiversity aspects as an integral component in their plans.

(iii) In a zeal to go ahead with ambitious development projects, quite often there is purposeful neglect or concealment about the potential harm that such projects may cause to essential aspects of biodiversity.

(iv) Often, sheer economic gains or issues related to elimination of poverty through gainful employment overshadows basic biodiversity issues. A reconciliation between both these equally important aspects is not attempted except under pressure.

Sacred groves are known by several names in India depending on the place. Commonly they were called *Nandanvanasin* ancient or medieval literature.

8.7.1 Methods to Propagate Biodiversity Awareness

Environmental awareness needs to be created through formal and informal education to all sections of the society. Everyone needs to understand it because 'environment belongs to all' and 'every individual matters' when it comes to conservation and protection of environment. For this purpose, various methods or steps may be taken at different stages.

(i) Among students through education : Educating students about the importance of biodiversity and its benefits should start right from their childhood. Following directives of the Supreme Court, environmental studies have been introduced as a compulsory subject in schools and colleges. It is a welcome step in the right direction.

(ii) Among the general public through mass-media : Media can play an important role to educate the masses on biodiversity related issues through articles, promote or sponsor environmental rallies, plantation campaigns, street plays, real eco-disaster stories as well as success stories of conservation efforts. Television serials and documentaries related to the conservation efforts could create and propagate the seeds of environmental awareness in all age groups. Social media is a very suitable platform to create awareness about our environment in general and biodiversity in particular. It can play a big role to rectify a general misconception that development activities and protection of biodiversity are in perpetual opposition. This is where the concept of sustainable development comes in. This has been discussed threadbare in *Section 8.8*.

(iii) Among the planners, decision-makers and leaders : Since this elite section of society plays perhaps the most important role in shaping the future of a country and society, they ought to be subjected to a thorough orientation and training through workshops, different programmes and brain-storming sessions. Publication of environment, and biodiversity-related resource material in the form of pamphlets or booklets published by Ministry of Environment & Forests, can also help to keep this section abreast of the latest developments in the field.

(iv) Community involvement : Engaging local communities in conservation efforts to foster a sense of ownership has most often paid a great dividend. Participatory management in social forestry as discussed in Section8.6.4 is a case in point. Empowerment of women-folk, forest-dwelling tribes and indigenous communities to protect their abode is very effective in protecting biodiversity and promote other conservation efforts.

8.7.2 Role of Non-Government Organisations (NGO's) in Biodiversity Awareness

Voluntary organisations, non-government organisations, self-help groups can all help by advising the government about local biodiversity related issues and at the same time interact at grass-root levels–forming an effective and viable link between the two. At the same time, they can act as an 'action group' or a 'pressure group'. They often play a lead role in creating awareness and organise public movements for the protection of environment. You already know about some of them such as the 'Chipko Movement', the 'Narmada Bachao Andolan', the 'Appiko Movement', from the preceding sections. The NGOs have been at the forefront in many such movements. Their active involvement played a crucial role in generating awareness, mobilize public support, and influence government policy decisions. Their presence in large numbers at different international conferences hosted by different United Nations bodies has played a vital role in bringing the message home to its citizens. You have probably already heard of bodies such as *The Bombay Natural History Society* (BNHS), the *World Wide Fund for Nature - India* (WWF, India), *Kerala Sastra Sahitya Parishad*, the *Centre for Science and Environment* (CSE). Their extensive research and fact-finding teams perform a stupendous task in preparing annual or periodic State-of-the-environment reports. One of the reports by CSE on the presence of pesticides in cola-drinks beyond the permissible limit has sensitized people all over the country. Before we can all take up the task of environmental protection and conservation, we have to be environmentally educated and made aware. It is aptly said *"If you want to act green, first think green."*

Some notable campaigns on biodiversity awareness that have achieved significant success at other corners of the globe include:

A. *The Photo Vogue Festival 2025: “Biodiversity: Through the Lens”*

The PhotoVogue Festival in its ninth edition is to be held from March 6th to 9th, 2025, in Milan, Italy, showcasing "Biodiversity: Through the Lens" exhibition. This event is to feature compelling visual presentations highlighting the intricate relationship between humans and nature. By collaborating with organizations like UNESCO and Nautilus, the festival seeks to emphasize the importance of preserving biodiversity through the powerful medium of photography and foreground the interconnectedness of health, biodiversity, oceans, and the planet. [Source: vogue.com]

B. *The “Nature Alert” Campaign*

In response to proposed changes that threatened the European Union's nature laws, over 120 environmental NGOs, including BirdLife Europe and WWF Europe, coordinated the "Nature Alert" campaign. This initiative mobilized citizens across Europe to voice their concerns. As a result, in December 2016, the EU announced that the existing nature laws would remain intact and committed to developing an action plan to improve their implementation. This campaign exemplifies how public awareness and collective action can influence policy decisions to protect biodiversity. [Source:greentumble.com]

C. *The “Endangered Species Mural Project”*

The CBD launched the "Endangered Species Mural Project" to raise awareness about species at risk. By collaborating with artists to create murals in public spaces, the project brings attention to local endangered species and the broader issue of biodiversity loss. These vibrant artworks serve as educational tools and inspire communities to engage in conservation efforts. [Source: biologicaldiversity.org].

D. *The “Great Green Wall” Initiative*

The "Great Green Wall" is an African-led movement aiming to grow an 8,000-km natural wonder across the entire width of Africa. This ambitious project seeks to combat desertification, halt land degradation, and promote biodiversity by restoring degraded landscapes in the Sahel region. Beyond environmental benefits, the initiative also focuses on creating jobs and boosting food security for millions of people. [Source: weforum.org]

E. *The "Plastic Bag Ban" Campaigns*

Various countries and cities worldwide have implemented campaigns to ban or reduce the use of plastic bags. These initiatives aim to decrease plastic pollution, which poses a significant threat to marine and terrestrial biodiversity. Public awareness campaigns highlighting the environmental impacts of plastic have led to policy changes and increased adoption of reusable bags among consumers. [Source: dynamicsandlearning.com]

These examples demonstrate the power of awareness campaigns in fostering a deeper understanding of biodiversity issues and driving positive change. By engaging communities, influencing policies, and promoting sustainable practices, such campaigns contribute significantly to the global effort to preserve our planet's rich biological diversity.

SAQ II

1. (a) What is the role of the Chipko Movement in biodiversity conservation?
   (b) What are Ramsar Sites, and why are they important?
   (c) Where did the 'Green Belt Movement' originate? What is its basic objective?

2. State whether the following statements are 'True' or 'False'.

(a) *Ex-situ* conservation is always more effective than in-situ conservation.

(b) Biosphere reserves include core, buffer, and transition zones to ensure sustainable biodiversity conservation.

(c) Wildlife corridors help in connecting fragmented habitats and promote genetic diversity.

(d) Cryopreservation is a method of in-situ conservation.

(e) The Montreal Protocol focuses on reducing carbon emissions to prevent global warming.

(f) Eco-tourism is an unsustainable practice that negatively impacts biodiversity.

(g) The Convention on Biological Diversity (CBD) is an international treaty aimed at biodiversity conservation, sustainable use, and fair benefit-sharing of genetic resources.

(h) The Bonn Challenge is a global effort to restore deforested and degraded land.

3. Select the correct answer –

(a) Which of the following is a global biodiversity awareness program?

(i) Project Tiger
(ii) International Day for Biological Diversity
(iii) Namami Gange
(iv) Green India Mission

(b) The Participatory Forest Management project originated in

(i) Kupwara of Jammu & Kashmir
(ii) Bharatpur in Rajasthan
(iii) Uttarkashi in Uttarakhand
(iv) Arabari in West Bengal

(c) The Appiko Movement took place in the

(i) Western Ghats
(ii) Eastern Ghats
(iii) Sunderbans
(iv) Bhitarkanika of Orissa

8.8 Sustainable Development and its goals

Unless we act now, the 2030 Agenda will become an epitaph for a world that might have been.
António Guterres, Secretary-General, United Nations

The concept of *sustainable development* (SD) was first mooted at the 1972 UN Conference on the Human Environment. It was in a report called the *Limits of Growth* by a group of scientists from MIT. In 1980, the International Union for Conservation of Nature (IUCN) used the term “sustainable development” to position the concept as a global priority. Today, the definition commonly accepted for “sustainable development” is *“development that meets the needs of the present without compromising the ability of future generations to meet their own needs”*. This definition was used in the 1987 Brundtland Report, *“Our Common Future”*, published by the United Nations World Commission on Environment and Development (WCED). In September 2015, this definition was adopted by all member states of the UN as part of the *2030 Agenda for Sustainable Development*–which had set out a 15-year plan to achieve the Goals–the Sustainable Development Goals (or SDGs) and their related targets. Never before had world leaders pledged common action across such a broad and universal policy agenda.

In 2015, a total of 17 goals and 169 targets were enunciated with 193 countries as signatories, to be achieved by the end of 2030. The UN believes that sustainable development can be achieved by harmonizing economic growth, social inclusion, and environmental protection. The SDGs are interconnected, apply to all countries, and need to be carried out by all stakeholders–which include governments, the private sector, civil society, the UN bodies–all in a collaborative partnership. For the purpose, a report named *Our Common Agenda*, was drawn up to kick-start implementation of the SDGs after the setback due to the Covid-19 pandemic. An SDG summit in 2024 came out with a Report–*The Sustainable Development Goals Report 2024*. It detailed significant challenges the world was facing in making substantial strides towards achieving the SDGs based on the latest data and estimates. It featured areas with setbacks while also showcasing where tangible progress was registered–for instance, in reducing global child mortality, preventing HIV infection, and access to energy and mobile broadband. The report also highlighted where action must accelerate, particularly in critical areas undermining SDG progress–climate change, peace and security, inequalities among and between countries, among others. The Report asserts that with just six years remaining, current progress fell far short of the target. It stated that without massive investment and scaled up action, the achievement of the SDGs will remain elusive. The lingering impacts of the COVID-19 pandemic, escalating conflicts, geopolitical tensions and growing climate chaos had severely hindered progress. The report set out urgent priorities and areas needed for stronger and more effective action to ensure the 2030 promise to end poverty, protect the planet and leave no one behind.

Let us first study the goals and the problems associated with them. The 17 goals are give in **Box 8.2**.

Goal 1. *End poverty in all its forms everywhere.*

In 2020, the number of people living in extreme poverty (living on less than USD $ 2.15 a day) rose to 724 million. Those living in extreme poverty struggle to fulfill the most basic needs (health, education, access to water and sanitation). Recovery from the pandemic has been slow and uneven, with extreme poverty dropping from 9.3 per cent in 2020 to 8.8 per cent in 2021. The conflict in Ukraine has disrupted global trade, leading to increased living costs that are disproportionately impacting the poor. Furthermore, climate change poses substantial threats to poverty reduction. By the end of 2022, an estimated 8.4 % of the world's population, i.e., ~ 670 million people were projected to be still living in abject poverty. Poverty affects developed countries as well. No less than 30 million children in the world's richest countries are growing up poor. Eradicating poverty in all its forms remains one of the greatest challenges facing humanity. A surge in action and investment is deemed crucial in alleviating poverty, enhance economic opportunities, improve education and extend social protection to all, particularly the most excluded.

Box 8.2 Seventeen sustainable development goals

Goal 1. No Poverty

Goal 2: Zero Hunger

Goal 3: Good Health and Well-being

Goal 4: Quality Education

Goal 5: Gender equality

Goal 6: Clean Water and Sanitation

Goal 7: Affordable and Clean Energy

Goal 8: Decent Work and Economic Growth

Goal 9: Industry, Innovation and Infrastructure

Goal 10: Reduced Inequalities

Goal 11: Sustainable Cities and Communities

Goal 12: Responsible Consumption and Production

Goal 13: Climate Action

Goal 14: Life Below Water

Goal 15: Life On Land

Goal 16: Peace, Justice and Strong Institutions

Goal 17: Partnerships for the Goals

Goal 2. *End hunger, achieve food security and improved nutrition and promote sustainable agriculture.*

More than 600 million worldwide were projected to face hunger by 2030. However, in 2022, ca. 735 million people were already in the midst of chronic hunger. High food prices continue to plague many nations. One in three people in the world face moderate to high food insecurity. One-third of world's food is wasted yet 821 million people are undernourished. The malnutrition has severely jeopardized children's well-being and future development. For example, there is little or no progress in combating anaemia since the year 2000. Anaemia in women aged 15-49 years has remained stagnant at around 30%. In 2022, 148 million children had stunted growth and 45 million children under the age of 5 were affected by wasting. Extreme hunger and malnutrition remains a barrier to sustainable development and creates a trap from which people cannot easily escape. Hunger and malnutrition mean less productive individuals, who are more prone to disease and thus often unable to earn more and improve their livelihoods, **achieve food security and improved nutrition and promote sustainable**

Goal 3. *Ensure healthy lives and promote well-being for all at all ages*

In recent years, we have seen modest progress on improving global health. For example, 146 out of 200 countries or areas have already met or are on track to meet the SDG target on under-5 mortality.

> The SDG Goal 3.2 is to reduce under-5 mortality to at least 25 per 1000 live births and neonatal mortality to at least 12 per 1000 live births.

Effective HIV treatment has reduced global AIDS-related deaths by 52 %. Also, at least one neglected tropical disease has been eliminated in 47 countries. However, insufficient progress has been made in other areas, such as on reducing maternal mortality and expanding universal health coverage. In 2020, ca. 800 women died every day from pregnancy or childbirth. Universal health coverage (UHC) aims to ensure that everyone can access quality health services without facing financial hardship. But, in 2019, ca. 381 million people were pushed into extreme poverty due to out-of-pocket payments for health. Immunization is one of the most successful and cost-effective health interventions. However, the COVID-19 pandemic and ongoing crises have caused a great decline in child vaccinations, the largest decline in three decades. Tuberculosis and malaria deaths have increased compared with pre-pandemic levels. Polio vaccinations have been greatly affected in the Israeli-Palestinian conflict in the Gaza strip on the West Bank.

Goal 4. *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*

Obtaining a quality education is the foundation to improving people's lives and sustainable development. Without additional measures, it is feared that an estimated 84 million children and young people will still be out of school, and about 300 million students will lack the basic numeracy and literacy skills necessary for success in life. To deliver on Goal 4, education financing must become a national investment priority. Furthermore, measures such as making education free and compulsory, increasing the number of teachers, improving basic school infrastructure and embracing digital transformation are essential.

Goal 5. *Achieve gender equality and empower all women and girls*

Gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world. With only six years remaining, a mere 15.4 per cent of Goal 5 indicators with data are "on track", 61.5 per cent are at a moderate distance and 23.1 per cent are far or very far off track from 2030 targets. At the current rate, it will take an estimated 300 years to end child marriage, 286 years to close gaps in legal protection and remove discriminatory laws, 140 years for women to be represented equally in positions of power and leadership in the workplace, and 47 years to achieve equal representation in national parliaments. Political leadership, investments and comprehensive policy reforms are needed to dismantle systemic barriers to achieving Goal 5.

Goal 6. *Ensure availability and sustainable management of water and sanitation for all*

Only 0.5 per cent of water on Earth is useable and available freshwater warns the World Meteorological Organization. Clean, accessible water for all is an essential part of the world we want to live in. Water scarcity affects more than 40% of the world's population. In 2020, 2.4 billion people lived in water-stressed countries. The challenges are compounded by conflicts and climate change. Despite great progress, billions of people still lack access to safe drinking water, sanitation and hygiene. Achieving universal coverage by 2030 will require a substantial increase in current global rates of progress: six-fold for drinking water, fivefold for sanitation and threefold for hygiene. Limiting global warming to 1.5°C compared to 2°C would approximately halve the proportion of the world population expected to suffer water scarcity.

Goal 7. *Ensure access to affordable, reliable, sustainable and modern energy for all.*

It is a challenge confronting every country and it touches everyone. However, the four aspects of affordability, reliability, sustainability and modernity overlap. The heterogeneity of energy use across the world is due largely to different natural resource endowments and purchasing power. For example, a country with large coal deposits will likely make wide use of this resource to generate power and industrialize its economy. Whereas people without ready stocks of fossil fuels has to rely on more primitive methods of combustion, such as wood fibers or perhaps even animal dungs. Indeed, this was the condition for the vast majority of humankind throughout its history and this condition still prevails in many parts of the developing world.

An estimated 2.7 billion people (about 40 per cent of the world's population) still rely on traditional biomass fuels for cooking -- a major source of indoor air pollution (International Energy Agency, *Energy Poverty: How to make modern* *energy access universal? Special early excerpt of the World Energy Outlook (WEO) 2010 for the UN General Assembly on the Millennium Development Goals.* (Paris, 2010) p. 9, 20).

Goal 8. *Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.*

Economic growth throughout the world has suffered during the Covid pandemic 2020-2022. Many countries have recovered somewhat. In 2023, an all time high of over 2 billion workers worldwide constituting 58% of the global workforce, were in precarious informal jobs lacking social protection. One in four young people are not in education, employment or training–and young women are more than twice as likely to be in this situation compared to young men. There is a considerable gender gap too: globally, only 63% of women aged 25 to 54 are in the labour force, compared to 94% of men of the same age.

Goal 9. *Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.*

Economic growth, social development, and climate action are all dependent on investments in infrastructure, sustainable industrial development, and technological progress. In 2022, global growth in the manufacturing sector had plateaued to 2.7%, from 7.4 per cent in 2021. In this, the share of the Least Developed Countries (LDCs) was meagre. A concerted effort is needed to promote inclusive and sustainable industrialization and foster innovation. It is also essential to support LDCs, invest in advanced technologies, lower carbon emissions and increase mobile broadband access.

Goal 10. *Reduce inequality within and among countries.*

Inequality can threaten long-term social and economic development, harm poverty reduction, and destroy people's sense of fulfillment and self-worth. The incomes of the poorest 40% of the population had been growing faster than the national average in most countries. In order to address and tackle inequality, we need to: dismantle systemic barriers; promote inclusivity and social cohesion; combat discrimination; promote diversity and inclusion; ensure equal opportunities for all individuals; empower marginalized groups through education, skills training, and economic empowerment initiatives.

Goal 11. *Make cities and human settlements inclusive, safe, resilient and sustainable.*

About 3.9 billion people—half of the world's populations—currently live in cities globally. By 2030, it is projected to rise to 5 billion people. Cities across the world occupy just 3% of the Earth's land, yet account for 60–80% of energy consumption and 75% of carbon emissions. Serious challenges exist from the point of view of viability and safety of cities which can meet increased future demands. Moreover, continuous conflicts in Ukraine, Syria, Gaza among others has seriously dented all prospects of reaching this goal.

Goal 12. *Ensure sustainable consumption and production patterns*.

The SDG 12 calls for "responsible consumption and production". Meanwhile, the scenario remains gloomy. In 2022, 19% of all *food* at the retail or consumption stage was wasted, which amounts to 1.05 billion metric tons. In 2022, *e-waste generation* rose to 7.8 kg per capita, but only 1.7 kg per capita was properly managed. Global crises triggered resurgence in *fossil fuel subsidies*, which nearly doubled from 2020 to 2021. In 2022, it hit a record high of $1.53 trillion. In 2021, although 828 million people faced *hunger*, the post-harvest loss of food (along the supply chain from farm to consumer) was 13.2 % of the world's food. By the time global population reaches 9.8 billion, the equivalent of almost three planets will be required to provide the natural resources needed to sustain current lifestyles. It is imperative that continued support should be extended to developing countries to move towards more sustainable patterns of consumption by 2030.

Goal 13. *Take urgent action to combat climate change and its impacts**

Let us realise that every person, in every country in every continent will be impacted in some way or the other by climate change. There is a climate cataclysm looming, and we are underprepared for what this could mean. Climate change is caused by human activities and threatens life on earth as we know it. With rising greenhouse gas emissions, climate change is occurring at rates much faster than anticipated. We already witnessed 2010-2019 as the warmest decade ever recorded and the year 2024 as the warmest, an increase of 1.450C above preindustrial levels, threatening to breach the 1.50C level (as decided at the Paris Climate Conference, 2015). Each year we witness massive wildfires, hurricanes, droughts, floods and other climate disasters across continents. To limit global warming to 1.5°C, emissions need to be reduced by almost half by 2030, barely five years away. We need to act now, going beyond platitudes and hollow promises in order to avoid catastrophic consequences and secure a sustainable future. You need to ask: *What can I do to help*?

Fortunately, there are many things that each of us can do as individuals. To find out what you can do, go to: www.un.org/en/actnow

Goal 14. *Conserve and sustainably use the oceans, seas and marine resources for sustainable development.*

Healthy oceans and seas are essential to human existence and life on Earth. Oceans cover three-quarters of the Earth's surface, contain 97 % of the Earth's water, and represent 99 % of the living space on the planet by volume. The world's largest ecosystem, it is home to nearly a million known species with a vast untapped potential for scientific discovery. They provide key natural resources such as food, medicines, biofuels, and minerals; help breakdown and remove waste and pollutants; and their coastal ecosystems act as buffers to reduce damage from storms. They also act as the planet's greatest carbon sink to absorb ~ 23 % of annual CO_2 emissions and helps mitigate other impacts of climate change. In fact, oceans absorb > 90% of the excess heat in the climate system. Furthermore, marine fisheries provide 57 million jobs globally and provide the primary source of protein to over 50% of the population in least developed countries. Indeed, oceans and fisheries together support the global population's economic, social and environmental needs. However, the ocean is in a state of dire emergency through escalating eutrophication, acidification, warming and plastic pollution. Currently, the ocean's average pH is 8.1 which are about 30 % more acidic than in pre-industrial times. Ocean acidification threatens the survival of marine life, disrupts the food web, and undermines vital services provided by the ocean and our own food security. Additionally, the alarming trend of overfishing persists, leading to the depletion of over one third of global fish stocks. Despite its critical importance, conserving oceans were never prioritized -- decades of irresponsible exploitation have led to an alarming level of degradation. To counter these trends, swift and coordinated global action is imperative. This entails increasing funding for ocean science, intensifying conservation efforts, advancing nature- and ecosystem-based solutions, addressing the interconnections and impacts of human-induced pressures, and urgently turning the tide on climate change to safeguard the planet's largest ecosystem. For Open Ocean and deep sea areas, sustainability can be achieved only through increased international cooperation to protect vulnerable habitats. Establishing complete, effective and equitably managed systems of government-protected areas should be pursued to conserve bio-diversity and ensure a sustainable future for the fishing industry. One example is the Biodiversity Beyond National Jurisdiction Agreement in 2023 that provides a legal framework for all activities in the ocean and seas. At a local level, we should make ocean-friendly choices when buying products or eating food derived from oceans and consume only what we need. Reducing our plastic use is also critical.

> *Overfishing* is the removal of a species of fish from a water body at a rate greater than that at which the species can replenish its population naturally. It causes the species becoming increasingly underpopulated in that area. Overfishing can occur in water bodies of any sizes, such as ponds, wetlands, rivers and so on.

Goal 15. *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*

Terrestrial ecosystems are vital for sustaining human life, contributing to over half of global GDP and encompassing diverse cultural, spiritual, and economic values. However, the world faces a triple crisis of climate change, pollution and biodiversity loss. Escalating trends of forest loss, land degradation and the extinction of species pose a severe threat to both the planet and people. Despite some progress in sustainable forest management, protected areas, and the uptake of national biodiversity values and natural capital accounting, most improvements have been modest. The recently adopted Kunming-Montreal Global Biodiversity Framework provides renewed impetus for Goal 15, outlining four outcome-oriented goals to be achieved by 2050 and 23 targets to be achieved by 2030. To fulfill Goal 15, a fundamental shift in humanity's relationship with nature is essential, along with accelerated action to address the root causes of these interconnected crises and take better cognizance of the tremendous value of nature. Conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, particularly in forests, wetlands, mountains and drylands; sustainable management of all types of forests; to combat desertification, restore degraded land and soil; conservation of mountain ecosystems and their biodiversity are among the important target outcomes. [source: https://sdgs.un.org/goals/]

Goal 16. *Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.*

People everywhere should be free of fear from all forms of violence and feel safe as they go about their lives, irrespective of their ethnicity, faith or sexual orientation.Goal 16 aligns with the broader human rights framework by promoting societies that respect and uphold individual rights, as well as the right to privacy, freedom of expression, and access to information.Armed violence and insecurity adversely affects a country's economic growth and development, often creating long-term grievance among communities. Violence also affects children's health, development and well-being, and their ability to thrive. It causes trauma and weakens social inclusion. Lack of access to justice means that conflicts remain unresolved and people cannot obtain protection and redress. Institutions that do not function according to legitimate laws are prone to arbitrariness and abuse of power, and less capable of delivering public service to everyone. To exclude and to discriminate not only violates human rights, but also causes resentment and animosity, and could give rise to violence. To summarise: SDG 16 is important because it aims to create peaceful and inclusive societies by

promoting the rule of law, enhance access to justice, build accountable and transparent institutions, reduce violence and related deaths, protect the most vulnerable, ensure legal identity for all, end abuse and torture of children and reduce the flow of illicit arms and finance. It was for the first time that these goals were universally recognized as a path to peace and development. It is considered a cornerstone for the other global goals. However, ongoing and new violent conflicts around the world are derailing the global path to peace and achievement of Goal 16. Alarmingly, the year 2022 witnessed a more than 50 per cent increase in conflict-related civilian deaths – the first since the adoption of Agenda 2030 – largely due to the war in Ukraine. While the war continues in Ukraine, new areas of conflict and genocide of in Gaza, Lebanon and other parts of West Asia, has created unprecedented misery among civilian populations – mostly women and children. Governments, civil society and communities need to work together to find lasting solutions to conflict and insecurity. Strengthening the rule of law and promoting human rights is crucial, as is reducing the flow of illicit arms, combating corruption, and ensuring inclusive participation at all times.

What can we do?

It is important that you exercise your rights to hold your elected officials to account, to freedom of information and share your opinion with your elected representatives. Promote inclusion and respect towards people of different ethnic origins, religions, gender, sexual orientations or different opinions.

Goal 17. *Strengthen the means of implementation and revitalize the global partnership for sustainable development*.

The Sustainable Development Goals can only be realized with a strong commitment to global partnership and cooperation to ensure no one is left behind in our journey to development. However, not all countries are setting off from the same start line, and low and middle income countries are facing a massive trade deficit, especially after the COVID-19 pandemic. By the end of 2022, out of the 69 poorest countries, 37 countries were in acute debt crisis or at a high risk of it. Their problems have compounded by record inflation, escalating interest rates, competing priorities and constrained fiscal capacity, underscoring the urgent need for debt relief and financial assistance.

- While official development assistance (ODA) flows continue to reach record peaks, the increase in 2022 is primarily attributed to spending on refugees in donor countries and in providing aid to Ukraine and the victims in West Asia–particularly Gaza and Lebanon.
- In 2022, an estimated 66% of the world's population (5.3 billion) used the Internet, compared with 40% (3 billion) in 2015. Globally, 259 million more men than women used the Internet in 2022. Despite a 65 % improvement, accesses to Internet services are yet to reach all people.
- Geopolitical tensions and the resurgence of nationalism hinder international cooperation and coordination, highlighting the importance of a collective surge in action to provide developing countries with the necessary financing and technologies to accelerate the implementation of the SDGs.
- International funding for data and statistics amounted to only $541 million in 2020, a decrease of more than $100 million and $138 million from funding levels in 2019 and 2018, respectively. Between 2018 and2020, ODA funding for data dropped by more than 20%.
- The total trade of tracked Environmentally Sound Technologies (ESTs) in 2020 was $2,364 billion, an increase of 5% since 2015.

The COVID-19 pandemic have opened our eyes to the need for strengthening multilateralism, global partnerships and cooperation in order to combat our common problems more than ever before.

8.8.1 SDGs – measures to be adopted

Several measures have been advocated to tackle the shortfalls and hurdles in attaining the SDG targets. These include :

(a) **Use of appropriate technology** – onewhich is locally adaptable, eco-friendly, resource-efficient and culturally suitable. It mostly involves local resources and local labour. Indigenous technologies are more useful, cost-effective and sustainable. Nature is often taken as a model, using the natural conditions of that region as its components. This concept is known as *"design with nature"*. The technology should use less of resources and should produce minimum waste.

(b) **Reduce, Reuse, Recycle approach –** the 3-R approach – it advocatesminimal resource use, their repeated use to the extent possible, and recycling the materials. It reduces pressure on our scarce resources, reduces waste and pollution.

(c) **Promotion of environmental education and awareness**–it puts environmental education at the centre of all learning process. It would hopefully help change how people think, their attitude, towards environment. It is hoped that *'Earth thinking'* will gradually will occupy centre-stage in our thinking and action. This could prove crucial in transforming our life stylesto sustainable ones.

(d) **Resource utilization as per carrying capacity –** Any system can sustain a limited number of organisms on a long-term basis, which is known as itscarrying capacity. In humans, the carrying capacity concept becomes all the more complex. It is because unlike other animals, humans apart from food always seek out many other components for survival and a quality life.

Let us remember that the *sustainability* of a system relies to a large extent on the *carrying capacity* of the system. Once the carrying capacity is surpassed (say, by over exploitation of a resource), environmental degradation sets in and continues till it reaches a point of no return. Carrying capacity of course has two basic components: *supporting capacity*, the capacity to regenerate and *assimilative capacity*, the capacity to tolerate different stresses. In order to attain sustainability, it is very important to utilize the resources based on these two components of carrying capacity. It is important to ensure that consumption does not exceed regeneration and that changes remain well within the tolerance capacity of the system.

8.8.2 Major hurdles in attaining the set goals

Forcing developed countries to meet their financial commitments to the goals set in the Paris Climate Agreement (2015) and the Kunming-Montreal Global

Biodiversity Framework is challenging for the least developed countries (LDCs), as they have limited political and economic leverage on the global stage. For instance at the 29th COP meeting at Baku, Azerbaijan 2024, the rich countries of the global North pledged only to release $300 billion out of $1.3 trillion necessary to keep rise of global temperature within 1.50C from the pre-industrial years, as decided at the Paris Climate Conference. Left with little option, LDCs can use a combination of strategies to push for accountability and financing.

(a) *By strengthening collective bargaining power*

LDCs can form alliances, such as the Alliance of Small Island States (AOSIS) and the Least Developed Countries Group (LDC Group) within the UN framework. By collectively demanding action, LDCs can amplify their voices, apply greater political pressure, and increase the visibility of their needs and the resource gap in international negotiations.

(b) *By highlighting the moral and ethical imperative*

LDCs are the most vulnerable to climate change impacts, despite contributing the least to global emissions. By framing the issue as a matter of justice, LDCs can appeal to the moral responsibility of developed nations to take action and meet their financial obligations. International media and environmental organizations can be leveraged to increase public awareness and create pressure on developed nations.

(c) *By utilizing international legal frameworks*

LDCs can explore the use of international courts or bodies, such as the International Court of Justice (ICJ) or the Permanent Court of Arbitration, to seek advisory opinions or legal rulings on the responsibility of developed countries for climate finance and biodiversity conservation. This would not be a direct enforcement mechanism but could apply significant pressure and establish a legal precedent for accountability.

(d) *By engaging with global financial institutions*

LDCs can work with institutions like the World Bank, the International Monetary Fund (IMF), and the Green Climate Fund (GCF) to create mechanisms that condition financing for certain projects in developed countries on the fulfillment of climate finance obligations. This approach could make funding contingent on actions by developed nations to meet their international commitments.

(e) *By leveraging trade agreements and economic incentives*

LDCs could work with large trading partners or economic blocs, such as the European Union, to introduce "climate accountability clauses" in trade agreements. This could mean preferential trade terms for countries that fulfill their commitments or increased tariffs or other barriers for countries that fail to comply.

(f) *By utilizing domestic and international advocacy*

By partnering with international NGOs, climate activists, and influential voices within developed countries, LDCs can raise public awareness about the commitments that developed countries have made but not fulfilled. Citizen advocacy and media campaigns in developed nations can help increase domestic political pressure on these governments to fulfill their obligations.

(g) *By developing independent reporting and accountability mechanisms*

LDCs can collaborate with organizations and think tanks to independently monitor and report on the climate finance provided by developed nations. This transparency would make it harder for developed countries to avoid accountability and would create a basis for future diplomatic or legal action.

(h) *By encouraging carbon markets and private sector involvement*

Through carbon offset markets, LDCs can create economic incentives for companies in developed countries to invest in climate and biodiversity projects in their regions. While this does not directly compel governments, it can still result in a transfer of resources to LDCs, aligning with their climate and biodiversity goals.

(i) *By using future COPs and international summits as platforms*

The annual Conference of the Parties (COP) meetings and similar summits offer opportunities for LDCs to pressure developed nations of the North, particularly as they often want to be seen as global leaders. LDCs can make strong, united statements at these events to hold developed countries publicly accountable for their commitments.

Admittedly, the path to compelling the developed North to fulfill their climate and biodiversity commitments is neither straightforward nor easy. However, through international alliances, legal pathways, advocacy, financial institutions, and consistent pressure in public and diplomatic spaces, global South can increase the accountability and willingness of developed nations to fulfill their financial and climate obligations. [Source: https://www.un.org/en/exhibits/page/sdgs-17-goals-transform-world - sdg1].

8.8.3 SDGs – the Indian Context

In 12 July 2024, the NITI Aayog released fourth edition of the SDG India index, outlining its achievement in 2023-24. Together with States and Union Territories, NITI Aayog has focused on the institutionalisation of the SDGs – not only to look at sustainable development as a standalone or parallel framework, but also to make them an integral part of national development through institutional ownership, collaborative competition and capacity building following a holistic approach embracing the entire society. The SDG India Index was launched in 2018, which provided the impetus for a localisation push, reaffirming the role of the States and UTs as key stakeholders in this transformative journey. The SDG India Index provides a comprehensive and comparative analysis of progress on the goals. Its performance has improved consistently over the years. By fostering a collaborative competition, the Index encourages States to learn from each other and close outcome-based gaps between them. Grounded in the globally accepted SDSN methodology, the development of the Index followed extensive consultations with the States and UTs (the primary stakeholders), Union Ministries and UN agencies. The Index represents the articulation of the comprehensive nature of the Global Goals under the 2030 Agenda while keeping the national priorities in mind. The SDG India Index 2023–24 is also live on an online dashboard. The dashboard provides user friendly visualizations to identify crucial development outcome based gaps at the national and sub-national levels.

Key highlights and results from the fourth edition of the SDG India Index :

- The composite score for India improved from 57 in 2018 to 66 in 2020-21 and further to 71 in 2023-24.
- India has taken significant strides in accelerating progress on the SDGs between 2020-21 and 2023-24 editions of the Index. Noteworthy advancements have been observed India in Goals 1 (No Poverty), 8 (Decent Work and Economic Growth), 13 (Climate Action). These are now in the 'Front Runner' category (a score between 65–99).
- Among these, most improvement was noticed in Goal 13 (Climate Action) with its score increasing from 54 to 67. Goal 1 (No Poverty) follows closely, with its score rising from 60 to 72. The progress underscores the effects of the focused programmatic interventions and schemes of the Union and State Governments in improving the lives of its citizens.

- Since 2018, substantial progress was also observed in other key SDGs, such as in Goals 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 9 (Industry, Innovation and Infrastructure) and 11 (Sustainable Cities and Communities).
- Government's focus on ensuring food & nutrition security, health, education, electrification, housing for all, sanitation, clean cooking fuel & energy has significantly contributed to the improvements.
- Goal 14 has not been included in the calculation of the Composite Score for the Index as it solely pertains to the nine coastal States.

Box 8.3 Index methodology :

The methodology for constructing the Index involves a series of steps. First, raw data are compiled for the selected indicators and data gaps (if any) are identified. Subsequently, target values for 2030 are kept in sight for each indicator, to provide clear benchmarks for evaluating progress. The raw data is then normalised, transforming it into a score ranging from 0 to 100. The Goal score for each SDG is computed by taking the arithmetic mean of the normalized scores of its relevant indicators. The *composite SDG India Index score* is derived as an average of all Goal scores. The index and indicators are updated incorporating the latest developments in data availability.

It is important to point out that technological advancement such as remote sensing, satellite images, use of biotechnology to conserve endangered species or improve their resilience–have all contributed to our conservation efforts. At the same time, different innovative tools and techniques have been developed to support conservation efforts.

8.9 Summary

Effective biodiversity conservation hinges on a multifaceted approach. By integrating strategies such as establishing protected areas–in situ conservation practices, restoring ecosystems, resorting to ex situ conservation and promoting sustainable practices, we can safeguard vital ecosystems, their bioresources, and thereby ensure quality life for humans and the biodiversity around us. Different social approaches to conservation such as protection of Sacred Groves, Sthalavrikshas have been given due importance. Engaging local communities in conservation efforts through participatory management and utilization of local resources to foster a sense of ownership has paid rich dividends. The popularity of social forestry initiated at

Arabari, West Bengal, is a case in point. Our country has witnessed a number of environmental movements such as within the Bishnoi community, Chipko, Narmada Bachao, Silent Valley, Appiko movement, and many others. They bear testimony to rising awareness of the importance of protecting virgin forests and other relatively undisturbed habitats.

A host of educational and public awareness programmes have been instrumental in raising awareness about the importance of biodiversity and its benefits. A variety of legal and policy measures such as enactment and enforcement of environmental laws to protect biodiversity and prevent habitat destruction are already in place – both at the national and international level. Some government and a host of non-governmental organisations, sections of the mainstream media, the social media are active in voicing concern about climate change, biodiversity loss and species threatened with extinction–never witnessed before in the history of our planet. The sustainability development goals and their related targets set out by the UN and adopted by all nations, offer a clear benchmark and a rare opportunity for humankind to restore our planet, our ecosystems and biodiversity from impending disaster. Addressing climate change and enhancing monitoring, education, and funding are also crucial. These combined efforts are essential for preserving our planet's rich biodiversity and ensuring a sustainable future for generations to come. Various technological advancements and innovative tools have aided our conservation efforts.

The concept of *sustainable development* was first formally defined in the 1987 *Brundtland Report*, also known as "Our Common Future", published by the World Commission on Environment and Development (WCED). The report was chaired by Gro Harlem Brundtland, the former Prime Minister of Norway. It is a holistic approach to progress that seeks to meet "the needs of the present without compromising the ability of future generations to meet their own needs". The UN's Sustainable Development Goals (SDGs) are a set of 17 global objectives adopted in 2015, which outline specific targets for achieving a more sustainable and inclusive world by 2030. The concept of SDGs marked a turning point in global thinking by linking environmental concerns with economic and social issues, emphasizing the interdependence of these dimensions for long-term human progress.

8.10 Terminal questions

(a) Answer in brief :

(i) What is in-situ conservation, and how does it differ from ex-situ conservation?

(ii) How do protected areas like national parks contribute to biodiversity conservation?

(iii) What is the rationale for 'cryopreservation'?

(iv) How do community-based conservation programmes contribute to biodiversity protection?

(b) Fill in the blanks :

(i) The conservation of species in their natural habitats is known as ______ conservation.

(ii) The world's largest seed bank, located in Norway, is called the ______.

(iii) Captive breeding of threatened animals in zoos is an example of ____________ conservation.

(iv) The international agreement that seeks to ensure fair and equitable sharing of genetic resources is called the ______ Protocol.

(v) The Silent Valley Movement in India was a successful campaign against the construction of a __________ in a biodiversity-rich forest.

8.11 Answer key

SAQ I

1. See Section 8.4.6. 2. See Section 8.4.8; 3. (a) (ii); (b) (ii); (c) (ii)

SAQ II

1. (a) The Chipko Movement was an environmental movement in India (1970s) where villagers, particularly women, hugged trees to prevent deforestation, emphasizing the importance of community participation in biodiversity conservation.

(b) Ramsar Sites are wetlands of international importance designated under the Ramsar Convention to conserve biodiversity, maintain ecological balance, and protect migratory bird habitats.

(c) Kenya. Founded by Wangari Maathai, this movement promotes tree planting and women's empowerment.

2. 'True' or 'False'.

(a) False; (b) True; (c) True; (d) False; (e) False (It focuses on phasing out ozone-depleting substances.); (f) False (Eco-tourism promotes conservation while benefiting local communities.); (g) True; (h) True

3. Select the correct answer—(a) (ii); (b) (iv); (c) (i)

Terminal questions :

(a)(i) In-situ conservation is the protection of species within their natural habitat, such as national parks and wildlife sanctuaries. Ex-situ conservation involves protecting species outside their natural habitat, such as in seed banks, botanical gardens and zoos.

(ii) They provide a safe habitat, prevent habitat destruction, regulate human activities, and promote species conservation through legal protection.

(iii) A very low temperature of - 196°C ensures that the cells remain in a completely inactive state where physical and cellular metabolic processes are suspended, and they are free of contamination by pathogens, However, genetic drift is not halted.After keeping the plant tissues/organs/cells in this way for an indefinite period, they can be recovered and grown again, to regenerate a whole plant whenever required.

(iv) These programmes involve local communities in conservation efforts, promote sustainable resource use, and protect biodiversity while ensuring livelihoods such as through eco-tourism and sustainable farming.

(b) (i) In-situ; (ii) Svalbard Global Seed Vault: (iii) ex situ; (iv) Nagoya; (v) hydroelectric dam.

8.12 References and Further Readings

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Unit – 9 ❑ Plant diversity in a Changing World

Structure

9.1 Objectives

This unit emphasizes

- How plant diversity contributes to ecosystem resilienceand stabilizes yield,suppress weeds, pests and plant diseases, provide food for humans and livestock, as well as timbre, fibres, clean water, and controls erosion control, are a source of traditional medicine and provide a home and support to animals and microbes.
- Species composition and its relation to biodiversity;
- Threatened species and the major sources of threat – habitat loss, fragmentation and degradation;

- Over-exploitation;
- Invasive species;
- Air pollution and its relation to plant diversity conservation; and the
- Relation of plant diversity to anthropogenic climate change

9.2 Introduction

There is insufficient awareness or sense of urgency about the importance of conserving plant diversity. As a taxonomic group, green plants are the most diverse except perhaps the plant-dependant fungi. At the CBD meeting held in Nagoya 2010, the *Global Strategy for Plant Conservation* (GSPC) decided that its first target for 2020 would be to create ‘an online flora of all known plants (www.cbd.int/gspc/targets.shtml). The objective remains unrealized. Estimates from different sources puts the number of land plants (from bryophytes to angiosperms) at about 500,000 species, concentrated mostly in the humid tropics. This is a setback because these tropical rainforests are mostly in low-income countries that can ill-afford participation in ambitious conservation efforts without monetary support. Furthermore, close to one-thirds of all plants are at risk of extinction including many that are still unidentified or little known. In addition to plant species which we use directly, many more play important roles in natural ecosystems with the services they provide. Therefore, a thorough knowledge of *species composition* is important. Because the richness and diversity of plant species within ecosystems play key roles in shaping resilience in today’s world–that witnesses almost regularly climate fluctuations, natural disasters and other adverse human impacts. However, we need to dig deeper into the intricate relationship between plant diversity and ecosystem resilience, to reveal how diverse plant communities contribute to productivity, nutrient cycling, soil stability, pest and disease resistance, habitat provision, pollination and reproduction. All these collectively bolster an ecosystem’s capacity to endure and recover from various perturbances. Conversely, denuded landscapes with low plant diversity prove inherently more vulnerable and less adaptive to our rapidly changing world.

The *major threats* to plant diversity come from habitat loss, land fragmentation, degradation and overexploitation, alien invasive species, pollution and of course anthropogenic climate change. Viewed globally, conservation of plant diversity is a stupendous task. However, the combination of a well-designed and well-managed protected area system and *ex situ* gap-filling and back-up, come in handy. One urgent task would be to complete the global botanical inventory and an assessment of the conservation status of the ca. 94% of plant species not yet evaluated. This would enable efficient management of both *in situ* and *ex situ* conservation efforts. The hyperdiverse lowland tropics will obviously need the most attention.

9.3 Species Composition

Species composition refers to the total number of different living organisms within a given biome or ecosystem. In a forest, the species composition would refer to all the different plants, animals, invertebrates, vertebrates, bacteria, and fungi within the environment.

Plant species composition is important for biodiversity conservation because it can indicate the structure and function of a community, and it can help distinguish one community from another. It also shows us how ecosystems function and how they resist, recover, and manage to remain stable. Let us now examine how plant species composition is related to biodiversity conservation:

- *Ecosystem health or its functions and services* such as nutrient levels, nutrient turnover, and productivity are intricately linked to plant species composition. Therefore, the specie composition could be used as an effective surrogate in planning for biodiversity conservation. Plant species composition may also be used to determine the biotic integrity index (BII) of ecosystems. The presence or absence of specific plant species can significantly impact the BII.
- *Community succession*. The species composition of a community changes as species are replaced and lost in the course of succession.
- *Stand conditions*. The conditions of a stand directly affect the survival, growth, and development of species within the community.
- *Species diversity*. Increasing species diversity can increase the likelihood that species will use complementary resources, which can lead to increased ecosystem productivity.
- *Habitat degradation*. Human activities, such as grazing of livestock and other exploitative pressure, can lead to habitat degradation and reduce plant species diversity and density.

- *Agroecosystems*. The composition and diversity of woody plant species in agro-ecosystems are critical determinants of ecosystem health, resilience, and productivity.

> **Biotic integrity index** is ascientific tool that assesses the health of an ecosystem by examining various ecological indicators such as the condition of its organisms, resources, and ecological processes. First developed in 1981 by Robert G. Karr to assess the health of riverine ecosystems based on fish assemblages, it has since been adapted for use in lakes and other environments.

9.4 Threatened Species

Using the IUCN Red List criteria, we find that globally, close to 20,000 plant species have been formally assessed so far. Among them, the proportion of land plants threatened is not accurately known. About 30% of plants are estimated to be threatened or near-threatened. For the major groups assessed so far, it ranges from 11% in the legumes threatened to 40% for gymnosperms. Compared with other groups assessed in the same way, plants are more threatened than birds, are similar to mammals, and less threatened than amphibians. However, this sampling is necessarily an underestimate of the actual threat level because it excludes the species still unknown to science. The habitat with most threatened species is plainly the tropical rainforests. A recent model-based assessment of the conservation status of 15,200 Amazonian tree species estimated that 36% – 57% would likely qualify as threatened under IUCN Red List criteria and the authors go on to suggest that the majority of the world's >40,000 tropical tree species may be threatened (ter Steege *et al*., 2015). If these estimates are confirmed, it suggests that tropical trees are among the most threatened taxa on Earth.

As against threat assessments, actual global extinctions among plant species are still few–and this too is likely an underestimate according to IUCN. However, plants don’t sing or fall prey to baits, and neither do they walk past camera traps like vertebrates or invertebrates. This makes it very difficult and time-consuming to truly assess their conservation status. There exists an estimated 1.4 trillion individual trees >10 cm in diameter in the tropical and subtropical forests that harbour most of the world’s plant diversity (Crowther et al., 2015), and trillions more small trees, shrubs and herbs, so it is easy to overlook the last few individuals of a threatened species, particularly when the identifying characters we look for are high up in the canopy of most large trees; or they only visible for a brief period each year, as is true for many smaller plants.

9.5 Major threats–from habitat loss to overexploitation

Habitat lossis the outright conversion of a habitat to another use (e.g., forest to farmland). *Habitat fragmentation* isolates plant populations, reducing gene flow between them. This can lead to a loss of genetic diversity within the fragmented populations, making them more vulnerable to diseases, environmental changes, and less able to adapt. Habitat loss and fragmentation together are believed to be the biggest single threat to plant diversity, particularly in the tropics, where conversion of tropical forests to pastures and commercial crop monocultures (such as oil palm, rubber, soybean) has replaced small-scale cultivation by poor farmers as the major driver of forest loss. Few forest-adapted plant species can withstand total deforestation, and even if a substantial fraction of the original forest cover remains, fragmentation drives changes that tend to reduce plant diversity. *Habitat degradation* is a reduction in the quality of a habitat, making it less suitable for some species (e.g., pollution, overgrazing).Large areas of the remaining forest, whether fragmented or not, are degraded by logging, fire, and other impacts, including fuelwood harvesting in densely populated areas. Non-forest habitats, from savannas and grasslands to deserts, are similarly threatened by agricultural development. Many plant species are confined to specialized habitats, such as limestone or ultramafic outcrops, which are unsuitable for commercial agriculture, but such habitats often are subject to different, highly specific threats, such as mining of limestone to make cement and of ultramafic rocks for nickel.

9.5.1 Overexploitation

Overexploitation of the entire plant or enough of it to reduce the chance of survival is the second most important threat to plant species. This threat is often somewhat species-specific, although some species can be lumped together for specific uses, e.g., dipterocarps with similar wood in the timber trade or plants with similar properties in the medicine trade. People collecting plants for home use or for sale face the same difficulties in locating them as botanists do, so exploitation to the point of extinction is likely only in species with a restricted range or where the value increases with rarity, as is often true for luxury products.

In cacti, collection for the horticultural trade and for private collections is the biggest single threat (Goettsch et al., 2015). In many areas, orchids as well as cycads and ornamental species across other families, face a similar threat. Extinction is also likely to be slow where only the largest individuals are harvested, as happens with timber trees, since seedlings, saplings and undersize adults survive each round of logging. Actually, logging affects more than half of all remaining tropical forests, but over-logging threatens the timber supply long before it threatens individual tree species. Damage from harvesting of non-timber forest products (NTFPs) varies widely, depending on whether whole plants are removed or killed, and, if only parts of each plant are removed, how this affects growth, reproduction and survival. Of course, overexploitation of animals may also threaten plant species in the long term, by restricting seed dispersal or, in some cases, pollination.

SAQ I

(a) What is the difference between habitat loss and habitat degradation?

(b) Briefly state how habitat fragmentation can impact plant genetic diversity.

(c) Why is it important to consider plant species composition when assessing ecosystem health?

9.6 Invasive Species

Invasive alien species are another potential threat to native plant diversity. A recent study showed that > 13,000 species—3.9% of the world's vascular plant flora? have become naturalized somewhere outside their native range as a result of human activity. Tropical regions generally have fewer naturalized species than temperate regions, but these numbers are increasing as direct trade between tropical countries overcomes the geographical barriers that have isolated the major tropical regions during the period when most modern species evolved. Invasive plant species can indeed greatly reduce native plant diversity. We still know little about the longer-term impact of periodic and changing fire regimes and nutrient cycling, on regional and global plant diversity. Even on oceanic islands, where local impacts tend to be much greater than on the mainland, non-native plants generally add to the total plant diversity, rather than replacing native species, and in continental areas there is little evidence that invasive plant species currently threaten any native species with extinction. It is possible that competitive exclusion of native species is simply very slow (Gilbert and Levine, 2013), but current evidence suggests that, despite often large local impacts, the *extinction risk* from invasive plants is low. Invasive animals may be more of a threat, particularly generalist herbivores, such as goats, on islands that lack native vertebrate grazers and browsers (Chynoweth *et al.*, 2013).

9.7 Air Pollution

Every plant on Earth today is exposed to an atmosphere that differs significantly in composition from any that its ancestors would have experienced. Changes in the concentration of the major greenhouse gases (CO_2, CH_4, N_2O) are considered separately below, but other air-borne pollutants can also impact plant diversity The major source of air pollution is the burning of fossil fuels and the most important primary pollutants are sulphur dioxide and nitrogen oxides. Ozone, which is produced from hydrocarbons and nitrogen oxides in the presence of sunlight, is the most important secondary pollutant. Particulates (or aerosols: solid and liquid particles suspended in the air) are derived from a variety of primary and secondary sources. Air pollution is declining in Europe and other developed regions, but increasing in much of Asia. Wet and dry deposition of nitrogen compounds not only acidifies the soils but can also dramatically change nutrient cycles, as has happened over much of southern China, with a largely unknown impact on plant diversity (Zhu *et al*, 2015).

9.8 Climate Change

The impacts of anthropogenic climate change are also complex and unpredictable, and even more pervasive. After around 1°C of global warming so far, many temperate zone plants are leafing and flowering earlier in spring and—less consistently—delaying leaf fall in autumn (Ge *et al.*, 2015). Some species have extended their ranges towards the poles and/or to higher altitudes, although other species have not done so. Growth rates have generally increased where temperature is limiting and decreased where water is. Although no global plant extinctions have yet been attributed to anthropogenic climate change, there is evidence that local extinctions have occurred at the climatic margins of species ranges (Buse *et al.*, 2015).

The Paris Agreement (UNFCCC, 2015) had set a target of keeping "the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels", but the path to these targets is still hazy. Even a 2 °C rise in global temperature means generally greater warming of land surfaces, particularly at high northern latitudes, and will be associated with less predictable changes in rainfall and other climatic parameters (IPCC, 2013). Climate change will also interact with other impacts: both negatively, as with fires and fragmentation, but also perhaps positively with rising carbon dioxide levels. When changes in the local climate exceed the range of natural variation, plant populations can either *acclimate* (i.e. adjust physiologically within the lifetime of an individual), *adapt* (by evolutionary changes over multiple generations), move to somewhere with a more suitable climate, or *die*. There is very little information available on either acclimation capacity or evolutionary potential for all but a few model plant species. Such studies suggest that most plant species will find it difficult or impossible to track the expected rate of climate change, except in steep topography where climatic gradients are equally steep. Moreover, some current climatic conditions cannot be tracked, since they will completely disappear, while large areas of tropical and subtropical lowlands will have climates by the mid to late 21st century that do not currently exist anywhere on Earth (IPCC, 2013, Corlett 2016).

SAQ II.

(a) Briefly explain how air pollution, specifically acid rain, can affect plant diversity.

(b) Fill in the Blanks

(i) The non-native species introduced into a new environment is known as an __________ species.

(ii) __________ is the process of clearing forests for other land uses.

(iii) Changes in temperature and precipitation patterns are key components of __________.

(iv) __________ occurs when the rate of resource use exceeds its rate of replenishment.

(v) __________ refers to the physical breakdown of large, continuous habitats into smaller, isolated patches.

(vi) Air pollutants like sulphur dioxide and nitrogen oxides can contribute to __________, which can harm plant life.

(c) State whether the following statements are 'True' or 'False.'

(i) Habitat loss is the single biggest threat to plant diversity globally. (True)

(ii) Climate change only affects plant species in tropical regions. (False)

(iii) Invasive species always have a negative impact on native plant communities. (True)

(iv) Overexploitation of plant resources can lead to local extinctions. (True)

(v) Seed banks are a valuable tool for conserving plant genetic resources. (True)

(vi) True or False : Plant species composition is irrelevant to ecosystem health. (False).

(d) Multiple Choice Questions

(i) Which of the following is NOT a major threat to plant diversity?

- Habitat loss
- Use of medicinal herbs by indigenous communities (Answer)
- Invasive species
- Climate change

(ii) Which factor contributes most significantly to habitat fragmentation?

- Natural disasters
- Human developmental activities (Answer)
- Climate change
- Seed dispersal

(iii) Which of the following is an example of overexploitation?

- Sustainable harvesting of timber
- Illegal poaching of rare orchids (Answer)
- Controlled burning of grasslands
- Reforestation efforts

(iv) Which of the following best describes the impact of climate change on plant phenology -- the timing of life cycle events?

- No impact

- Shifts in timing, potentially leading to mismatches with pollinators or other interacting species (Answer)
- Uniformly beneficial effects
- Only affects tropical plants

(v) Invasive species are often successful because they:

- Have many natural predators in the new environment.
- Are well-adapted to the new environment and lack natural controls. (Answer)
- Are always native to the region.
- Require very specific environmental conditions.

(vi) Which of the following is a key strategy for conserving plant diversity?

- Ignoring the problem
- Protecting and restoring habitats (Answer)
- Introducing more non-native species
- Afforestation

9.9 Summary

Conservation of plant diversity unfortunately does not get the attention it deserves. Of the ca. 500,000 land plants many are still unidentified, others not fully described, while a third of all land plants are at risk of extinction. Assessment of the conservation status of ca. 94% plant species is still incomplete. The problem is compounded because most of the species diversity is concentrated in the tropical rainforests – countries with low income that can ill-afford participation in ambitious conservation efforts without monetary support from rich countries and international donors. In addition to plant species which we use directly, many more play important roles in natural ecosystems and the services they provide. Plant diversity contributes to resilience in ecosystems subject to climate fluctuations, natural disasters and varied human impacts. We need to delve deeper into this and expose how diverse plant communities contribute to productivity, nutrient cycling, soil stability, pest and disease resistance, habitat provision, pollination and reproduction. All these collectively boost the ecosystem’s capacity to endure and recover from various perturbations. Conversely, denuded landscapes with low plant diversity prove inherently more vulnerable and less adaptive to our rapidly changing world. First of all, we need a thorough account of species composition. Habitat loss, land fragmentation, degradation and overexploitation, invasive species, pollution and anthropogenic climate change pose the major threats to plant diversity. The degree of threat to plant diversity which each of these changes is still insufficiently known. Therefore we need to mobilize all our resources and innovative skills in stalling these threats. Conservation of plant diversity is doubtless a huge task. Here, a combination of a well-designed and well-managed protected area system and ex situ gap-filling with suitable backups may come in handy. To sum up, plant diversity in a rapidly changing world increases ecosystem resilience, improve yield stability, suppress weeds, pests and diseases, provide essential products and services, support traditional medicine, are the primary producers in all ecosystems and provide the home and support to numerous animal species and microbes.

9.10 Terminal Questions

1. How can overexploitation of a medicinal plant species negatively impact the ecosystem it is a part of?
2. Describe two ways in which climate change can exacerbate the threat of invasive species to native plant communities.
3. What role do seed banks play in conserving threatened plant species?

9.11 Answer key

SAQ I.

(a) *Habitat loss* is the outright conversion of a habitat to another use (e.g., forest to farmland). Habitat degradation is a reduction in the quality of a habitat, making it less suitable for some species (e.g., pollution, overgrazing).

(b) *Habitat fragmentation* isolates plant populations, reducing gene flow between them. This can lead to a loss of genetic diversity within the fragmented populations, making them more vulnerable to diseases, environmental changes, and less able to adapt.

(c) *Plant species composition* reflects the overall health and functioning of an ecosystem. Changes in composition can indicate underlying environmental problems (e.g., pollution, nutrient imbalances) and can have cascading effects on other organisms in the food web.

SAQ II.

(a) Acid rain can acidify soils and water bodies, making it difficult for some plant species to absorb nutrients. This can lead to reduced growth, increased susceptibility to disease, and ultimately, loss of diversity.

(b) Fill in the Blanks

(i) invasive; (ii) deforestation; (iii) climate change; (iv) overexploitation; (v) habitat fragmentation; (vi) acid rain.

(c) 'True' or 'False.'

(i.) True; (ii) False; (iii) True; (iv) True; (v) True; (vi) False.

(d) Multiple Choice Questions

(i) Use of medicinal herbs by indigenous communities;

(ii) Human developmental activities;

(iii) Illegal poaching of rare orchids;

(iv) Shifts in timing, potentially leading to mismatches with pollinators or other interacting species;

(v) Are well-adapted to the new environment and lack natural controls;

(vi) Protecting and restoring habitats.

Terminal Questions

1. Overexploitation can lead to population declines or local extinctions of the medicinal plant. This can disrupt ecological interactions like pollination, seed dispersal, and herbivory, affecting other species in the ecosystem.
2. Climate change can create conditions that favor invasive species (e.g., altered temperature or precipitation regimes). It can also weaken native plant communities, making them less resistant to invasion.
3. Seed banks store seeds of diverse plant species, acting as a backup in case wild populations are lost. They provide material for future restoration efforts and research.

9.12 References and Further Readings

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Unit – 10 ❑ Importance of Forestry–Benefits, Management & Commercial Aspects.

Structure

10.1 Objectives

From this unit you should get a clear idea how

- Forestry benefits us
- Forestry is managed for conservation of biodiversity
- Forests and their products are utilised in a sustainable manner
- We derive other economic and social benefits from forests
- Forests protect us through carbon sequestration and in mitigation of climate changes
- Threatened species inside forests are vulnerable to destruction
- Forests play a crucial role in meeting sustainable development goals and in protection of livelihoods.

10.2 Introduction

Forests constitute one of the most important natural resources on Earth, making it the only known green planet. In 2020, the world had a total forest area of 4.06 billion ha, which was 31 % of the total land area. This area is equivalent to 0.52 ha per person. Roughly 80% of the forest is in patches larger than one million hectare. About one-thirds of total forested area is primary forest. Though net loss of forest area decreased from 7.8mha per year in the 1990s to 4.7 mha per year during 2010 to 2020, some 10 mha continue to be lost each year through conversion to agriculture and other land uses. Arrest of the fast declining natural forest cover is a top priority in almost all countries. More than half (54 %) of the world's forests is found in only five countries–the Russian Federation (20.1%), Brazil (12.2%), Canada (8.6%), the United States of America (7.6%) and China (5.4%). The total forest cover of our country is 7, 13,789 Km2, which is 21.71% of the geographical area of the country. Madhya Pradesh has the highest forest cover by area, followed by Arunachal Pradesh. Mizoram has the highest forest cover in terms of percentage of total geographical area (*India State of Forest Report, 2021*). The *Forest Survey of India* (FSI) has been conducting biennial assessment of forest cover using satellite data since 1987

10.3 Importance of Forestry

The importance of forests and forestry cannot be overstated in a world that is rapidly heating up like never before. Escalating deforestation and degradation of pristine forests has been attributed mostly to agricultural expansion though ravaging forest fires over the last few years without the opportunity for regeneration may well add to our collective misery. Forests not only produce innumerable material goods, but also provide several environmental services which are essential for life. They are the abode of countless life, play a crucial role in biodiversity conservation, and maintain ecological balance. Forests are a foremost carbon sink -- a great insurance against a heating planet. Forestry is a fundamental tool for biodiversity conservation, climate regulation, and the provision of ecosystem services. Protecting and managing forests sustainably is essential for maintaining ecological balance and ensuring the well-being of both nature and humanity. Let us now examine in brief, each of the various important aspects of forestry in greater detail. Later on, we will examine why forestry is a very important component of sustainable development goals.

10.3.1 Forestry in conservation of biodiversity and protection of habitats

Forests are home to over 80% of terrestrial biodiversity, not only of plants and fungi but countless animals and microbes too. As *biodiversity hotspots*, forest ecosystems, especially tropical and subtropical forests, harbor the largest variety of plant species. According to a report by the Food and Agriculture Organization (FAO), forests cover nearly 31% of the global land area and provide habitat to a significant portion of the world's plant species (FAO, 2020). Moreover, they offer various niches and microhabitats that support different species, from towering trees to forest floors. Protecting forests is therefore essential to prevent the extinction of species that rely on these ecosystems for survival. Recent studies have highlighted the effectiveness of conservation actions in halting and reversing biodiversity loss. A landmark study by the University of Oxford found that conservation interventions, including the establishment and management of protected areas and habitat restoration, improved biodiversity in most cases compared to no action taken. The study emphasized the need for increased funding and political support for conservation efforts.

Protection of forests enables preservation of terrestrial habitats. Unsustainable forestry practices lead to *habitat fragmentation*, which disrupts biodiversity. Managed forests and protected areas help maintain contiguous habitats, essential for the survival of diverse plant species.

10.3.2 Forestry in Carbon Sequestration and Climate Regulation

Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C in the last decade, and 1.450C in 2024 above the pre-industrial revolution base level around the 1850s. With this, it already threatens to breach the 1.50C critical threshold point set in the 2015 Climate Conference in Paris. Meanwhile, emission of greenhouse houses and burning of fossil fuels continue unabated. The myriad promises made by the rich countries at the annual climate conferences ring hollow. Global greenhouse gas emissions, principally fossil fuel emission has escalated CO_2 levels from 280 ppm at the preindustrial level to 421 ppm in 2024. Forests act as major carbon sinks, absorbing significant amounts of CO_2 and storing it in the biomass. Forest degradation and deforestation reduce this capacity, impacting ecosystem stability and plant biodiversity (Pan *et al*., 2011). This carbon sequestration helps mitigate climate change by reducing greenhouse gas concentrations. According to the Global Forest Resources Assessment, forests absorb approximately 7.6 billion metric tons of CO_2 annually. The tropical rain forests, such as in the Amazon Basin or our Western Ghats are considered the "lungs of the planet." They absorb about one-thirds of the total atmospheric carbon and play a crucial role in modulating the global carbon cycle. *The Sixth Assessment Report of the IPCC*, 2023 warns that if CO_2 emission and global warming continues unabated, the tropical rain forests would collapse well before the end of the century and initiate a global catastrophe affecting nearly 800 million people worldwide. Sustainable forestry practices such as selective logging and afforestation promote carbon storage and help mitigate the effect of climate change on plant biodiversity.

10.3.3 Forest-derived economic and social benefits

Forests are a renewable resource that supports the livelihoods of over 1.6 billion people who depend on them for food, fuel, and other resources. Forest products are aplenty and they contribute to economic development in many ways. They also provide recreational opportunities and cultural value, enriching human lives in numerous ways.

10.3.3.1 Forest products and their commercial use

Forests products were used by humans even before the advent of civilization. Man was primarily a forest dweller who depended on the forest for food and shelter. Today, in spite of the vast strides that have been made in science and technology, a high proportion of the earth's population depend on forests for their basic requirements and well-being. Even in the most advanced countries life would come to a standstill without direct and direct use of forest products. In India the dependence on forest products is high both in the urban and rural areas.

India is one of the ten most forest-rich countries of the world. In 2002, forestry industry contributed 1.7% to India's GDP. In 2010, the contribution to GDP dropped to 0.9%, for a variety of reasons. Since 2013 there has been a partial increase. In 2021, the forestry and logging sector contributed about 2.2 trillion Indian rupees to the agricultural gross value. Today, the forestry and logging sector itself contributes roughly 1% to India's GDP. With all direct benefits accounted for, forest resources, contribute ~ 2.9% to the adjusted Net Domestic Product for the country.

The major commercial and non-commercial forest products of India have been listed below :

(i) Fuelwood, charcoal, or energy.

(ii) Fodder, mainly grasses and leaves.

(iii) Timber, structural timbers, specific utility or industrial timbers, ornamental timbers.

(iv) Bamboos and canes used for various purposes, such as furniture, building construction and fodder,

(v) Grasses used as raw material for paper and pulp manufacture, fodder, matting, ropes, cordage and thatching.

(vi) Fibres, such as jute, flax, leaf fibres and cotton.

(vii) Flosses for stuffing of mattresses, pillows, cushions and life belts.

(viii) Coir, primarily coconut coir.

(ix) Essential or volatile oils, such as grass oils, flower oils, leaf oils, root oils, and wood oils.

(x) Fixed oils, such as castor oil, cotton seed oil, coconut oil, mahua oil, neem oil, and sal butter.

(xi) Waxes, such as candelilla wax and white wax.

(xii) Dyes mainly flower and fruit dyes, bark and wood dyes, and root dyes.

(xiii) Tannins obtained from species, like khair, sal and Terminalia.

(xiv) Medicines and drugs obtained from different parts of forest species are used in the treatment of different disorders and diseases.

(xv) Food – the principal edible parts being leaves, pulp of fruits, seeds, enlarged starchy rhizomes, young and succulent culms and nut kernels.

(xvi) Gums exuded by many tree species.

(xvii) Resins including gum resins, oleo resins and gum oleo resins.

(xviii) Lac excreted by the lac insect which feeds on some trees.

(xix) Leaves of certain forest species may be used for wrapping, cups, plates, fodder, thatching, finishing and polishing. Beedi or tendu leaves are an important forest product.

(xx) Honey and wax.

(xxi) Soap substitutes.

Let us examine some of these in terms of commercial importance,

(a) *Raw materials* – wood, timber, rubber, construction materials, furniture, paper, and other processed forest wood and non-wood products. One third of the wood harvest is used for building materials as lumber, plywood and hardwood, particle board and chipboard. One sixth of the wood harvest is converted into pulp and used for paper industry. India's paper industry produces over 3,000 metric tonnes annually from more than 400 mills.

(b) *Fuel* – energy from firewood and pulpwood. About half of the timber cut each year is used as fuel for heating and cooking. India is one of the world's largest consumers of fuel-wood. It meets ~ 40% of the energy needs of the country. Fuelwood is used by roughly 80% of the rural people and 48% of the urban people.

(c) *Miscellaneous uses* – forestry in India is more than just about wood and fuel. India has a thriving non-wood forest products industry, which produces latex, gums, resins, essential oils, fragrances and aroma chemicals, incense sticks, handicrafts, thatching materials. About 60% of non-wood forest products are consumed locally. Close to 50% of the total revenue from the forestry industry in India is in the non-wood forest products category.

(d) *As sources of drugs and medicines* – forests act as nature's pharmacies. They hold the secrets to life-saving drugs and medications. Many untapped chemicals could present in forest plants has the potential to revolutionize healthcare and could be the key to a healthier, more sustainable future. The use of forest plant species for medicinal purposes has been practiced since ancient times. Indigenous communities across the globe have harnessed the healing properties of various tree species, passing down this knowledge through generations. This traditional wisdom has laid the foundation for modern pharmacology, with many of today's most effective drugs tracing their origins back to compounds found in trees. From an economic standpoint, forests represent a form of natural capital that, if managed sustainably, can provide long-term returns in the form of medicinal discoveries and healthcare advancements. In this way it can help meet the target of SDG3 (Good Health and Well-being). Demand for herbal medicines has increased in recent decades in both developing and developed countries. Forest animals are also a source of medicines, including toxins purified from venomous snakes, spiders, insects and scorpions. We shall deal with the medicinal properties of plants and related issues in Unit 12, in considerable more details.

(e) Source of livelihood and employment opportunities. The forests provide whole time daily employment to about 15 lakh persons engaged as wood-cutters, sawyers, carters, and craftsmen and in other related forest industries.

10.3.3.2 Forests in ecosystem services and other ecological benefits

Forests provide essential ecosystem services such as clean air, water filtration, soil fertility and stability, facilitate pollination and regulate climate. These services are vital for human survival and agricultural productivity. Forests also play a an important role in the global water cycle, moving water across the earth – by releasing water vapour and capturing rainfall. While a typical tree produces commercial goods worth about $590 it provides environmental services worth nearly $196,250. The preservation of plant biodiversity in forests is critical for these services to function effectively.

The major ecosystem services provided by our forests include :

Production of oxygen : The trees produce oxygen by photosynthesis which is so vital for life on this earth. They are rightly called as earth's lungs.

Mitigation of global warming : Carbon dioxide, the main greenhouse gas, is absorbed by the forests as a raw material for photosynthesis. Thus, forest canopy acts as a sink for CO_2 thereby reducing the impact of CO_2 in global warming. Forest degradation and deforestation reduce this capacity, impacting ecosystem stability and plant biodiversity. Sustainable forestry practices such as selective logging and afforestation promote carbon storage, helping to mitigate climate change's effects on plant biodiversity.

Wildlife habitat : Forests are the homes of millions of wild animals and plants. About 7 million species are found in the tropical forests alone. Well-managed forestry practices can support the regeneration of native species, many of which are threatened or rare. Preservation of endemic and native plant species is critical for maintaining biodiversity in forested regions.

Conservation of genetic diversity through Forest Reserves : Forests contribute to genetic diversity, as they harbour diverse populations of both rare and common plant species. By maintaining species and genetic diversity, forestry practices enhance resilience and adaptation to environmental changes, including climate change. Protected forest areas are a key to preserving the genetic diversity of wild plants. It was observed that diverse forest ecosystems are better equipped to withstand disturbances like pests, diseases, and climate extremes.

Regulation of hydrological cycle : Forested watersheds act like giant sponges, absorbing the rainfall, slowing down the runoff and slowly releasing the water for recharge of springs. About 50-80% of the moisture in the air above tropical forests comes from their transpiration which helps in bringing rains.

Soil Conservation. Forests bind the soil particles tightly in their roots and prevent soil erosion. Soil temperature is influenced by the forest cover to a great extent. There is an increase in the minimum and decrease in the maximum soil temperatures. Each year the forest cover adds large quantities of organic matter to the soil in the form of raw humus which is later decomposed and passed on to the layers below. Less water is evaporated from soil under a forest cover and up to a certain distance on the leeward side. The forest cover improves both the physical and chemical condition of the soil. Forests also maintain a balance in the soil moisture content.

Pollution moderators : Forests can absorb many toxic gases and can help to keep the air pure. They have also been reported to absorb noise and help in reducing air and noise pollution.

Control of Invasive Species : Sustainable forestry helps manage invasive species, which can outcompete native plants and decrease biodiversity. Forest managers implement strategies such as controlled burning and selective logging to minimize invasive species impact.

A number of *ecological benefits*accrue from forests. They have important influences on the climate, soil, erosion, run-off and the environment. The major influences have been summarized below:

(a) *Climate*

(i) Forests have a considerable moderating effect on the speed and direction of prevailing winds. On entering a forest, it is noticed that there is relative calm even it is widely outside. The physical obstacle offered by forests deflects upwards a large part of the moving mass of air.

(ii) Air temperature is moderated by forests. This influence is more pronounced in stands having a dense foliage.

(iii) The air outside a forest is more humid than that in open areas, even though the variation in absolute moisture content is somewhat less than what would be expected in view of the large quantity of water transpired by trees.

(b) *Soil*

(i) Soil temperature is influence by the forest cover to a great extent. There is an increase in the minimum and decrease in the maximum soil temperatures.

(ii) Every year the forest cover adds large quantities of organic matter to the soil in the form of raw humus which is later decomposed and passed on to the layers below.

(iii) Less water is evaporated from soil under a forest cover and up to a certain distance on the leeward side. The forest cover improves both the physical and chemical condition of the soil.

(iv) Forests also maintain a balance in the soil moisture content.

(c) *Erosion and Run-off*

(i) Forests prevent or substantially check soil erosion and control run-off.

(ii) Environment Protection: Forests help to protect the environment by reducing soil erosion, maintaining the ecological balance, regulating the water cycle, keeping the atmosphere free of air pollutants, lowering noise pollution and moderating temperatures.

SAQ I.

(a) What is forestry?

(b) What percentage of terrestrial species depends on forests?

(c) How do forests contribute to biodiversity conservation?

(d) How does afforestation differ from reforestation?

10.3.3.3 Recreational Use

Forests are a major source of recreation, with opportunities for physical activity, mental well-being and bonding with others. Recreational activities in forests allow people to connect with nature and unwind from daily stresses. It nurtures people's appreciation for the essential role that forests play in preserving the health of our planet and the well-being of its inhabitants. Recreational forestry provides economic benefits through eco-tourism by attracting visitors who engage in nature-based activities, supporting local economies through increased demand for services and infrastructure. Popular recreational activities include walking, hiking, different sports, picnicking, bird-watching, camping, and so on.

10.4 Threatened species of forests

Many plant species in the world’s forests are threatened with extinction due to illegal logging and wildlife trade, poaching, overharvesting timber and fuelwood, and habitat destruction. There are many trees, Magnolias, firs, ferns, carnivorous species and bromeliads among the threatened forest species. Examples include – Mandragora (popularly called Mandrake, a small, almost stemless perennial herb with large tap roots, family Solanaceae, overexploited for its hallucinogenic alkaloids) , Red Sandalwood, *Pterocarpus santalinus* (initially listed as an 'endangered species' by the IUCN, because of overexploitation for its timber in South India, later reclassified as 'near threatened' in 2018, and is listed in the appendix II of the CITES, which means that a certificate is required in order to export it). *Buchananiacochinchinensis* (chironji) once common in the dry deciduous forests of the country is now labelled as 'vulnerable.' Mahogany (a valuable tropical hardwood tree) has been rendered vulnerable by uncontrolled harvesting and widespread illegal logging. Many *Magnolia* species are now endangered or critically endangered due to habitat loss. Many species of fir (Guatemalan fir–*Abies guatemalensis*, Fraser's fir–*Abies fraseri*, Korean fir–*Abies koreana*) are all critically endangered. The Venus' Flytrap (*Dionaea muscipula*, the only species of the monotypic genus, a carnivorous plant) has become 'vulnerable' due to habitat destruction and exploitation by traders. The list is quite long.

Of course, many animals of forested areas also grace the threatened list. Examples include: all the eight species of Pangolins (genus *Manis*), their conservation status ranging from vulnerable to critically endangered, by overhunting, illegal trafficking, and habitat loss. The smallest elephant species, the African forest elephant *Loxodonta cyclotis* is critically endangered due to habitat loss. A subspecies of leopard, the Amur leopard (*Panthera pardus orientalis*), native to the forests and mountains of eastern Russia and northern China is critically endangered. The Black rhino (*Diceros bicornis*), hunted and poached for its horns, remains critically endangered. The Bornean pygmy elephant (*Elephas maximus borneensis*), the smallest Asian elephant subspecies is critically endangered, its population size having shrunk to less than 1500. They are threatened by habitat fragmentation, habitat loss and human-wildlife conflict principally by the expansion of palm oil plantations. Giant panda (*Ailuropoda melanoleuca*) is listed as vulnerable with around 1800 in their native habitat, and another 600 pandas in zoos and breeding centres around the world. Jaguars (*Panthera onca*), apex predators mainly active during the night, require a large amount of territory to survive. They are considered near threatened chiefly through habitat destruction and fragmentation, climate change, and conflict with farmers and ranchers. All three species of Orangutan (genus *Pongo*), the Asian great apes found in the rainforests of Southeast Asian islands of Sumatra and Borneo, are critically endangered by hunting, fires, and habitat destruction.

Organizations such as the International Union for Conservation of Nature (IUCN) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report on threatened, rare, and endangered species and suggest measures to protect them.

10.5 Management of forestry

Effective forestry management helps maintain biodiversity, ecosystem services, ensures the sustainable use of forest resources while maintaining ecological balance and provides for resilience against climate change. Forestry management has as its key goals the practice of *sustainable forestry*–to harvest trees without depleting forest resources; ensure sustained *economic benefits*–as source of timber, eco-tourism, and forest-based livelihoods; promote *agroforestry*–combining trees with crops/livestock; develop *community forestry*—with local participation in forest conservation; create *protected areas*–to establish national parks and reserves; ensure *soil and water conservation*–to prevent erosion and regulate watersheds, and so on.

10.5.1 Approaches to management of forestry

(a) *Sustainable Forest Management (SFM)*–to ensure that forests are used without compromising their health and productivity. It includes among others–

(i) Selective Logging : harvesting mature trees while preserving young ones.

(ii) Reforestation & Afforestation : replanting trees in deforested areas.

(iii) Agroforestry : integrating trees with agriculture.

(iv) Monitoring & Certification : verifying that forests are sustainably managed (e.g., Forest Stewardship Council – or FSC certification).

(b) *Community-Based Forest Management (CBFM)* – involve local communities in conservation efforts, to ensure that they benefit from forest resources while protecting ecosystems. Examples include –

(i) Joint forest management programmes.

(ii) Indigenous land stewardship.

(iii) Sustainable harvesting of non-timber products (e.g., honey, medicinal plants).

(c) *Industrial Forestry*—aims at large-scale timber production. This type of management focuses on:

(i) Plantation Forestry–growing trees in controlled environments for commercial use.

(ii) Fast-Growing Species–using species like eucalyptus and pine for high-yield timber.

(iii) Forest Certification–ensuring that commercial logging meets sustainability standards.

(d) *Protected Area Management*–many forests are designated as national parks, wildlife sanctuaries, and biosphere reserves to conserve biodiversity and prevent exploitation. You are already aware with this practice. To remind you, it involves creation of –

(i) Core Conservation Zones : areas with no human activity.

(ii) Buffer Zones : areas where controlled human activities like eco-tourism and sustainable farming are permitted.

(iii) Corridors : to connect protected areas to allow wildlife movement.

10.5.2. Key Strategies in Forest Management

(a) *Forest Conservation Laws & Policies* -- many countries including ours, have laws to regulate forest use. Examples include the *Forest Stewardship Council* (FSC) standards for sustainable forestry; the *REDD + programme* (Reducing Emissions from Deforestation & Forest Degradation) under the UNFCCC; Protected Area Laws to prevent illegal logging and poaching.

> **The Forest Stewardship Council (FSC)** certifies forests that are managed in an environmentally responsible, socially beneficial and economically viable manner. This promotes sustainable forestry practices and supports biodiversity conservation. [Source: https://fsc.org/en]

(b) *Afforestation & Reforestation*–Afforestation involves planting trees where none existed before. Reforestation seeks to restore degraded forests.

(c) *Forest Fire Management*—the measures include

(i) Controlled Burns : intentional fires to clear dry vegetation.

(ii) Firebreaks : creating gaps in vegetation to stop spread of fire;

(iii) Surveillance & Early Warning Systems : monitoring forests with satellites and drones.

> **Reducing emissions from Deforestation and Forest Degradation (REDD+)** is a global effort to reduce emissions from deforestation and forest degradation in developing countries. It provides financial incentives to countries that successfully reduce emissions from their forests. [Source: https://unfccc.int/topics/land-use/workstreams/reddplus]

(d) *Wildlife Conservation & Biodiversity Protection*. It involves --

Establishing wildlife corridors to connect fragmented forests;

Protecting endangered species through breeding programmes and anti-poaching measures;

Encouraging natural regeneration of forests.

(e) *Use of Technology in Forest Management*

GIS & Remote Sensing : Monitoring forest cover changes using satellite data.

Drones : Surveying and tracking illegal deforestation.

AI & Big Data : Predicting deforestation trends and planning conservation efforts.

Box 10.1 The Forest (Conservation) Act, 1980 in India

It is a law in India that regulates the use of forest land. It aims to balance the need for forest conservation with the need for sustainable development. The chief features of the *Forest (Conservation) Act, 1980* are :

- it allows the use of forest land for development only when unavoidable;
- it requires prior approval from the central government for any use of forest land other than for conservation and management;
- it prohibits the de-reservation of forest land or its use for non-forest purposes without approval;
- it allows the central government to make rules for carrying out the provisions of the Act.

10.5.3 Challenges in Forest Management and the future

Sustainable forest management is essential to balance economic development with ecological conservation. Through community involvement, technological advancements, and strong policies, forests can be preserved for future generations.

Despite efforts to manage forests sustainably, several challenges remain. One such is *deforestation* due primarily to agriculture, urban expansion and illegal logging; periodical *conflicts over land use* between conservationists and industries; *weak law enforcement*, allowing illegal activities like poaching and deforestation; and *climate change*, leading to unpredictable forest fires and habitat loss.

So, what does the future of management of forestry portend? Mitigating climate change is of course the reigning concern. Sustaining the livelihoods of millions of indigenous communities and tribal people who continue to survive in and depend on forests is crucial. Preservation and enhancement of biodiversity is equally important in sustainable livelihoods. Ensuring water security, regulating rainfall and preventing floods is another major concern.

10.6 Forestry and Sustainable Development Goals (SDGs)

How doforestry practices relate to the Sustainable Development Goals (SDGs) of the UN? You might recall from previous sections how forestry is closely linked to multiple Sustainable Development Goals (SDGs) -- chiefly because forests contribute to environmental health, economic stability, and social well-being. Sustainable forestry ensures that forests can continue to provide these benefits for future generations.

Let us look back at how forestry relates to some key SDGs :

❒ **SDG 13: Climate Action**

Forests are major carbon sinks that absorb the greenhouse gas CO2 from the atmosphere and help mitigate climate change. Sustainable forestry practices like reforestation and prevention of deforestation, support climate resilience and help stabilize global temperatures.

❒ **SDG 15: Life on Land**

This goal emphasizes the protection, restoration, and sustainable use of terrestrial ecosystems. Forests are crucial for biodiversity, providing habitats for 80% of the world's terrestrial species. Sustainable forestry helps conserve these ecosystems and the species they support, preventing biodiversity loss.

- **SDG 6: Clean Water and Sanitation**

  Forests play an important role in water cycles by regulating rainfall, maintaining watersheds, and filtering pollutants. Sustainable forestry helps preserve forested watersheds, which are essential for clean and stable water supplies for communities and ecosystems.

- **SDG 8: Decent Work and Economic Growth**

  Forestry provides jobs and livelihoods for millions of people globally. Sustainable forestry promotes responsible economic growth by balancing resource extraction with long-term forest health, supporting both local economies and ecological integrity.

- **SDG 12: Responsible Consumption and Production**

  Sustainable forestry promotes responsible use of forest resources by preventing overexploitation, promoting recycling, and encouraging the sustainable production of timber and non-timber products.

- **SDG 1: No Poverty and SDG 2: Zero Hunger**

  Forests provide food, fuel, shelter, and medicine, especially for rural and indigenous communities. Sustainable forestry supports poverty reduction by ensuring forests can provide resources without depletion, contributing to food security and income.

- **SDG 3: Good Health and Well-being**

  Forests contribute to clean air and water, which are fundamental to health. They also offer plants used in traditional and modern medicine. Sustainable forest management ensures these resources remain available and that forests continue to benefit human health.

SAQ II.

(a) Briefly explain the term "sustainable forestry."

(b) Which SDG is directly linked to climate action?

(c) Name two forest management practices.

(d) Give some examples of the use of technology in monitoring of forests.

(e) Match the columns

	Column I		Column II
1.	Selective Logging	(i)	Medicinal plants, honey, and bamboo
2.	REDD+ initiatives	(ii)	Instead of clear-cutting, only mature trees are harvested, preserving younger trees and biodiversity.
3.	Non-timberproducts	(iii)	A sustainable forestry practice to help reduce emissions from deforestation and forest degradation.
4.	Watershed protection	(iv)	Prevents soil erosion
5.	Agroforestry	(v)	clean air, water filtration, soil fertility and stability, pollination, climate regulation
6.	Forest ecosystem services	(vi)	Combines forest trees with agriculture and / or livestock.

10.7 Summary

Forestry is the science, art and practice of managing and using forests and related tree resources for economic, environmental, and social benefits. It involves activities like afforestation, reforestation, sustainable harvesting, and conservation. Forestry plays a crucial role in plant biodiversity conservation, as forest ecosystems are among the most diverse on Earth, supporting approximately 80% of terrestrial species, including many plants, animals, fungi, and microbes. They support biodiversity in different ways–by providing habitat for wildlife, regulating climate and water cycles, maintaining genetic diversity and preventing land degradation.

Effective forestry management helps maintain biodiversity, ecosystem services, ensures the sustainable use of forest resources while maintaining ecological balance and provides for resilience against climate change. Forestry is closely linked to multiple Sustainable Development Goals (SDGs) as forests contribute to environmental health, economic stability, and social well-being. These SDGs are: SDG 15 (Life on Land)–protecting ecosystems and preventing deforestation; SDG 13 (Climate Action)–forests absorb CO_2, mitigating climate change; SDG 6 (Clean Water): forests regulate watersheds and prevent erosion; and SDG 8 (Decent Work & Economic Growth) --forestry provides jobs in sustainable industries.

10.8 Terminal Questions

I. Select the correct answer.

(a) Why is forestry important for plant biodiversity conservation?

(i) It provides timber and wood products.
(ii) Forests create habitats that support diverse plant species.
(iii) Forests reduce the need for other natural resources.
(iv) It promotes urban development.

(b) How do forests help protect endangered plant species?

(i) By promoting recreational activities in forest areas.
(ii) By providing isolated, controlled environments with minimal human disturbance.
(iii) By increasing soil erosion.
(iv) By removing invasive species.

(c) Which of the following best describes how forestry management contributes to biodiversity conservation?

(i) By maximizing timber yield for economic gain.
(ii) By clearing land for agricultural use.
(iii) By removing native species to make room for exotic plants.
(iv) By implementing practices that ensure the protection of rare plant species and maintain ecosystem balance.

(d) Whatis a key forestry strategy to maintain plant biodiversity in forests?

(i) Selective logging to reduce habitat disruption.
(ii) Monoculture planting for higher productivity.
(iii) Intensive use of pesticides to protect plants.
(iv) Introduction of non-native species to increase diversity.

(e) How do forests contribute to soil health, which is essential for plant biodiversity?

(i) They prevent the accumulation of organic matter in the soil.
(ii) Forest trees and vegetation cover help prevent erosion and enhance nutrient cycling.
(iii) Forests prevent water infiltration into the soil.
(iv) They increase the frequency of soil disturbances.

II. Decide whether the following statements are 'True' or 'False.'

(a) Deforestation has little impact on biodiversity.

(b) Forests play a vital role in regulating water cycles.

(c) Maximizing timber production is a primary goal of sustainable forestry.

(d) Biodiversity loss often has negative impact on human health.

(e) Sustainable harvesting of non-timber products like honey is permitted in community based forest management.

10.9 Answer Key

SAQ I.

(a) Forestry is the science and practice of managing forests.

(b) 80%

(c) By providing habitat, regulating climate, and maintaining ecosystems.

(d) Afforestation is planting trees where none existed before, while reforestation is restoring lost forest cover.

SAQ II.

(a) Sustainable forestry seeks to ensure that forests remain productive and resilient while meeting the needs of both people and nature. In effect, selective logging while maintaining ecological balance are crucial. Through responsible management, forests can continue to provide economic, social, and environmental benefits for generations to come.

(b) SDG 13.

(c) Sustainable forestry, agroforestry

(d) Helps in early detection of forest fires and climate impacts. GIS, remote sensing, drones, and AI are used to track deforestation and illegal logging. Technology can help in early detection of forest fires and other climate impacts.

(e) Match the Columns I & II.
Ans. 1. (ii); 2. (iii); 3. (i); 4. (iv); 5. (vi); 6. (v)

Terminal Questions

I. (a) (ii); (b) (ii); (c) (iv); (d) (i); (e) (ii).

II. (a) False; (b) True; (c) False; (d) True; (e) True;

10.10 References & Further Reading

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Unit – 11 ❑ Plantation Strategies

Structure

11.1 Objectives

At the end of this unit, you should

- Have a clear idea about how plantation programmes are carried out;
- Know avenue trees suitable for planting at different sites ;
- Become familiar with ornamental plants;
- Know about plants suitable for nurseries and kitchen gardens; and
- The crucial role tree and other plantations play in perpetuating sustainable livelihoods.

11.2 Introduction

Plantations are established for a variety of reasons such as for use of timber or wood products; soil and water conservation; carbon sequestration; as avenue trees for providing shade; nurseries as repositories for distribution of ornamentals, locally available fruit and vegetable seeds and plantlets, and for afforestation and plantation programmes; as a ready source of easily grown fruits and vegetables in our backyards–the so-called ‘kitchen-gardens’; and so on. To what extent such growing land use change influences biodiversity, however, is still poorly understood. Considerable debate exists as to whether plantations are actually ‘green deserts’ or valuable habitat for indigenous flora and fauna. Avenue trees constitute a very important component of urban dwellings, roadsides and highways. Trees planted in parks and nature resorts, also contribute to greenery, and together with avenue trees mitigate to some extent heat-islands in densely populated cities, acts as carbon sink and improves the air quality index. Ornamental plants, in addition, brighten up our vicinities, whether on roadside or our gardens with a splash of colour. Nurseries serve as the source of seeds or plantlets, some of which may not be locally available. This helps perpetuate rare and important species. Kitchen gardens are a ready source of cheap, fresh, organic vegetables, fruits and of course flowers of different hues throughout the year.

In the following sections we shall examine more closely all these and discuss their significance in biodiversity conservation, human welfare and climate mitigation.

11.3 Plantations–significance and strategies

A number of studies suggest that the value of plantations for biodiversity varies considerably depending on whether the original land cover is grassland, shrub land, primary forest, secondary forest, degraded or exotic pasture, and whether native or exotic tree species are planted. Some of the studies show that plantations are most likely to contribute to biodiversity when established on degraded lands rather than replacing natural ecosystems, such as forests, grasslands, and shrublands; and further, when indigenous tree species are used rather than exotic ones. Furthermore, mixed species (Michelsen et al. 1996; Hartley 2002), broadleaved species are judged to be more effective. Some plantations also provide critical habitat for endangered species, thus increasing the need to integrate conservation goals into management strategies (Brockerhoff et al. 2001; Pejchar et al. 2005; Arrieta and Suarez 2006). Other researchers and land managers point to the utility of plantations as wildlife corridors, which, from a landscape ecology standpoint, may play an important role in sustainable development (Lindenmayer and Hobbs 2004). Still others suggest that, in terms of conserving species diversity, plantations may be a “lesser-evil” alternative to agriculture or urban development (Carnus et al. 2006; Brockerhoff et al. 2008). Without dwelling at length on such aspects, we restrict our focus in the present unit on the different avenue trees, ornamentals, nurseries and the species planted in our backyards as a ready source of nutritious and organic fruit trees and vegetables.

11.3.1 Different strategies adopted for plantation programmes

There exist different plantation strategies to enhance the green cover in cities, towns and villages. Tree plantation programmes have acquired a new dimension today with climate change posing a huge challenge to sustainable livelihoods. Loss of biodiversity, genetic erosion of our crops and drastic change in land use patterns accompanying urbanization, and a plethora of development projects pose a serious threat to human welfare. Afforestation programmes and protection of forest cover as discussed in Unit 10, though crucial is not sufficient. The air quality indices in cities and urban settlements have worsened. Particulate matters in the atmosphere have risen sharply. Our country has the dubious distinction of having most polluted cities in the world. In this context, planting of avenue trees on roadside, ornamental species in gardens, parks and places of residence draws pollinators and enhances beauty. Nurseries are a repository of local plants suitable for planting, whether on the roadsides or kitchen gardens. Species ideally suited for plantation programmes have been discussed in the following sections. We should try to stick to native species as far as possible instead of planting exotic species. Plantations should also be managed over longer time periods. Intensive site preparation should be kept to a minimum or best avoided. With these caveats, let us explore one by one, the plantation of avenue trees, ornamental species, followed by a brief account of nurseries and kitchen gardens.

11.3.1.1 Avenue Trees

Avenue is a wide road or main thoroughfare in a village, town or city usually bordered by trees. Avenue plantation is one of the important practices of growing trees along roads or canal side to increase, to provide shade to stray animals and travellers and add aesthetic value. In our country, avenue trees are known since the time of Emperor Ashoka. They were common even during Akbar’s rule. In the post-independent era, an important landmark was the *National Forest Policy of 1988*, which stressed the need for afforestation programmes. Planting avenue trees was also a component of social forestry programmes widely adopted throughout the country. We have already dealt with such programmes in a previous section.

Apart from the obvious utility of providing shade from sun and rain, it binds soil particularly along canal sides, helps retain soil moisture, increase precipitation, is a home to a variety of birds and animals, mitigates atmospheric pollution, act as carbon sinks to produce biomass and help maintain the ecological balance over a large area. However, avenue trees have often fallen victim to changes in land-use such as widening of streets for vehicular traffic, construction of flyovers, urban transport projects and so on. A number of studies have been conducted on the effect of automobile exhaust and particulate matter on roadside trees and shrubs such as Neem (*Azadirachta indica*) and *Polyalthia longifolia* (Debdaru). Trees most suitable for planting were discussed at length. At roadsides where Banyan, Peepul and Neem once dominated, we now see many new trees, some of them exotic. The qualities required in such trees in urban areas are broad-leaved species of compact habit and moderate height with a reasonably quick rate of growth and preferably with an evergreen spreading canopy. It must be sturdy too, should not easily shed its branches without warning, and must be able to withstand gusty winds. If it bears beautiful flowers, it adds to the beauty of the landscape. Fruit trees have the added advantage of attracting birds, animals and insect pollinators that aids in seed dispersal

Among the larger trees used for this purpose the commonest are perhaps–*Putranjivaroxburghii*, Debdaru (*Polyalthia longifolia*), the Spanish mahogany – *Swietenia mahagoni*; of these the first two are extremely suitable, but the third although excellent in other respects and one of the finest trees to be found in India, eventually attains a size that will probably be too big for roadsides. The Bakul –*Mimusopselengi*, and the Chhatim/ Saptaparni tree–*Alstoniascholarisare* excellent compact tree of fair size with dense evergreen foliage, the former is very frequently planted in streets as well as in gardens. The Desi Badam–*Terminalia catappa* has horizontal branches, a flat head and handsome bright green leaves–all of which make it suitable for street planting. Among the relatively smaller trees, there is Portia tree or *Hibiscus populneus*–a quick-growing, evergreen tree with a rounded bushy head, leaves similar to Peepul, and with yellow Hibiscus-like flowers. Where space is limited, a better choice can hardly be made. Another tree of rather similar habit, but slower growth, is the Alexandrian laurel–*Calophylluminophyllum*, with attractive evergreen leaves and pretty white flowers. Less common, though indigenous and often planted on roadsides, is the Karanja–*Pongamia pinnata* or Indian beech, a beautiful tree only marred by its diseased foliage with an ugly whitish colour. The Moreton Bay Chestnut *Castanospermum australe* is planted sporadically. With its extensive root system it is particularly useful in agroforestry, protects roadside canals, river banks and catchment areas but it is easily damaged by storms. Kurpa or *Lepisanthestetraphylla*, introduced from South India, has been planted in some numbers; it has denseevergreen foliage and a fairly compact habit.A few trees are commonly grown in streets for their flowers, and some of theroads in the residential areas are a magnificent sight in hot season when these are infullbloom. Unfortunately, however, few of them are really suitable for street planting, because they are either too delicate or fragile or they provide insufficient shade. The Gulmohor–*Delonix regia*, although planted frequently on roadsides, is reallyonly suitable for parks and gardens, because it has brittle branches and is easilyblown over. Some roads are largely lined with the Jarul–*Lagerstroemia speciosa*. Another species of Jarul is *Lagerstroemia thorellii*, introduced from Indo-China, has also been much planted, but it must be considered too small for an avenue tree. The Copperpod/Rusty shield Tree *Peltophorumpterocarpum* or kanakchura has beautiful evergreen foliage, compact growth and a wealth of lovely yellow flowers appearing in summerand is succeeded by attractive rust-coloured pods. Peltophoruminermeis also common. Another tree need special mention, the Rain Tree–*Albizia* saman, which was introduced into India at the end of 18th century, is well known. Many streets in the suburbs are lined with this huge, quick-growing majestic tree. Where there is space for its sprawling limbs it provides extensive shade. This tree should better be confined to parks and the larger gardens, or to the sides of country roads. (Benthall, 1984).


Mimusopselengi


Hibiscus populneus


Castanospermum australe


Lepisanthestetraphylla


Peltophorumpterocarpum


Terminalia catappa


Alstoniascholaris


Delonix regia

Calophylluminophyllum *Putranjivaroxburghii* *Polyalthia longifolia* *Albizia saman*

Figure 11.1 A few avenue trees

Table 11.1 A list of common avenue trees

Name	Family	Common name
DilIenia indica	Dilleniaceae	Chalta
Polythia longifolia	Annonaceae	Debdaru
Bombax ceiba L.	Malvaceae	Simul
Sterculia foetida	Malvaceae	Jangli badam
Pterygota alata	Malvaceae	Buddha nanikela
Kleinhovia hospita	Malvaceae	Rola
Pterosprmum acerifolium	Malvaceae	Kanak champa
Berrya cordifolia	Malvaceae	
Garuga pinnata	Burseraceae	Jum
Azadirachta indica	Meliaceae	Nim
Swietenia mahagoni	Meliaceae	Mahogony
Swietenia macrophylla	Meliaceae	Mahogony
Toona ciliata	Meliaceae	Tun
Aphanamixis polystachya	Meliaceae	Tikta raj
Schelichera aleosa	Sapindaceae	Kusum
Dimocarpus longam	Sapindaceae	Asphal
Mangifera indica	Anacardiaceae	Am
Myroxylon balsamum	Leguminosae	
Dalbergia sissoo	Leguminosae	Sisu
Castanospermam australe	Leguminosae	
Peltophorum pterocarpum	Leguminosae	Radhachura

Name	Family	Common name
Delonix regia	Leguminosae	Gul mohor
Colvillea racemosa	Leguminosae	
Cassia fistula	Leguminosae	Sonnalu, Bandarlathi
Cassia siamea	Leguminosae	Minziri
Albizia lebbeck	Leguminosae	Siris
Terminalia catappa	Combretaceae	Desi badam
Terminalia arjuna	Combretaceae	Arjuna
Syzygium cumini	Myrtaceae	Kala jam
Barringtonia acutangulla	Lecythidaceae	Hidjal
Lagerstroemia speciosa	Lythraceae	Jarul
Lagerstroemia thorelii	Lythraceae	Belati Jarool
Breonia chinensis	Rubiaceae	Kadam
Mimusops elengi	Sapotaceae	Bakul
Diospyros malabarica	Ebenaceae	Gad
Alstonia macrophylla	Apocynaceae	
Alstomia scholaris	Apocynaceae	Chatim
Millingtonia hortensis	Bignoniaceae	Akas nim
Kigelia pinnata	Bignoniaceae	The sussage tree
Tectona grandis	Lamiaceae	Sagun
Trewia mudiflora	Eupthorbiaceae	Pitali
Putranjiva roxburghii	Putranjivaceae	Jia pata
Bischofia javanica	Phyllanthaceae	
Trema orientalis	Cannabaceae	Jilan or Chikun
Artocarpus integer	Moraceae	Kathal
Ficus benjamina	Moraceae	
Ficus retusa	Moraceae	Jir
Ficus virens	Moraceae	Pakur
Ficus rumphii	Moraceae	Gaiasvattha
Ficus religiosa	Moraceae	Asvattha

Name	Family	Common name
Ficus benghalensis	Moraceae	Bot
Casuarina equisetifolia	Casuarinaceae	Belati jhau
Phoenix sylvestris	Arecaceae	Khajur
Borassus flabellifer	Arecaceae	Tal

SAQI. What qualities would you look for in avenue trees to be selected for planting in cities?

Activity 1. Make a list of 25 avenue trees (scientific and local names with family) close to your home. Point out the characters you find suitable for avenue trees. Base your answer on what you have learnt in Section 11.3.1.1.

11.3.1.2 Ornamental Plants

Ornamentals are all those plants which are cultivated with the main aim of being marketed and used for decorative purposes. The art and science of cultivating ornamental plants and flowers constitute floriculture, which plays a multifaceted role in promoting biodiversity and enhancing the health of ecosystems. With a few exceptions (such are the flowers of daylilies *Haemerocallisor* those of nasturtiums *Tropaeolum*) they are not edible, or at least, not used primarily as food sources. The ornamental plants are, and have always been, an indispensable part of human life: planted outdoors, they improve our environment, while in indoor use they contribute to our health, well-being and creativity.

Classification of ornamental plants

The range of ornamental plants is enormously wide and diverse; it includes practically the entire plant world. Their classification is not so much on a botanical (systematic) basis, butinstead is usually on a practical basis. According to the *method of cultivation* we can distinguish protected cultivation and open-ground cultivation. According to the application, the two main groups are plants used for *indoor decoration* and plants used for *outdoor decoration*. According to the season in which they grow, we have *spring, summer* or *winter ornamentals*; or we may consider them as *annuals, biennials, perennials*, and so on. Some people even have the *colour of the flowers* in mind – say, red or orange, yellow, pink or mauve, blue or lilac, white or cream-coloured or even the *attractive foliage* – while planting those (Figs. 11.2-11.7).

In most cases, ornamental plants grown under protection (in glasshouses, plastic houses, etc.) are used for indoor and those grown in the open (without protection) are for outdoor decoration. There are, however, many overlaps and exceptions. Bedding plants, for example, are produced in protected structures but the finished product is planted out in the open. Fewer ornamental crops are grown (at least partially) in the open and later used for indoor decoration. Such are the flower bulbs grown for forcing, or open-ground cut flowers. Other examples are some foliage plants (*Yucca, Dracaena, Cycas*, etc.) which are grown first to half-finished stocks in the tropics in open ground, and after being transported to the place of final destination, they are finished under glass to market-ready products for use in the temperate zone. Based either on the method of cultivation or on use, further subdivision of the two main groups is essentially the same, and goes as follows:

Protected cultivation (plants grown and used mainly for indoor decoration) are subdivided into :

- Cut flowers;
- Cut foliage;
- Pot plants (flowering pot plants and foliage pot plants);
- Bedding plants and balcony plants (annual, biennial and partially perennial ornamentals, grown under cover but used mainly outdoors);
- Open ground cultivation (plants grown mainly for outdoor decoration or as a starting material for protected cultivation);
- Woody nursery stocks (deciduous trees and shrubs, broadleaved evergreens, climbers, and conifers, grown either in the field or in containers);
- Herbaceous perennials (usually container- or pot-grown in perennial nurseries);
- Rose bushes (grown in specialized rose-nurseries);
- Flower bulbs, corms, and tubers (grown for forcing in greenhouses or for planting out in the open);
- Open-ground cut flowers and cut foliage;
- Dried flowers; and
- Some bedding plants, grown (or finished) in the open.

Gardening which was only an art and science in the earlier days has now emerged as a huge industry. With the importance and need of gardening in improving and conserving the environment being strongly felt now, the concept of landscaping and gardening is growing rapidly. Ornamental gardening and landscaping have expanded as a multi-faceted industry encompassing activities such as propagating and rearing ornamental plants, landscaping, production of growing media, pots and other accessories, etc., generating huge employment opportunities and simultaneously promoting activities that would improve the environment.

For centuries a number of beautiful plants, mostly of Indian origin but a few imported from other countries, have been cultivated for aesthetic reasons in Indian gardens, and since the early days of the nineteenth century a succession of enthusiastic European botanists and gardeners have added to the list of exotic plants grown in Kolkata, until today they hold perhaps one of the richest collections of tropical plants of horticultural interest to be found in the world. Very fine displays of ornamental trees may be seen in the Victoria Memorial Garden and in the grounds of the Tollygunge club, as well as in the Royal Agri-Horticultural Garden and, of course, in the famous Royal Botanic Garden at Shibpur. Apart from many rare kinds found only in these collections, a complete list of the trees cultivated in private gardens around and about Kolkata would certainly include nearly all the species described in this book and probably a good many more as well. To attempt a complete account of all these species is clearly impossible here and all that can be done is to mention some of the commonest and the most striking.

The following have red or orange flowers (Fig. 11.2):

Bombax ceiba (Simul) - The silk cotton tree. A tall deciduous tree with large crimson flowers among the bare branches, seen in early spring,

Erythrina variegata (Palita mandar) - A small tree or a shrub, bearing clusters of crimson flowers in early spring, before the leaves appear.

Butea monosperma (Palas)- “The flame of the forest”. An ungainly tree with large leaves, bearing in early spring, masses of scarlet flowers with brown velvety calyces.

Delonix regia (Gulmohor) - “The gold mohur”, a spreading tree with feathery leaves, bearing magnificent red or orange flowers at the end of the hot weather.

Colvillea racemosa - A rather rare relative of the last; bears tight clusters of dull orange flowers in August and September.

Saraca indica (Asoka) - A low spreading evergreen tree, bearing in the hot months small masses of crimson, orange, or yellowish flowers, close to the branches.

Brownea coccinea (Mountain Rose) - A low tree with large dense clusters of bright red flowers seen at the end of hot season and during the rains.

Amherstia nobilis (Pride of Burma, Urbasi) - A low tree bearing during summer months, magnificent pendulous sprays of scarlet and yellow flowers.

Callistemon lanceolatus (Bottle brush tree) - A small evergreen tree with very narrow pointed leaves and red flowers arranged in cylindrical spikes near the ends of the twigs.

Cordia sebestena (Geiger tree) - A low evergreen shrub or tree, with small clusters of orange-red flowers at the ends of twigs and found blooming throughout the year.

Spathodeacampanulata (Rudrapalash) - The African tulip-tree. A fairly tall evergreen tree blooming in early spring, majestic, large crimson flowers in compact clusters at the ends of the branches, an exotic from West Africa.

Bombax ceiba *Erythrina variegata* *Butea monosperma*

Colvillea racemosa *Cordia sebestena* *Spathodea campanulata*

Figure 11.2 Red-Orangecoloured ornamental flowers

The following have pink or mauve flowers (Fig. 11.3):

Hibiscus mutabilis (Sthalpadma) - The changeable rose. A small tree or shrub with broad, lobed leaves and large flowers, which, in the typical variety, open pure white in the morning and fade through pink to deep crimson in the evening; other varieties remain pink throughout.

Kleinhoviahospita (Bola) - A fairly tall evergreen tree with broad leaves, bearing small pink flowers during the late rainy season.

Sesbania grandiflora (Bak phul). A small quick growing tree, bearing large pink or white flowers from September to April.

Pongamia pinnata (Karanja). The Indian beech. A middle-sized, nearly evergreen tree with shining, bright green leaves and rather inconspicuous, dull pink or mauve flowers, born in May or June.

Gliricidia sepium (Saranga). A small tree bearing pale pink or almost white flowers in dense clusters scattered along the otherwise bare branches in early spring

Millettia peguensis (Tuma). A very pretty little deciduous tree with a rounded crown and drooping part of the hot season.

Cassia javanica (Burmese Shonalu Ful). A small spreading tree bearing pink and white flowers during the hot season.

Bauhinia variegata (Rakta kanchan). A small tree with leaves shaped like a camel's hoof-print, bearing in the early spring large white, pink, or purplish flowers on the bare branches.

Bauhinia purpurea (Deva kanchan). A tree similar to the last but bearing its flowers among the leaves at the end of the rains.

Lagerstroemia speciosa (Jarul). A tall tree with leaves in opposite pairs, bearing large flowers in open clusters at the ends of the branches in April and May. The common form has lilac flowers but there are varieties with pink and cerise flowers.

Lagerstroemia thorelii (Belati Jarool). A tree very similar to the last but smaller in all its part and bears mauve or pale purplish flowers during the rains.

Hibiscus mutabilis *Sesbania grandiflora* *Gliricidia sepium* *Cassia javanica*

Bauhinea purpurea *Milletiapeguensis* *Pongamia pinnata* *Kleinhoviahospita*

Figure 11.3 Pink or mauve–coloured ornamental flowers

Cochlospermumreligiosum *Brya ebenus* *Acacia auriculiformis* *Cascabelathevetia*

Figure 11.4 Bright yellow-flowered ornamental trees

Lagerstroemia speciosa *Jacaranda mimosifolia* *Lagerstroemia thorelli* *Jacaranda obtusifolia*

Figure 11.5 Blue or lilac-coloured ornamental trees

Millingtonia hortensis *Nyctanthes arbor-tristis* *Ervatamia divaricata* *Gardenia jasminoides*

Figure 11.6 Predominantly white or cream-coloured ornamental trees

Caesalpinia violacea *Corymbia citriodora* *Grevillea robusta* *Araucaria cunninghamii*

Figure 11.7 A few trees grown chiefly for their handsome foliage

The following have bright yellow flowers (Fig. 11.4):

Cochlospermumreligiosum (Sonali Simul) The yellow silk-cotton. A small tree with broad, lobed leaves, bearing large yellow flowers on the bare branches early in March.

Thespesia populnea (Paras). The Portia tree. A middle sized, evergreen tree with leaves shaped rather like those of the Peepul, and yellow, hibiscus-like flowers which fade to dull purple.

Brya ebenus. A low, slender, evergreen tree, or a shrub, with very small dark green leaves grouped in pairs, and scented orange flowers borne throughout the hot weather and rains.

Peltophorumpterocarpum (Copperpod / Iron shield). An evergreen tree of moderate size bearing yellow flowers in large clusters at the ends of the branches during the hot season.

Cassia fistula (Amaltas, Bandarlathi, Golden Shower). “The Indian laburnum”. A small deciduous tree bearing beautiful pendulous sprays of yellow flowers during March.

Cassia glauca. An evergreen shrub or a small tree, bearing numerous small clusters of yellow flowers at most seasons; the leaves are of a rather bluish green.

Cassia multijuga. A beautiful shrub or a small tree with bright green leaves and a rather straggling habit; the flowers are borne in large clusters at the ends of the branches in October or November.

Acacia auriculiformis (Akashmoni). A medium-sized evergreen tree with drooping twigs and minute yellow flowers combined in small spikes; the flowers are produced at intervals almost throughout the year.

Acacia farnesiana. A small thorny tree or a shrub with minute yellow flowers joined in small spherical heads; much like the common babul (Acacia arabica Willd.), but the flowers are scented. Blooms from June to February. Not very common.

Cascabelathevetia (Kolke phul). "The yellow oleander". A small spreading evergreen tree with very narrow leaves and large, yellow, pinkish, or whitish flowers borne almost all the year round.

Tecoma stans (Chandaprabha). An evergreen shrub or small tree bearing tubular yellow flowers in small clusters throughout the hot weather and rains.

The following have blue or lilac-colouredflowers (Fig 11.5):

Lagerstroemia speciosa (Jarul). The common variety of this tree has lilac-coloured flowers. It is a tall tree, though it often blooms when only about 15 feet high. The flowers appear in April and May.

Jacaranda obtusifolia. A medium-sized, deciduous tree with fern-like leaves and numerous pale-violet flowers borne in clusters along the bare twigs, mostly in February and March.

Jacaranda mimosifolia (Neelkantha)- A tree similar to the above but taller, with more finely divided leaves, and flowering later in March and April, or even later.

The following have flowers that are predominantly white or cream-coloured (Fig. 11.6):

Muntingiacalabura (The Chinese cherry) - A small, spreading, evergreen tree with pointed leaves, which are silvery beneath, with small white flowers, and cherry-like fruits.

Murraya paniculata (Kamini)- An evergreen shrub or small tree with dark green leaves and short clusters of scented white flowers.

Gardenia jasminoides (Gandharaj) - An evergreen shrub or small tree with dark green leaves and short clusters of scented white flowers.

Plumeria rubra (Gorurchampa) - The frangipani. A small deciduous tree with large, dark green leaves and soft, thick twigs; the tubular white and yellow flowers are borne at the ends of the twigs throughout the hot weather and rains.

Ervatamiadivaricata (Tagor) - An evergreen shrub or small spreading tree with narrow shining leaves and numerous white flowers, scented at night, borne almost throughout the year. Some varieties have flowers with yellow eyes and others have "double" flowers.

Nyctanthes arbor-tristis (Parijat tree) - A charming and much-revered flowering tree with much cultural and religious importance in South Asia, particularly in India. It has delicate and highly fragrant white flowers that bloom at night, releasing a sweet and captivating aroma. The deciduous tree grows only up to 4 metres and is popularly grown in tropical and subtropical regions of India.

Holarrhenaantidysentrica (Kurchi). The Easter tree. A small deciduous tree bearing creamy-white, scented flowers on the bare twigs in March and April.

Millingtonia hortensis (Akash Neem) - The Indian cork tree. A tall tree with corky bark, nearly vertical limbs and drooping twigs; the long, tubular, white, scented flowers appear in November and December.

There are several other species and cultivated varieties, some of which have red or yellow flowers, or various combinations of pink, yellow, and white.

The following trees are grown chiefly for their handsome foliage (Fig. 11.7):

Polyalthia longifolia (Debdaru). A variety of the common debdaru with short drooping branches giving the tree a pillar-like outline resembling that of a Lombardy poplar.

Caesalpinia violacea. A low evergreen tree with very graceful foliage and slender, spreading branches; it occasionally bears small clusters of yellow flowers.

Haematoxylum campechianum (The logwood tree). A low spreading tree with delicate foliage not unlike that of the last. It bears small, pale yellow flowers from January to March.

Albizzia richardiana. A very beautiful, lofty, evergreen tree with smooth bark, a few gradually branches, forming a graceful, rounded crown.

Corymbia citriodora (The lemon-scented eucalypt). A fairly tall tree with a slender trunk with distinctive bark, a few slender branches, and sparse foliage consisting of narrow, pointed leaves, highly scented when rubbed.

Grevillea robusta (Rupasi) - A fairly tall tree with a slender outline and fern-like leaves, dark green above and silvery-grey beneath.

Araucaria columnaris (Christmas Tree) -- A tall tree with stiff, dark green foliage consisting of thorn-like leaves crowded on green twigs.

Araucaria cunninghamii (Christmas Tree) - A tall tree rather with softer, more cypress-like foliage.

Thuja orientalis (Jhau) - A dense evergreen shrub or small tree, often pyramidal in shape, with flat fern-like foliage.

In conclusion mention must be made of the various *Cycas* species and palms that constitute an important part of the ornamental vegetation. Previously, indigenous palms were much grown in Indian parks and gardens but they have now been almost entirely replaced by their more graceful exotic allies, e.g. *Roystonea regia, Dypsislutescens, Liquala spinosa, Coryphasp., Sabal* sp., etc. (Benthall, 1984).

SAQ II. What is the utility of ornamental plants?

11.3.1.3 Nursery

A *nursery* is a place or a facility where plants are propagated and grown to a desired size, for transplantation, as stock material for budding and grafting, for use in the plantations/fields or for sale. Some nurseries are retained for the propagation of native plants to restore the environment. They often play a crucial role in sustainable agriculture by providing healthy seedlings and plants for reforestation, agroforestry and urban greening. Usually however, the plants concerned are used for gardening, forestry, or conservation biology.

Nursery programmes can be aimed at mitigating many of the factors that are damaging our biological resources. Plants and/or seeds can be used for restoration and improvement of damaged or lost habitats. Tree improvement practices and subsequent nursery production can reduce harvest rotation time frames and create sustainable harvesting schedules.

Raising a nursery – Site selection is important to raise a nursery. For this, a sunny place with fertile deep soil preferably sandy loam with good drainage is ideal. The site once used is left fallow before it is again used, to avoid soil sickness. If the old soil is used, it should be treated with fumigants before planting seedlings. Rotational cropping combined with fallow system prevents several soil problems. In order to obtain a layout for the nursery, provisions should be made for seedbeds, nursery beds, transplant beds, pot yard, packing yard. The ratio between the surface area for seedbed and transplant bed is 1 : 20 or 25. Mother trees block is the most important component in the nursery. A record of the plants propagated from each of the mother tree must be maintained by keeping a separate register. Certain factors need to be considered. These include selection and location of site, soil type, irrigation facilities, labour availability and so on.

Let us sum up the role plant nurseries play in biodiversity conservation and sustainable livelihood. They are :

Propagation of native species – nurseries work with conservation organizations to grow and supply native plants for reforestation, habitat restoration, and conservation projects.

Reduction of harvest rotation – nursery production can create sustainable harvesting schedules and reduce harvest rotation.

Protection of rare and endangered plants – nurseries can help protect rare, endangered and threatened medicinal plants.

Conservation of traditional knowledge – nurseries can help preserve traditional knowledge and practices associated with medicinal and other useful plants.

As a component of Integrated Pest Management – to reduce the use of chemical pesticides.

Promotion of organic cultivation – to use natural fertilizers and compost.

Education of the community – nurseries can provide opportunities for community engagement and education, such as seedling production, tree planting campaigns and environmental education programmes.

Raising awareness – such activities can raise awareness about climate change, the importance of forests, and sustainable land management practices.

11.3.1.4 Kitchen Garden

Kitchen or home gardens have been an integral component of family farming and local food systems for centuries, facilitating adaptation and domestication of plants to extreme or specific ecological conditions. They are a very convenient, ready and cheap source of fresh, pesticide-free organic herbs, vegetables, and fruits, contributing to self-sufficiency and a nutritious diet. They promote sustainable livelihood, reduce grocery costs and encourage healthy eating. In this way kitchen gardens help reduce hunger and malnutrition and improve food security -- all important components of sustainability development goals. In addition, they provide opportunities to broaden the base of cultivated plant materials by harboring underutilized crop plants and crop wild relative species. You are fully aware that crop wild relatives contain a wide range of genetic diversity not available in cultivated crops.

You can start kitchen gardens in any place with abundant sunlight, from an open terrace or roof-top, a windowsill or south-facing window to a small patch of land beside your house. The place should be cool and shady with direct sunlight for four to five hours a day. Try covering the plants to prevent them from scorching heat as it can damage the growth of your plants. From earthenware pots to buckets and bathtubs should serve your purpose. A medium-sized bathtub is ideal for growing plants like cabbages, cauliflowers, radish, and onions. If you use earthen or plastic pots, ensure that there is adequate space for the plants to grow and holes made for aeration and to prevent accumulation of water at the roots. Add in a few pieces of pebbles. Getting the right mix of soil with proper nutrients is important. Get some regular soil from a nursery or from gardens and add compost coco peat and natural manure to it. You may also add vegetable peels and other wastes to create your compost. Good organic fertilizers will help your plants flourish.

It is best to start with easily grown herbs and vegetables such as basil, common mint / pudina, parsley, lettuce, spinach, tomato, pepper, eggplants, lemon, beans, radish, gourd, cucumber, papaya, and so on. You will profit by visiting your local nursery and see the range of plants suitable for your kitchen garden. It is a good practice to store seeds in cool and dry conditions collected from fruits and vegetables you buy in the market. They may be sown at the appropriate time to perpetuate your garden.

Activity 2. Select *two* species each from the subfamilies of Fabaceae as Avenue Trees and *three* species from Solanaceae for your Kitchen Garden.

Activity 3. You have been provided with a small plot of open space measuring 4 metres × 2 metres. Select species for planting so that you have a regular supply of items for a balanced diet throughout the year. You may wish to discuss your planting strategies with your university counselor in addition to your local vendor at the market or *sabji mandi*.

11.4 Summary

Avenue trees are planted along roads, streets, highways, along sides of canals in cities, towns or in the countryside, to provide shade, greenery, and aesthetic value as the immediate objective. They vastly improve the air quality index; gives shelter to birds, insects and other animals; reduce particulate matters and pollutants in the ambient atmosphere, and considerably reduce heat islands in densely populated urban dwellings. Popular avenue trees in our roadsides include: the Neem, Banyan, Pipul, Gulmohar, Mango, Coral tree (*Erythrina indica*), Copperpod tree (*Peltophorumpterocarpum*), Putranjiva, Debdaru (*Polyalthia longifolia*), Spanish mahogany (*Swietenia mahagoni*), Bakul (*Mimusopselengi*), Chhatim (*Alstoniascholaris*, Desi Badam – *Terminalia catappa*, the Portia tree (*Hibiscus populneus*), Alexandrian Laurel (*Calophylluminophyllum*), the Rain tree and so on. The common characteristics sought in avenue trees include the canopy size and shade, compact habit, moderate height, robustness and resilience to storms, wide-leaved nature.

There exists a huge array of *ornamental plants* which are principally cultivated for their aesthetic value and trade. They may be classified according to the *method of cultivation*, the *season in which they grow*, the *principle method of propagation*, their *colour or attractive foliage*, their *chief utility* and so on. In most cases, ornamental plants grown under protection in glasshouses, green houses and indoor gardens. Some of them are grown in the open (without protection) mainly for outdoor decoration. Gardening has fuelled a huge industry. The concept of landscape gardening has captured the popular imagination. The number of popular ornamentals is vast. Rose (for their beauty, variety and cultural practice), Dahlia, Marigold, Hibiscus, Zinnia, Carnation (all of which brightens up gardens, parks and homes), Tulips (bright and colourful, a perfect choice for gardens in springtime), Lavender (for their fragrance and soothing properties), orchids (exotic and elegant, often used in floral arrangements) – the list is vast.

Nurseries are facilities where plants are propagated and grown to a transplantable size. They play a crucial role in sustainable agriculture by providing healthy seedlings and plants for reforestation, agroforestry, and urban greening.

Kitchen gardens are small plots where vegetables, herbs, and fruits are grown for household consumption. They provide fresh produce, reduce grocery bills, and promote healthy eating. For starting a kitchen garden it is best to begin with easily grown herbs and vegetables such as basil, common mint / pudina, parsley, lettuce, spinach, tomato, pepper, eggplants, lemon, beans, radish, gourd, cucumber, papaya, and so on.

11.5 Terminal Questions

(a) State the reasons why you feel afforestation is important?

(b) Briefly state the significance of plantations in general.

(c) How do you normally classify ornamental plants?

(d) Briefly state how you would prepare to raise a plant nursery.

(e) Mention whether the following statements are 'true' or 'false':

(i) The primary purpose of growing ornamental plants is to improve the visual appeal of spaces and create a pleasant environment.

(ii) Afforestation plays a crucial role in ecological conservation, economic development, and human well-being.

(iii) Forests rapidly decrease groundwater levels.

(iv) Nurseries can protect rare, endangered and threatened medicinal plants.

(v) Your kitchen gardens must necessarily be a shady place with diffuse light.

11.6 Answer key

SAQ I. The qualities in question would include – broad-leaved species of compact habit and moderate height, a quick growth rate, spreading canopy, reasonably robust. Showy flowers and edible fruits in such trees would be an added bonus.

SAQ II. Ornamental plants are grown for decorative purposes. They enhance landscapes, provide shade, and improve air quality due to their lush foliage and vibrant flowers.

Terminal questions

(a) Afforestation is important in :

Combating Climate Change – Trees absorb carbon dioxide, helping to reduce greenhouse gas levels and mitigate global warming.

Preventing Soil Erosion – Tree roots bind soil, reducing the risk of erosion caused by wind and water.

Enhancing Biodiversity – Forests provide habitats for diverse species of flora and fauna, supporting ecological balance.

Improving Air Quality – Trees filter pollutants from the air, releasing oxygen and improving overall air quality.

Regulating Water Cycle – Forests help in maintaining rainfall patterns and replenishing groundwater levels by reducing surface runoff.

Providing Livelihood Opportunities – Afforestation supports industries like timber, paper, and non-timber forest products, benefiting local communities.

Reducing Desertification – Tree plantations in arid and semi-arid areas help prevent desert expansion and restore degraded land.

Aesthetic and Recreational Benefits – Forests enhance scenic beauty and provide spaces for tourism, adventure, and leisure activities.

Mitigating Natural Disasters – Forests act as natural barriers against floods, landslides, and storms by stabilizing land and reducing water flow speed.

Supporting Sustainable Development – Managed afforestation ensures a renewable supply of resources like timber, medicine, and fuelwood, reducing pressure on existing forests.

(b) See Section 11.3.

(c) See Section 11.3.1.2

(d) See Section 11.3.1.3

(e) 'True' or 'False' (i) True; (ii) True; (iii) False; (iv) True; (v) False.

11.7 References and Further Readings

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Unit – 12 ❑ Important Medicinal Plants

Structure

12.1 Objectives

At the end of the section, you should

- Have a clear idea about the philosophy of plant-based therapeutics as practiced in the East and the West;
- Appreciate the vast wealth of active principles present in plants
- Realise that plants were the primary source of a substantial amount of drug formulations and their subsequent synthesis;
- Have a clear idea about the major medicinal plants of our country;

- Know the active constituents of plants with therapeutic potential;
- Appreciate why conservation of biodiversity also protects as yet unknown plants and their products which may prove crucial in treatment of different communicable and non-communicable diseases and disorders.

12.2 Introduction

Medicinal plants have been and continue to be a cornerstone of human health and well-being for millennia, offering essential therapeutic benefits and contributing to sustainable livelihoods. With over 25,000 species used in traditional medicine systems, they form a critical part of healthcare strategies, particularly in regions with limited access to modern pharmaceuticals. Their bioactive compounds such as alkaloids, flavonoids, glycosides and terpenoids, serve as sources for modern drug development. For example, the synthesis of aspirin, paclitaxel (taxol) and artemisinin demonstrate how plant-based remedies have seamlessly transitioned into mainstream medicine. The importance or significance of medicinal plants spans healthcare, economic development, cultural preservation, and environmental sustainability. These plants not only offer therapeutic benefits but also hold cultural, economic, and ecological significance. Beyond healthcare, medicinal plants play a pivotal role in sustaining livelihoods. They are the foundation of traditional medicine systems like Ayurveda, Unani, and Siddha, which emphasize holistic approaches to health. These systems rely on the diverse pharmacopeia of plants such as *Withaniasomnifera* (Ashwagandha), *Azadirachta indica* (neem), and *Curcuma longa* (turmeric), all of which are widely used for their therapeutic properties in treating a variety of ailments. The global market for medicinal plants and herbal products is projected to surpass $200 billion by 2030. This growth is fueled by increasing consumer preference for natural and organic treatments, rising chronic disease prevalence, pandemics and renewed interest in traditional medicine systems. Medicinal plants are integral to cultural traditions and indigenous knowledge systems. Preserving this knowledge is vital for maintaining cultural identity and understanding potential novel uses of plants in modern medicine. Medicinal plants contribute to biodiversity conservation and ecosystem health. Initiatives like agroforestry and community-based conservation projects integrate medicinal plants into sustainable farming systems, supporting livelihoods while preserving natural habitats. The cultivation of plants such as neem and turmeric (*Curcuma longa*) among others, in sustainable agricultural practices, exemplifies their dual role in ecological balance and income generation. Despite their importance, medicinal plants face threats from overharvesting, habitat destruction, and climate change. Strengthening regulations, promoting sustainable cultivation, and supporting community-led conservation efforts are crucial for safeguarding these resources for future generations.

12.3 Role of medicinal plants in traditional and modern medicine

Medicinal plants are the pillar of both traditional and Western medicine, bridging ancient practices and modern scientific advancements. Their bioactive compounds serve as remedies in traditional healthcare systems and as critical ingredients or templates in modern pharmaceuticals. Here, we examine their contributions to these fields.

12.3.1 Medicinal Plants in Traditional Medicine

Usage in culture and history for health solutions

Traditional medicine systems such as Ayurveda, Unani, Siddha, Traditional Chinese Medicine (TCM), and African ethnomedicine rely extensively on medicinal plants. These systems have developed over millennia, utilizing the natural therapeutic properties of plants which have minimal side effects and used extensively to treat a wide spectrum of illnesses. Medicinal plants in these systems address chronic diseases, pain, inflammation, insect bites and other forms of injury, and mental health, alongside boosting the general wellness. They often employ plant extracts in combination for synergistic effects. The preparations usually come in the form of powder, decoctions or syrups. The different traditional medicine includes the following :

- **Ayurveda.** From ancient times to the present, Ayurvedic medicine as documented in the *Atharva Veda*, the *Rig Veda* and the *Sushruta Samhita* has used hundreds of herbs and spices. Having originated in India around 1500 BCE, Ayurveda employs a wide range of medicinal plants like Ashwagandha (*Withaniasomnifera*) for stress relief, neem (*Azadirachta indica*) for a wide range of uses, *Curcuma longa* (turmeric) for inflammation and so forth. It emphasizes holistic health relying largely on its philosophy of panchavootam (the five ubiquitous elements earth, water, fire, air and sky/space) combining to form *tridosha* or energies: *vayu* (space and air), *pitta* (fire and water) and *kapha* (water and earth). According to Ayurveda, each *dosha* has its own characteristics, functions and qualities that affect our physical, mental and emotional health. The goal is to maintain or restore the harmony of the *doshas* according to one's prakriti (the unique constitution of every person).

- **Unani Medicine.** Its origin is in the doctrines of the ancient Greek physicians Hippocrates and Galen, later developed and refined through systematic experiment by the Arabs, most prominently by the Muslim scholar-physician Avicenna. It embodies the Empedoclean theory of four *elements* - air, water, fire and earth; four proximate qualities (*kayfiyat*) i.e. Hot, Cold, Wet and Dry. Humans, as also drugs or diet, have a unique temperament (*mizäj*): Hot & Dry, Hot & Wet, Cold & Wet and Cold & Dry. Here, plants such as *Nigella sativa* (black seed) is used for immune enhancement, *Cassia angustifolia* (senna) for digestive health, *Malva sylvestris (khubazi)* for its antibacterial, anti-inflammatory, antioxidant, and hepatoprotective properties, *Trigonella foenum-graecum* seeds used to treat backache, diarrhoea, dysentery, flatulence, and muscle diseases and so on.

- **Siddha Medicine.** It is an ancient Indian medical system practiced mostly in South India, particularly Tamil Nadu and parts of Kerala. Siddha medicine aims to restore balance in the body's three forces or humor and five elements (panchavootam). It also uses the wide-ranging properties and constituents of plants for holistic health remedies, as with Indian Bdellium (*Commiphora wightii*, Guggul) to manage obesity and cholesterol levels; support joint health and treats arthritis and for their detoxification and anti-inflammatory effects; Indian Sarsaparilla (*Hemidesmus indicus*) as a blood purifier, to treat urinary tract infections and kidney disorders, and for their anti-inflammatory and detoxifying properties.

- **Traditional Chinese medicine (TCM).** Thousands of years old, it holds that a vital force of life called *qi*, surges through the body and its imbalance can cause disease and illness. This imbalance is most often attributed to an alteration in the opposite and complementary forces that make up the *qi*, which are called *yin* and *yang*. The Chinese pharmacopoeia, the *Shennong Ben Cao Jing* records a number of herbal medicines such as hemp, ephedra for respiratory ailments, chaulmoogra for leprosy. This was expanded in the Tang dynasty *Yaoxing Lun*. Herbal remedies in TCM commonly uses *Panax ginseng* (Asian ginseng) roots to boost vitality, *Codonopsis* roots for general well-being and digestive health, *Astragalus* roots to boost immune system and alleviate oxidative stress, *Ephedra sinica* for respiratory conditions, and so on.

- **African ethnomedicine** is deeply rooted in indigenous knowledge, and use a variety of medicinal plants to address a broad range of health conditions. Here too, plants are commonly used in a holistic manner that incorporates spiritual, physical, and emotional well-being. Examples include: the African Aloe (*Aloe ferox*) to treat burns, wounds, and eczema, as a laxative and to boost immunity.

Challenges

However, there exist some *challenges* in integrating traditional knowledge of medicinal plants with modern scientific research. They include

- Language barriers and cultural differences in communicating traditional knowledge.
- Lack of standardized methods for collecting, processing, and analyzing plant materials.
- Intellectual property rights and fair benefit-sharing agreements with indigenous communities.
- Difficulties in conducting rigorous scientific studies on complex traditional formulations.

12.3.2 Ethnopharmacology

Ethnopharmacology, through the description of the beneficial effects of plants, has provided an early framework for the therapeutic use of natural compounds. It is defined as the interdisciplinary scientific exploration of traditionally employed indigenous drugs and biologically active agents. It involves a cross-cultural study of plants, animals, fungi, or other naturally occurring resources used as medicines by ethnic and cultural groups. The major focus of the field has been on discovering drugs based on the therapeutic use of plants by indigenous people. In this unit you will come across numerous examples of such plant-based drug discovery – aspirin, digitoxin, ephedrine, atropine, theophylline, cocaine, morphine, caffeine and so on – in use for thousands of years before being scientifically analyzed and introduced into modern medicine. Knowledge about quite a few of the traditional herbal medicines has come from received knowledge (often by oral tradition) from indigenous communities. Thus, artemisinin isolated by Chinese scientists in 1972 from *Artemisia annua* (sweet wormwood), used to treat falciparum malaria were known to Chinese herbalists for more than 2000 years. Similarly, the alkaloid Huperzine A was isolated in 1986 from the lycophyte *Huperzia serrata*, which had been in use in Chinese folk medicine for treatment of dementia, schizophrenia and similar disorders. The discoveries of these two drugs from knowledge of Chinese traditional medicine are examples of application of ethnopharmacology. However, modern ethnopharmacology incorporates the computational and experimental validation of active natural compounds, prior to the detection of ethnopharmacological evidence.

You may be already familiar with the discipline *ethnobotany* – which studies the complex relationships between cultures and their use of plants, focusing primarily on how plants are managed, used, and perceived across human societies. You can see that its concern is related to ethnobotany. There is a difference though. Ethnopharmacology involves interdisciplinary scientific exploration of traditionally employed indigenous drugs and biologically active agents – obviously a broader focus on exploring biologically active agents from plants, minerals, animals, fungi, and microbes. In both the fields however, the presentation of the use of extracts in a given disease is the first step, without investigating any potential causal relationship with their active constituents or compounds.

12.3.3 Economic and social role

In many rural and indigenous communities, in addition to affordable healthcare solutions medicinal plants sustain livelihoods through their cultivation and trade, particularly in developing countries. The trade of plants like neem (*Azadirachta indica*), basil (*Ocimum sanctum*), and aloe vera (*Aloe barbadensis*) contributes to local and global economies. The global Ayurveda market is estimated at over $10 billion, driven by increasing interest in herbal remedies and wellness products. The global reach of Unani medicine has expanded, with its products forming part of a $3 billion herbal medicine industry. Siddha medicine, while smaller in scale compared to Ayurveda and Unani, it contributes to local economies through the cultivation and trade of these plants.

SAQ I. *Match the Columns*

Column A		Column B
(a) Ayurveda	(i)	Sweet wormwood
(b) Chinese pharmacopoeia	(ii)	Ancient Indian system of medicine, especially in South India |
(c) Ethnopharmacology	(iii)	Ancient Indian system of medicine

(d) Siddha (iv) Study of how people use plants for medicine

(e) Artemisinin (v) Shennong Ben Cao Jing

12.4 Medicinal Plants in Western Medicine

The role of medicinal plants in Western Medicine has been significant throughout history, with many modern pharmaceuticals derived from natural compounds found in plants. In around 60 CE, the Greek physician Pedanius Dioscorides, working for the Roman army, documented over 1000 recipes for medicines using over 600 medicinal plants in *De materia medica*. The book remained the authoritative reference on herbalism for over 1500 years, into the seventeenth century. Let us not forget that most botanists of the medieval period, well into the 18th century were herbalists – medical practioners who used medicinal plants for curing different ailments. While the focus on synthetic drugs in the 20th century led to a decline in plant-based medicine, there has been a resurgence of interest in recent years, with a growing body of research supporting the efficacy and safety of many herbal remedies.Here are several well-known examples of plant-based remedies that have transitioned into mainstream medicine, highlighting their therapeutic significance:

(i) **Artemisinin** (*Artemisia annua*) – Derived from sweet wormwood, artemisinin is a cornerstone treatment for malaria, particularly drug-resistant strains. Artemisinin-based combination therapies (ACTs) are globally recommended by the WHO for treating *Plasmodium falciparum* malaria.

(ii) **Aspirin** (*Salix alba*, willow bark) – The active compound salicin was isolated from willow bark and chemically synthesized into acetylsalicylic acid, now widely used as aspirin. Aspirin is a leading anti-inflammatory, analgesic, and blood-thinning agent, with applications in preventing cardiovascular diseases.

(iii) **Morphine and Codeine** (*Papaver somniferum*, opium poppy) – It contains the alkaloid morphine, extracted from the opium poppy, is one of the most effective pain relievers available. It remains a gold standard for severe pain management in medical settings, particularly for cancer and postoperative care. For mild-to-moderate pain, codeine is often used as a combined medication with acetaminophen or with an NSAID like ibuprofen. The drug is often available as a combination product with promethazine or an NSAID like salicylic acid for cough and cold. Codeine is often marketed in the form of tablets and syrups

(iv) **Quinine** (*Cinchona spp*.) – Quinine, obtained from the bark of the cinchona tree, was the first effective treatment for malaria. It paved the way for antimalarial drugs and continues to be used in some formulations for resistant malaria strains.

(v) **Paclitaxel (Taxol)** (*Taxus brevifolia,* Pacific yew) – Paclitaxel, derived from the bark of the Pacific yew tree, as also from the Common Yew *Taxus baccata*, is a chemotherapy drug for breast, ovarian, and lung cancers. It is still a critical treatment in oncology, with semi-synthetic derivatives now mitigating concerns about sacrifice of these precious species for obtaining sufficient dosage of the drug.

(vi) **Digoxin** (*Digitalis purpurea,* foxglove) – Extracted from foxglove, digoxin is used to treat heart conditions, particularly atrial fibrillation and heart failure. It has been a foundational medication in cardiology for over two centuries.

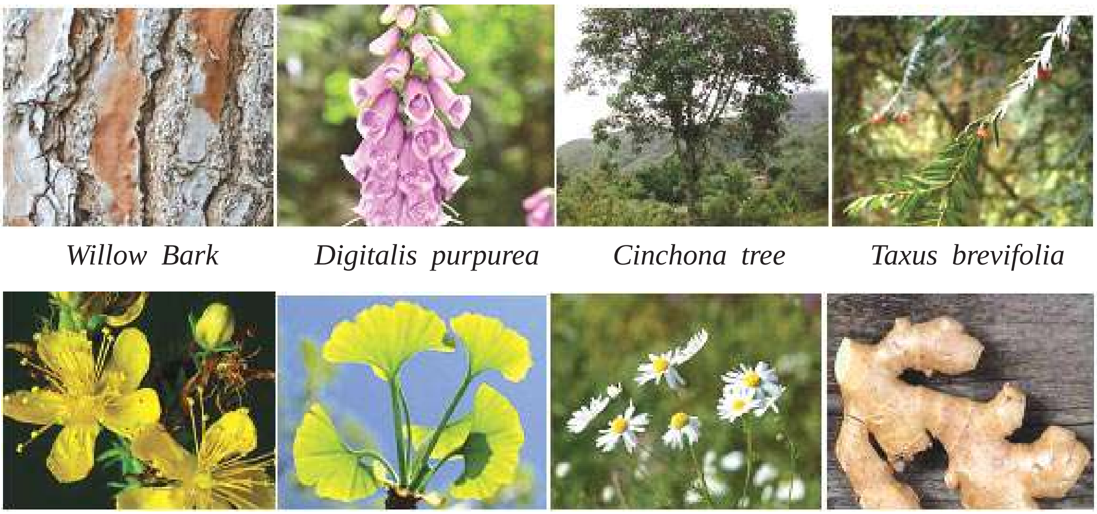
(vii) **Vincristine and Vinblastine** (*Catharanthus roseus,* Madagascar Rose periwinkle) – These alkaloids are used in chemotherapy for cancers such as leukaemia, Hodgkin's lymphoma, and breast cancer. They significantly improved survival rates in pediatric leukaemia and other malignancies.

(viii) **Ephedrine** (*Ephedra sinica*) – Derived from the *Ephedra* plant, ephedrine is widely used as a bronchodilator for asthma and as a nasal decongestant. It influenced the development of synthetic derivatives, such as pseudoephedrine, commonly found in cold medications.

(ix) **Reserpine** (*Rauvolfia serpentina*) – Extracted from the Indian snakeroot plant, reserpine was one of the first drugs used to treat hypertension and psychotic disorders. It revolutionized the treatment of high blood pressure and mental illness in the mid-20th century.

(x) **Atropine** (*Atropa belladonna,* deadly nightshade) – Atropine, derived from belladonna, is used to dilate pupils during eye exams and as an antidote for certain poisonings. It remains an essential drug in emergency and surgical medicine.

These examples illustrate how traditional remedies have laid the foundation for modern pharmacology, underscoring the importance of continued exploration of plant-based compounds in drug discovery.



Willow Bark *Digitalis purpurea* *Cinchona tree* *Taxus brevifolia*

Hypericum perforatum *Ginkgo biloba* *Matricaria chamomilla* *Ginger*

Figure 12.1. Common medicinal plants of immense value to Western Medicine.

12.5 Principal Indian Medicinal Plants

India has a rich heritage of medicinal plants that play a vital role in its traditional healthcare systems, such as Ayurveda, Siddha, and Unani. The following are a few examples of a large number of plants known for their therapeutic properties and widely used in treating various ailments.

1. Neem (*Azadirachta indica*)

Uses :

- Antibacterial, antifungal, and antiviral properties make it effective in treating skin conditions like acne, eczema, and psoriasis.
- Helps manage diabetes by lowering blood sugar levels.
- Used in oral health care for gum diseases and tooth decay.

Preparations : Neem oil, paste, and decoctions.

2. Tulsi (*Ocimum sanctum*)

Uses :

- Boosts immunity and helps treat respiratory disorders like colds, asthma, and bronchitis.

- Reduces stress and anxiety due to its adaptogenic properties.
- Known for its antioxidant and anti-inflammatory effects.

Preparations : Fresh leaves, herbal teas, and essential oils.

3. Turmeric (*Curcuma longa*)

Uses :

- Contains curcumin, the principal bioactive substance (curcuminoid), a highly pleiotropic molecule that exhibits antibacterial, anti-inflammatory, hypoglycemic, antioxidant, wound-healing, and antimicrobial activities which has powerful anti-inflammatory and antioxidant properties.
- Used to treat arthritis, digestive disorders, and skin conditions.
- Supports liver health and boosts immunity.

Preparations : Turmeric powder, pastes, and extracts.

4. Ashwagandha (*Withaniasomnifera*)

Uses :

- Acts as an adaptogen, reducing stress and enhancing physical stamina.
- Supports reproductive health and hormonal balance.
- Improves memory, focus, and overall cognitive function.

Preparations : Root powder, capsules, and herbal tonics.

5. Amla (*Phyllanthus emblica*)

Uses :

- Rich in Vitamin C, it boosts immunity and slows the aging process.
- Improves digestion and acts as a natural laxative.
- Enhances hair and skin health.

Preparations : Amla juice, powders, and as an ingredient in Chyawanprash.

6. Brahmi (*Bacopa monnieri*)

Uses :

- Enhances memory, concentration, and cognitive function.
- Reduces stress and anxiety by regulating neurotransmitters.

- Have anti-inflammatory properties beneficial for joint health.

Preparations : Leaf extracts, capsules, and herbal teas.

7. Ginger (*Zingiber officinale*)

Uses :

- Treats nausea, indigestion, and motion sickness.
- Known for its anti-inflammatory and pain-relieving properties, useful for arthritis and muscle pain.
- Helps alleviate cold and flu symptoms.

Preparations : Ginger tea, fresh root, and powder.

8. Shatamuli (*Asparagus racemosus*)

Uses :

- Supports women's reproductive health by balancing hormones and enhancing fertility.
- Acts as a galactagogue -- increasing breast milk production.
- Improves digestion and has adaptogenic properties.

Preparations : Root powder, syrups, and capsules.

9. Aloe vera (*Aloe barbadensis*)

Uses :

- Treats burns, wounds, and other skin conditions due to its soothing properties.
- Aids digestion and alleviates constipation.
- Boosts immunity and acts as a detoxifier.

Preparations : Aloe vera gel, juice, and creams.

10. Fenugreek (*Trigonella foenum-graecum*)

Uses :

- Regulates blood sugar levels and is beneficial for diabetes management.
- Enhances lactation in nursing mothers.
- Improves digestion and reduces cholesterol.

Preparations : Seeds, powders, and herbal teas.

11. Cinnamon (*Cinnamomum verum*)

Uses :

- Antioxidant and antimicrobial properties make it effective in treating infections.
- Regulates blood sugar and improves heart health.
- Aids in digestion and alleviates cold symptoms.

Preparations : Cinnamon bark, powder, and oil.

12. Sandalwood (*Santalum album*)

Uses :

- Known for its cooling and calming properties, it treats skin conditions like acne and blemishes.
- Used in aromatherapy to reduce stress and anxiety.
- Acts as an anti-inflammatory agent.

Preparations : Sandalwood oil and paste.

13. Arjuna (*Terminalia arjuna*)

Uses :

- Strengthens heart muscles and improves cardiac function.
- Lowers cholesterol levels and manages hypertension.
- Known for its antioxidant properties.

Preparations : Bark powder and decoctions.

14. Peepal (*Ficus religiosa*)

Uses :

- Treats respiratory and gastrointestinal conditions.
- Improves wound healing and skin health.
- Acts as an anti-inflammatory and antimicrobial agent.

Preparations : Bark, leaf extracts, and decoctions.

12.5.1 Selected Indian Medicinal Plants : Principal active constituents and uses

A detailed account of selected Indian medicinal plants with their principal active components and therapeutic uses follows.

1. Sarpagandha (*Rauvolfia serpentina*), Family Apocynaceae

Principal Active Components. Alkaloids : Reserpine, ajmaline, serpentine, and rauwolfine.

Uses : (a) *Hypertension :* Effective in managing high blood pressure.

(b) *Neurological Disorders :* Used as a sedative to treat anxiety, insomnia, and epilepsy.

(c) *Psychiatric Conditions :* Treats schizophrenia and other psychoses.

Preparations : Root extracts, powders, and tablets.

2. Kalmegh (*Andrographis paniculata*), Family Acanthaceae

Principal Active Components. *Diterpenoids* : Andrographolide and deoxyandrographolide.

Uses : (a) *Liver Disorders :* Acts as a hepatoprotective agent for liver detoxification.

(b) *Immune Support :* Enhances immunity and combats infections like cold and flu.

(c) *Fever Management :* Reduces fever, including those associated with malaria and dengue.

Preparations : Decoctions, capsules, and syrups.

3. Vasaka (*Justicia adhatoda*), Family Acanthaceae

Principal Active Components. *Alkaloids*: Vasicine and vasicinone; phenolics and essential oils.

Uses : (a) *Respiratory Disorders :* Relieves cough, bronchitis, and asthma due to its expectorant properties.

(b) *Bleeding Disorders :* Reduces internal and external bleeding, such as in haemorrhoids.

(c) *Antimicrobial :* Effective against respiratory infections.

Preparations : Leaf extracts, decoctions, and syrups.

4. Guduchi or Gulancha (*Tinospora cordifolia*), Family Menispermaceae

Principal Active Components : *Alkaloids* : Berberine, giloin, and tinosporin; *polysaccharides* and *diterpenoids*.

Uses : (a) *Immunity Booster :* Enhances immune function and combats recurrent infections.

(b) *Anti-inflammatory :* Beneficial in managing arthritis and joint inflammation.

(c) *Detoxification :* Supports liver and kidney health.

Preparations : Stem extracts, powders, and decoctions.

5. Chirayita (*Swertia chirayita*), Family Gentianaceae

Principal Active Components. *Xanthones* : Swertiamarin, mangiferin; *Alkaloids* and bitter *glycosides*.

Uses : (a) *Digestive Health :* Treats indigestion, loss of appetite, and dyspepsia.

(b) *Antipyretic :* Reduces fever, including malarial fever.

(c) *Skin Disorders :* Used in managing skin infections and conditions like eczema.

Preparations : Decoctions, powders, and herbal infusions.

6. Anantamool (*Hemidesmus indicus*), Family Apocynaceae

Principal Active Components : *Coumarins, saponins*, and *hemidesmin; Essential oils* and *tannins*.

Uses : (a) *Blood Purifier :* Detoxifies the blood and promotes skin health.

(b) *Urinary Health :* Treats urinary tract infections and kidney disorders.

(c) *Anti-inflammatory :* Reduces inflammation and manages arthritis symptoms.

Preparations : Root extracts, decoctions, and syrups.

SAQ II. Fill in the blanks :

(a) The compound ___________ found in willow bark is the precursor to aspirin.

(b) ___________ is the study of how people in different cultures use plants and other organisms for medicinal purposes, combining traditional knowledge with scientific investigation.

(c) Regulatory frameworks play a vital role in ensuring the ___________ and ___________ of herbal medicines.

(d) The primary active constituents in Rauvolfia serpentina are the alkaloids such as ___________ and _______.

(e) Swertia chirayita is a rich source of bitter __________.

(f) The primary active compounds in Andrographis paniculata are the ___________ ___________ such as andrographolide.

(g) Adhatoda vasica is a rich source of ___________ like vasicine and adhatodine.

(h) Tinospora cordifolia belongs to the family ___________.

12.6 Sustainable practices and Regulatory frameworks

Medicinal plants contribute to biodiversity conservation and ecosystem health. Initiatives like agroforestry and community-based conservation projects integrate medicinal plants into sustainable farming systems, supporting livelihoods while preserving natural habitats. The cultivation of plants such as neem and turmeric among others, in sustainable agricultural practices, exemplifies their dual role in ecological balance and income generation. Despite their importance, medicinal plants face threats from overharvesting, habitat destruction, and climate change. Strengthening regulations, promoting sustainable cultivation, and supporting community-led conservation efforts are crucial for safeguarding these resources for future generations.

Sustainable use and conservation of medicinal plants be ensured by

(i) Cultivation and domestication of medicinal plants to reduce pressure on wild populations.

(ii) Fair trade practices that support local communities and incentivize sustainable harvesting.

(iii) Conservation efforts to protect threatened plant species and their habitats.

(iv) Education and awareness programmes to promote responsible use of medicinal plants.

Regulatory frameworks have a definite role in ensuring the safety and efficacy of herbal medicines. They provide guidelines for

(i) Quality control of herbal products to ensure purity and potency.

(ii) Safety assessment to identify potential side effects and drug interactions.

(iii) Clinical trials to evaluate the efficacy of herbal medicines.

(iv) Labeling and marketing of herbal products to provide accurate information to consumers.

12.7 Summary

Medicinal plants bridge the gap between traditional and modern medicine, offering both economic and therapeutic value. While Western medicine benefits from their role in drug discovery, traditional systems like Ayurveda, Unani, and Siddha and various indigenous systems practiced among different communities through millennia are still witnessed in different parts of the world. These systems utilize whole plants or their parts, often in complex formulations, based on empirical knowledge passed down through generations. In this way, they continue to provide holistic healthcare solutions in remote places, among disadvantaged and poor sections of the community and at the same time sustain cultural values. To maximize the potential of such plants, sustainable harvesting practices, scientific validation, and equitable benefit-sharing with indigenous communities are believed to be essential. Much of this is a part of the discipline "ethnopharmacology." Modern medicine has benefited immensely from the study of medicinal plants. Many modern pharmaceuticals are derived from or inspired by plant compounds. For example, aspirin originated from salicin found in willow bark, and the cancer drug paclitaxel was discovered in Pacific yew trees. Scientists actively investigate plant extracts for potential therapeutic applications in areas like cancer, infectious diseases, and neurodegenerative disorders. Lately, innovative extraction technologies such as semi-bionic extraction, supercritical fluid extraction, microwave-assisted, ultrasonic-assisted, and enzyme-assisted extraction, molecular distillation methods, membrane separation techniques, new methodologies and instrumentation like HPLC-MS, LC-MS, GC-MS, NMR, and crystallography, alongside the development of biology, clinical and experimental medicine, have enabled the re-evaluation of the corpus of traditional knowledge, the determination of chemical components of plant extracts, the identification of active constituent(s), and the development of novel drugs.

India's diverse flora is the source of numerous medicinal plants with profound therapeutic benefits. Examples abound – Sarpagandha, Kalmegh, Vasaka, Chirayita, Brahmi, Anantamul – to mention a few. The wealth of medicinal plants in our sub-continent some of which with as yet unknown health benefits, holds much promise for future research – as valuable leads for drug discovery and development. Such plants are not only integral to traditional healthcare systems but also offer new ideas and clues for further research in modern medicine. The integration of all indigenous knowledge and traditional use of these plants into modern health-care systems, highlight their global significance.

12.8 Terminal Questions

1. What is the difference between traditional and Western medicine in their approaches to using medicinal plants?
2. How have medicinal plants contributed to the development of modern pharmaceuticals?
3. What are some of the challenges in integrating traditional knowledge of medicinal plants with modern scientific research?
4. What is ethnopharmacology, and how is it important for the study of medicinal plants?
5. State whether the following statements are 'True' or 'False'.

(a) Traditional medicine always relies on scientific evidence to support the use of medicinal plants.

(b) Western medicine has completely ignored the potential of medicinal plants.

(c) Ethnopharmacology is solely focused on documenting traditional knowledge without any scientific investigation.

(d) Cultivation of medicinal plants can help reduce pressure on wild populations.

(e) Regulatory frameworks are not necessary for herbal medicines as they are natural products.

(f) There are no known side effects or drug interactions associated with herbal medicines.

12.9 Answer key

SAQ I. (a)–(iii), (b)–(v), (c)–(iv), (d)–(ii), (e)–(i)

SAQ II. (a) Salicin; (b) Ethnopharmacology; (c) safety, efficacy; (d) reserpine, ajmaline; (e) glycosides; (f) diterpenoid lactones; (g) alkaloids; (h) Menispermaceae.

Terminal questions

1. Traditional medicine often relies on empirical knowledge passed down through generations, emphasizing holistic treatment and using plants in complex formulations. Western medicine, on the other hand, focuses on isolating specific compounds from plants and conducting rigorous scientific studies to understand their mechanisms of action.
2. Many modern drugs are derived from or inspired by compounds found in medicinal plants. For example, aspirin was originally derived from salicin, a compound found in willow bark. Other examples include digitalis (from foxglove) for heart conditions and paclitaxel (from yew trees) for cancer treatment.
3. Look up Section 12.3.1
4. Ethnopharmacology is the study of how people in different cultures use plants and other organisms for medicinal purposes. It involves interdisciplinary research, combining traditional knowledge with scientific investigation to understand the therapeutic potential of medicinal plants.
5. ‘True’ or ‘False’(a) False; (b) False; (c) False; (d) True; (e) False; (f) False

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Unit – 13 ❑ Fruits and Nuts

Structure

13.1 Objectives

From this unit, you get to know

- All the major fruits and nuts of the tropics and temperate countries and their scientific names
- Their considerable health benefits – the different phytochemicals, vitamins, mineral nutrients, and
- An overview of the different ways they are consumed.
- The different alcoholic beverages and their sources, their myriad variations and cocktails that brightens up the human society.

13.2 Introduction

Morphologically a fruit is the seed-bearing portion of the plant, and consists of the ripened ovary and its contents. *Simple fruits* are derived from a single ovary, and *compound fruits* from more than one. The *aggregate fruits* are formed from numerous carpels of the same flower, while *composite fruits* develop from the ovaries of different flowers of an inflorescence. *True nuts* are a specific type of dry fruit with a single seed encased in a hard shell, distinct from other commonly called "nuts" like almonds and peanuts. Their structure is an evolutionary adaptation for seed protection and dispersal, contributing to their ecological significance.

Tropical fruits and nuts thrive in warm and humid conditions with their unique flavours and vibrant colours. You are of course familiar with these – mangoes, pineapples, papayas, bananas, custard apples, pomegranates, guavas, jackfruits and avocados of the American tropics. Tropical nuts include cashews and Brazil nuts of South America, Oranges, apples, pears, peaches, plums, grapes, cherries and different berries, almond, walnuts and others are popular fruits and nuts of temperate climate. Fruits are indispensable dietary items that readily supply us with essential minerals, vitamins, anthocyanins and flavonoids, dietary fibres, and adequate hydration. Nuts like cashews and almonds contain healthy fats and antioxidants that help lower bad cholesterol and reduce the risk of heart disease. The combination of fibre and healthy fats in fruits and nuts can help you feel full longer and help in weight management. The export volume of tropical fruits reached close to 11 million tons in 2023, driven by strong demand in key importing countries. India grows a large variety of fruits belonging to the tropic and temperate regions. She produces around 227 kg of fruits and vegetables per person per year, which exceeds the general recommendation of annually 146 kg per person. However, their present availability is only 42.5 grams per adult per day, whereas a balanced diet requires 85 grams of fruits per adult per day.

Alcoholic beverages are not just drinks but cultural and economic staples that have evolved significantly over time. Whether it's a modest glass of wine, a robust whiskey, or country liquors favoured by indigenous communities or tribal people, each drink has a rich history and a wide-reaching impact on the world today. There is not and never had been a single country in the world that do not produce and consume alcoholic beverages. The oldest known winery was discovered in Armenia around 4100 BCE. The world's oldest bottle of wine from 325 AD is on display at a museum in Germany. The Gauls are credited with developing the first wine storage barrels while the Syrians developed the first wine glass bottles. Alcoholic beverages are typically categorized into three main types: *beers*, *wines*, and *spirits*. Each of these categories includes a wide variety of drinks, each with distinct flavours and production methods. Beers and wines are fermenteddrinks, while spirits such as whiskey, vodka, rum, gin, tequila, and brandy are distilled from fermented products to increase the alcohol content. Alcoholic drinks originate from various raw materials, each contributing to the unique taste and characteristics of the final product. The trade of alcoholic beverages is extensive but variable. This industry was valued at over $1.5 trillion in 2017. India has a rapidly growing market for alcoholic drinks, with revenues estimated at USD 60.48 billion in FY2023. In the fiscal year 2024, India imported over 543 thousand metric tons of alcoholic beverages. She also exported significant volumes.

13.3 Benefits of fruits and nuts

Fruits and nuts are vital components of human nutrition and hold significant economic, cultural, and ecological value. They play diverse roles in health, food security, sustainable agriculture, and the global economy, supporting livelihoods and global trade. Incorporating them into daily diets is vital for holistic well-being and sustainable development.

Health Benefits

Nutritionally, fruits are rich in vitamins and minerals; are excellent sources of essential nutrients such as vitamins A, C, and E, potassium, folate, and dietary fibres; potent source of antioxidants like flavonoids and polyphenols that combat oxidative stress and reduce the risk of chronic diseases; ensure hydration with their high water content -- watermelon and oranges are cases in point; and promotes digestive health -- dietary fibre in fruits supports gut health and prevents constipation. Red fruits and vegetables such as tomatoes, pink guavas, apricots, watermelons, and pink grapefruits are important sources of lycopene – a powerful antioxidant with the potential to reduce the risk of prostate cancers. From a standpoint of human health, fruits prevent diseases by reducing the risk of cardiovascular diseases, hypertension, and certain cancers. They are important in weight management -- low-calorie fruits like apples and berries aid in weight control. A few of them such as citrus and certain berries have anti-inflammatory properties. Nuts too have many nutritional benefits. They are rich source healthy fats like omega-3 and omega-6 fatty acids, making them calorie-dense and an excellent of energy. The Omega-3 fatty acids in nuts like walnuts for instance support cognitive function and reduce the risk of neurodegenerative disorders. The unsaturated fats, antioxidants, and phytosterols help reduce cholesterol levels and lower the risk of cardiovascular diseases. Pistachios are rich in lutein which supports eye health. Nuts also provide abundant plant-based proteins, and support muscle repair and growth, especially for vegetarians and vegans. They contain essential nutrients like magnesium, selenium, zinc and vitamin E – which are all crucial for immune function and cellular repair. Calcium and phosphorus in almonds and cashews support strong bones. Nuts are also known to improve insulin sensitivity and stabilize blood sugar levels.

Economic and Social Importance

As cash crops, Fruits and nuts are major export commodities, contributing significantly to the economies of producing countries. Bananas, mangoes, almonds are a few examples. See if you can add to the rather long list. Millions of smallholder farmers rely on the cultivation and sale of fruits and nuts for their income and livelihood. They are also essential components in processed foods, beverages, and confectionery.

Ecological importance

Fruit orchards and plantations support diverse ecosystems by providing habitats for various species. Many fruits and nuts attract pollinators like bees, contributing to the conservation of these species. Nut-bearing trees like walnuts, groundnuts and hazelnuts improve soil fertility through nitrogen fixation and prevent soil erosion.

Cultural and Culinary significance

Many fruits (e.g., Amla) and nuts (e.g., almonds) are integral to indigenous medicinal systems like Ayurveda and Traditional Chinese Medicine. Fruits and nuts hold symbolic importance in festivals, rituals, and gifting practices. They are essential ingredients in global cuisines, adding flavour, texture, and nutrition to a variety of dishes.

SAQ I

A. *Write at least two health benefits each, derived from apples, bananas, berries and mango.*

B. *Select the correct answer given within parenthesis to fill in the blanks.*

(i) Almonds are high in vitamin E which is good for (skin / bone) health.

(ii) Walnuts are rich in (omega-3 fatty acids / proteins), which improve cognitive function.

(iii) Cashew nuts (can /cannot) fix atmospheric nitrogen.

(iv) Pistachios are rich in lutein which supports (bone / eye) health.

Other Activities

1. *Find out the microbes which fix atmospheric nitrogen in cashewnut. List the names of three improved varieties of cashewnut developed in India*.[You may wish to visit the website of ICRISAT].

13.4 Important fruit crops of India

A good number of the fruits grown in India are introduced from foreign countries. The climatic diversity of the Indian Subcontinent has generated significant genetic diversity in cultivated tropical, subtropical, temperate, and arid fruits. Rich diversity is also exhibited in the wild relatives of these fruit types. Tropical fruits constitute a major proportion of the spectrum of fruit diversity available with large cultivation of indigenous fruits like mango (*Mangifera indica*), banana (*Musa spp*.), citrus fruits (*Citrus spp*.), jackfruit (*Artocarpus heterophyllus*), litchi (*Litchi chinensis*), which constitutes about 66.4% of the annual fruit production. They generally thrive with temperatures between 20 and 300 C, high humidity and plenty of rainfall throughout the year.

The cultivation of temperate fruits in the subcontinent extends from Northwest Himalayas, starting from Jammu and Kashmir to the subtropical plains in the north, to Arunachal Pradesh in the Eastern Himalayas. These fruits are also grown in the hilly regions of South India around 100°N and 75°E. They require cold winters for dormancy and moderate summer temperatures for growth. Apple (*Malus domestica*), pear (*Pyrus communis*), peach (*Prunus persica*), plum (*Prunus domestica*), almond (*Prunus amygdalus*), apricot (*Prunus armeniaca*), and cherry (*Prunus avium*) are commercially cultivated in the Northwest Himalayan region (Jammu and Kashmir, Himachal Pradesh, and Uttarakhand). The hot arid and semi-arid region spread over the Northwest India occupies around 12% of countries land, covering the states of Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, and Karnataka. These regions have comparatively few fruit species, but there is wide diversity within species, though confined to small pockets. Many fruits, such as amla (*Emblica* *officinalis*), bael (*Aegle marmelos*), kul (*Ziziphus mauritiana*), chironji (*Buchananialanzan*), jamun (*Syzygiumcumini*), karonda (*Carissa carandas*), ker (*Capparis decidua*), Khejri (*Prosopis cineraria*), lasoda (*Cordia myxa*), phalsa (*Grewia asiatica*), pilu (*Salvadorapersica*), date palm (*Phoenix sp*.), and wood apple (*Limonia acidissima*), are indigenous and present significant genetic diversity. Comparatively fewer species occur in the northern and north western plains and in the Aravalli Hills, such as *Carissa congesta*, *Capparis decidua*, *Grewia asiatica*, and *Ziziphus* spp. (*Z. mauritiana*, *Z. nummularia*).

The term "nut" used more broadly in culinary context includes seeds and drupes that are not true nuts botanically. Examples include : Almonds (*Prunus dulcis*) which are seeds of a drupe. They are grown mostly in Jammu and Kashmir, Leh, Kargil and Himachal Pradesh. Cashews (*Anacardium occidentale*) which are seeds of a false fruit are grown in many states. India is the second largest producer and exporter of cashew nuts in the world. Pistachios (*Pistacia vera*) are seeds of a drupe are grown mostly in Jammu and Kashmir. Walnuts (*Juglans regia*) are grown chiefly in Jammu and Kashmir, Uttarakhand, Himachal Pradesh and Arunachal Pradesh. Peanuts (*Arachis hypogaea*) are botanically legumes (not nuts). They are grown mostly in Gujarat, Rajasthan, Madhya Pradesh and South India.

13.5 Description of selected tropical fruits and nuts

Mango.

Mangifera indica L.; Family – Anacardiaceae; Eng.-mango; Bengali-Am; Hindi-Am, amb. (Fig. 13.1).

Uses. The mango fruit is one of the most highly prized dessert fruits of the tropics. It has a rich, luscious aromatic flavour and delicious taste in which sweetness and acidity are delightfully blended. Young and unripe fruits are usually acidic and used in pickles, chutney, and culinary preparations. Ripe fruits are preserved by canning or used in manufacture of juice and squash, jams and jellies, preserve (murabba) and ampapur. Sucrose, glucose and fructose are the principal carbohydrates present in ripe mango; maltose is also present. Unripe fully developed mangoes of pickling varieties contain citric, malic, oxalic, succinic acids. As the fruit ripens the acidity gradually decreases with a steep fall at ripe stage. Ripe fruits constitute a rich source of vitamin A; some varieties contain fairly good amounts of vitamin C also. The fruit is a rich source of potassium. Ripe mango fruit is considered invigorating, refreshing and fattening. The juice,along with aromatics, is recommended as restorative tonic. It contains vitamins A and C and is useful in heat apoplexy.

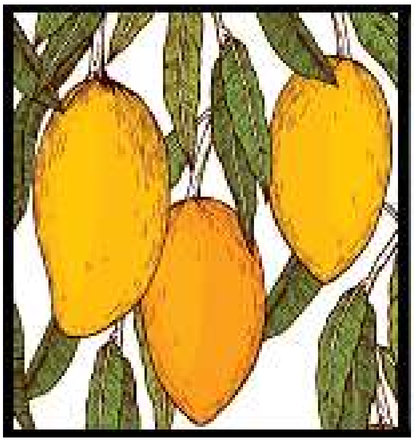

Figure13.1 Mango Figure 13.2Citrus reticulata (orange)

Citrus Fruits. (Fig. 13.2) They are supposed to be natives of Eastern and Southern Asia. Some of the citrus fruits have been cultivated for over 3,000 years. The citrus fruits possess considerable amounts of vitamin C as well as fruit acids. The flavone naringin and its aglycone naringenin present gives citrus fruits its bitter taste and displays strong anti-inflammatory and antioxidant activities. Investigation suggests that naringin supplementation with food is beneficial for the treatment of obesity, diabetes, hypertension, and metabolic syndrome.

They are also used in the preparation of juices, squashes and other canned products.

***Citrus aurantiifolia* (Christm.) Swing.,** Family-Rutaceae; Eng.-Lime; Hindi-Kaghzinimbu; Bengali-Kaghzinimbu, patinebu.

Uses. The fruits make a good source of vitamin C. They are used raw and pickled. The oil distilled from the peel is used in confectionery, pharmaceuticals and toilet preparations. Fruits are extensively used for culinary purposes; for flavouring jams, jellies, marmalades, and alcoholic drinks, and as a garnish. It is considered as an appetizer, a stomachic, and antiscorbutic

Citrus reticulata Blanco; Family-Rutaceae; Eng.-Mandarin; Hindi-Santara; Bengali-Kamala.

Uses. The fruits are delicious. They are rich in vitamin C which boosts collagen production and immune function. The peel is used for marmalades. Fruit is used mainly as dessert and in the production of orange juice. The essential oil is distilled mainly in Nagpur and Coorg and used in confectionery, pharmaceuticals and toilet preparations. It is a most valued commercial fruit. Petitgrain oil is obtained from leaves and twigs. peels yield Mandarin Oil.

Citrus sinensis (Linn.) osbeck; Family-Rutaceae; Eng.-Sweet orange; Hindi-Musambi; Bengali-Musambi.

Uses. The fruits are edible. They are good source of vitamin C. The peel is the source of orange oil. Fruit is sweet and juicy, nutritious, highly esteemed dessert fruit. peels are the source of an essential oil called orange Oil. Flowers also yield an essential oil, Neroli Oil. Leaves and young roots are another source of Petitgrain Oil. Fruit juice is useful in bilious affections.

***Citrus aurantium* L.;** Family-Rutaceae; Eng.-Sour orange; Hindi-Khatta.

Uses. The fruits are edible. The leaves are the source of an essential oil, which is used in confectionery, cosmetics and perfumery. Used in the preparation of confections, marmalades, liqueurs, and other drinks. Rich source of provitamin A and B. Lime oil obtained from the fresh rinds is the source of Bergamot Oil extracted from the peels. Leaves and tender twigs yield Petitgrain oil.

***Citrus maxima* (Burm.) Merrill;** Eng. Shaddock; Hindi-Chakotra; Bengali-Mahanibu, Sadaphal.

Uses. The fruits are edible. They are good source of vitamin C (ascorbic acid). Fruits esteemed for dessert; made into jams and marmalades; considered nutritive and refrigerant. Leaves are used in epilepsy, chorea, and convulsive coughs.

***Citrus medica* L.;** FamilyRutaceae; Eng.-Citron; Hindi-Baranimbu; Bengali-Bara nimbu, begpura.

Uses. The fruits are edible. They are enriched with vitamin C. Fruits are used mainly for pickling, also candied. Peel is made into marmalades and other preserves. Preserved rind is used in dysentery. Citron oil is obtained from fresh rinds.

***Citrus limettioides* Tanaka;** Family-Rutaceae; Eng.-Sweet lime; Hindi, Bengali-Mithanimbu;,

Uses. The fruits are edible and good source of vitamin C. It is also used as a root stock for sweet oranges and mandarins. The leaves yield an essential oil known as 'petitgrain oil', which is used in confectionery and cosmetics as a flavouring substance.

***Citrus paradisi* Macf.;** Family-Rutaceae; Eng.-Grapefruit.

Uses. The fruits are edible. Rich in vitamin C. Also, a fair source of vitamin B1. Used mainly as a breakfast fruit. Rinds yield grapefruit oil, employed in perfumery and as a flavouring. Grapefruit juice is recommended for building up resistance to common colds. Dry and fortified wines, brandies and cordials are prepared from the fruits.

***Citrus limon* (L.) Burm. f.;** Family-Rutaceae; Eng.-Lemon; Hindi-Nimba; Bengali-Baranebu, goranebu.

Uses. The fruits are eaten raw and pickled. The juice is used for lemonade and other beverages and as a flavouring substance. Bleaching agent and stain remover. The rind is the source of oil of lemon. Lemon oil is used in perfumery and toilet soaps. It is also utilized in confectionery. Used for culinary purposes and in the preparation of beverages. Citric acid, pectin, and lemon oil are obtained as by products. Oil of lemon is also used as carminative and for flavouring liqueurs. Lemon juice is very useful for scurvy. Pickled fruit is useful in hypertrophy of spleen.

Litchi

***Litchi chinensis* (Gaertn.) Sonn.;** Family-Sapindaceae; Eng.-Litchi; Hindi-Lichi; Bengali- Lichu.

Uses. Litchi fruits are usually consumed fresh. They remain in fit condition for 3-5 days. The litchi fruit consists of peel, aril and seed. The aril which can be readily separated from seed, is soft and juicy with a delicious flavour and is generally eaten fresh. Litchi arils can be preserved try canning with syrup.

Banana

***Musa paradisiaca* L.;** Family-Musaceae; Eng.-Banana; Hindi-Kela; Bengali-Kola.

Uses. There are many varieties of bananas. The most popular ones are – *Poovan* of Tamil Nadu which is also known as Lalvelchiin Maharashtra, Champa in Bengaland *Karpura Chakkerakeliin* Andhra Pradesh. *Ba* in certain places, *Yamankeliin* South India. *Kabuli* in Bengal and Orissa, *Bhusavaliin* Maharashtra and Madhya Pradesh. *Harichhal*, also known as Bombay green incertain areas *'Nendran'* and *'Kadali'* varieties of Kerala are also important.

Uses. The fruits are edible. They have a high content of carbohydrates with some fats and proteins. Their food value is three times that of wheat. Green bananas may be cooked and eaten as vegetable, Banana powder can be used as baby food and in the manufacture of chocolate and biscuits.The Kerala banana chips famous all over India, are prepared from raw *'Nendran'* varieties. Ripe *'Nendran'* when cooked in steam and dried under the Sun, can be kept months together like dried date palm fruits and it forms a very good breakfast. Edible bananas of hybrid origin valued for their seedless fruits. Unripe fruits are eaten as vegetable. Fruit-pulp is dried and made into flour; used also for jams and jellies, sugar coated chips and several Indian confections. It makes a fair source of minerals and vitamins particularly of B group. Peels are used as cattle feed. Inflorescence before opening is used as a vegetable. Core of pseudostem is eaten after cooking; starch in pseudostem is used for finishing of textiles. Banana fruit is laxative and used in intestinal disorders, uraemia, nephritis, hypertension and other vascular diseases. It is a very nutritious fruit.

Guava

***Psidium guajava* L.;** Family-Myrtaceae; Eng.-Guava; Sanskrit-Mansala; Hindi-Amrud, safed safari; Bengali-Goachhi, peyara, piyara.

Uses. The fruits are edible. It is aromatic, sweet, juicy and highly flavoured. It contains acid, sugar and pectin. It is one oi the richest sources of vitamins A, B and C and of ascorbic acid. It is commonly used for making jellies, jams and pastes. Fruits are also canned, preserved, spiced or made into jam, butter, marmalade, pies ketchups and chutneys. Seeds yield a fatty oil. Leaves contain an essential oil used as a flavouring. Leaves are used as an astringent for bowel troubles. Decoction of bark is given in diarrhoea. Fruits are tonic. They have a cooling and laxative effect and are useful in colic and bleeding gums.

Custard Apple

***Annona squamosa* L.;** Family Annonaceae; Eng. Custard apple/Sugar apple; sweet sop; Hindi-Sharifa; Sanskrit-Sitaphal; Bengali-Ata. (Figure. 13.3)

Uses. The fruits are edible and quite popular. The pulp of fruit is eaten. The edible pulp is juicy white or cream-yellow delicately flavoured, sweet flesh. They can be made into drinks and fermented liquor. Seeds yield fatty oil. The family possesses a class of polyketide natural products called acetogenins, which exhibit potent anti-cancer, anti-parasitic and insecticidal properties.



Figure 13.3 Annona squamosa L Figure 13.4 PapayaFigure 13.5 Pomegranate

Papaya (Fig. 13.4)

***Carica papaya* L.;** Family-Caricaceae; Eng.-Papaya; Hindi-Papita; Bengali-Pappaiya, pepe.

Uses. It is an excellent breakfast fruit. The orange coloured flesh possesses sweet musky taste. It is also used for salads, sherbets and confections. Unripe fruits are cooked as vegetable and pickled. The latex, obtained from the fruits, is used in preparing chewing-gums and for tenderizing meat. It is also used in medicine as an anthelmintic. The latex of papaya is known as papain which is used medicinally. The ripe fruits are source of vitamins and papain. Fruit pulp may be used as an ingredient in face creams and hair shampoos. Milky juice of unripe fruits is used as a cosmetic to remove freckles and other blemishes from the skin. Plant yields a blood anticoagulant. Leaves yield an alkaloid carpaine. Seeds yield fatty oil.

Pomegranate

***Punica granatum* L.;** Family-Punicaceae; Eng.-Pomegranate; Hindi-Anar; Bengali-Dalim. (Fig. 13.5)

Uses. This is a very refreshing fruit. The bark and fruit shells are used for tanning. The peel of the fruit is used medicinally in dysentery and diarrhoea. Fleshy testa is edible. Among the numerous types grown, *Bedana* and *Kandhari* are considered the best. Seeds of wild trees are sour and dried ones constitute *Anardana*, used as condiment. Fruit is a good source of sugars, vitamin C, and a fair source of iron, but poor in calcium. Pomegranates have anti-inflammatory properties owing to their high antioxidant content. A phenolic compound punicalagin found in the peel, seeds, juice, flowers, leaves and bark, have antioxidant, anti-inflammatory and anti-cancer properties. Seed juice is a favourite drink, which may also be used for making wine. Bark is used to expel tapeworms, *iso-pelletierine* is the most potent among the active principles; given as decoction. Rind is used as an astringent in diarrhoea and dysentery. Flower-buds are used in bronchitis. Fruit rind is rich in tannin and used as a tanning material, also yields a dye. Flowers yield a red dye.

Pineapple

***Ananas comosus* (L.) Merr.;** Family-Bromeliaceae; Eng.-Pineapple; Hindi-Ananas; Bengali-Anaras. (Fig. 13.6)

Uses. The fruits are edible. In addition to the content of sugar and fruit acids, a valuable digestive ferment, *bromelain*, is present. The slices of pineapples and pineapple juice are canned for export and domestic consumption. In the fresh form the fruit is a good source of vitamins A and B and is very rich in vitamin C. It is highly valued as a fresh fruit. In countries like Hawaii, Australia, etc., where the canning industry is more of the total small quantities are consumed by the industry. The dried waste after extraction of juice, known as pineapple bran, is a valuable stock feed. Alcohol, calcium citrate, citric acid and vinegar are other products for the manufacture of which pineapple juice is utilized, although in small quantities. The leaves are the source of a strongfibre, which is made into fabrics. Pineapple waste is used for making vinegar. Juice from ripe fruit is diuretic and antiscorbutic (vitamin C 63 mg/100 gm); that from unripe fruits, purgative and abortifacient. Leaves yield a fibre, Pina, a delicate fabric of Philippines, is made from t after extraction is used for paper making.



Figure 13.6. Pineapple Figure 13.7 Water melonFigure 13.8 Kharmuj

Date Palm *Phoenix dactylifera* L.; Family: Arecaceae; Eng.-Date Palm; Hindi-Pindkhajur;Bengali-Khajur, Khejur.

Uses. The dried fruits are rich in sugar (75-80%), mainly glucose and fructose. In addition, it also contains a very significant level of potassium, iron and nicotinic acid. The fruits are used as common table fruit and also used in jams, alcoholic beverages, pastes, etc. The dates are also used in bakery and made into preserves. Brandy of good quality is prepared from dates. Sap is sweet, nutritive and laxative; used for preparation of jaggery and sugar. The dates are demulcent, expectorant, and also used in respiratory diseases and fever. Leaves are used in the preparation of mats etc. The fibre from leaves is used for making ropes, baskets, and cordage.

Jambolana

Syzygiumcumini (L.) Skeels; Family-Myrtaceae; Eng.-Java plum, Jambolana; Hindi- Jamun; Bengali-Jam, Kalajam.

Uses. The fruits are edible. They are rich in Iodine. The vinegar is prepared from fruit juice. The seeds are used as fodder. A spirituous liquor as well as wine is prepared from the ripe fruits. The fruits are also used for making preserves, jams, squashes, and jellies.

Bael

Aegle marmelos (L.) corr.; Family-Rutaceae; Eng.-Bael; Hindi-Bel; Bengali-Bel.

Uses. The ripe fruits are edible. The cold drinks and squashes are prepared from the fruits. The unripe fruits are eaten after roasting. The fruits are used as astringent, stomachic and also in the treatment of diarrhoea and dysentery. The mucilaginous substance of the fruits is used as gum and is also used as varnish. The pulp of ripe fruits is aromatic and cooling and used in the form of sherbet. Marmelosin is the active constituent; it acts as a laxative and diuretic, in strong doses a cardiac depressant. Dried fruits, freed from pulp, are used as pillboxes. Stem yields a gum. Leaves contain an essential oil.

Water Melon

***Citrullus vulgaris* Schrad. ex Eckl. &Zeyh;** Family-Cucurbitaceae; Eng.-Water melon; Hindi-Tarbooz; Bengali-Tarmooz. (Fig. 13.7)

Uses. The red pulp of the fruit is eaten. The white solid flesh of the fruit is used for making jams, jellies and preserves. The seeds are used as food. They are considered cooling, tonic, diuretic; yield a fatty oil. Fruit juice forms a cooling and refreshing beverage; also considered diuretic.

Melon

***Cucumis melo* L.;** Family-Cucurbitaceae; Eng.- Musk melon; Hindi-Kharbuza; Bengali-Kharmuj.(Fig. 13.8)

Uses. The fruits are edible. They are rich in sugar and proteins. The melons are eaten as dessert. The seeds are edible and contain a fixed oil. The seeds are diuretic, refrigerant and nutritious. The pulp is useful in chronic eczema.

Avocado

***Persea americana* Mill.** Family–Lauraceae; Eng.- Alligator pear /avocado pear.

An evergreen tree native to the tropical Central and South Americas (Mesoamerica), prized for its large and unusually oily berry with a single large seed. They are a key ingredient in many cuisines, and are known for their creamy texture and mild flavor. Avocado, often labelled a superfood, is packed with a variety of nutrients -- monounsaturated fats, especially oleic acid, which can help reduce inflammation; vitamin C, K and folates; potassium (more than in bananas) for heart health and muscle function; magnesium for muscle and nerve function, regulation of blood sugar and blood pressure regulation; the carotenoids lutein and zeaxanthin, which promote eye health;

  

Figure 13.9 Cashew nut Figure 13.10 Pistachio Figure 13.11 Groundnut

Cashew nut (Fig. 13.9)

***Anacardium occidentale* L.;** Family– Anacardiaceae; Eng- Cashew, Cashew apple; Beng &Hindi- Kaju Badaam.

The cashew nut of commerce, it is a major export of the developing world, commercially cultivated mainly in Brazil and India. The false fruit (hypocarp) is both consumed locally and used to distill “Feni,” an alcoholic beverage. In S. America, especially Brazil, the juice from the cashew apple is marketed widely as a popular drink. The cashew nut shell liquid is used for industrial purposes and has medicinal value. The seeds, rich in oil and distinctively flavoured, are commonly used in South and Southeast Asian cuisine and are a characteristic ingredient of numerous chicken and vegetarian dishes of southern India. In Western countries they are eaten mainly as a premium-quality protein-rich snack food.

Pistachio (Fig. 13.10)

***Pistacia vera* L.;** Family – Anacardiaceae; Eng- Pistachio; Beng- Pesta; Hindi: Pista.

Pistachio is cultivated for nuts which are mainly used for eating out of hand as fresh, dried, and roasted with or without salt and flavourings. It is unique in the nut trade because the shell splits of its own before harvesting. They are a good source of protein, dietary fibre, vitamins, minerals, and antioxidants. They are high in unsaturated fatty acids and low in saturated fatty acids. They are the only nuts with significant amounts of lutein (a carotenoid) -- about 1405 µg of lutein plus zeaxanthin per 100 g in raw pistachios -- which plays a critical role in protecting the eye macula from damage by blue light.

Groundnut or Peanut (Fig. 13.11)

***Arachis hypogea* L.** Family – Fabaceae. Eng- Groundnut; Beng- Chinabadam; Hindi- Moongphali.

Groundnut is regarded as one of the most important protein-rich cash crop grown in over 100 countries, with Africa and Asia producing about 90% of the world's supply. It occupies fifth position as oilseed crop globally, after soybean. The kernels are a source of vegetable protein, and are eaten directly or ground into peanut butter. Groundnut oil is used for cooking, making vanaspati, and as a lubricant. It can also be used in soap-making, leather dressings, furniture, creams, and so on. Groundnut oil cake is used as feed for cattle and other farm animals. Groundnut shells are used to make activated carbon.

13.6 Description of selected temperate fruits and nuts

Apple

***Malus pumila* Mill.;** Family-Rosaceae; Eng.-Apple; Sanskrit-Seba; Bengali and Hindi- Seb, sev. (Fig. 13.)

Uses. Apples are valued mainly as dessert fruits. Fruits may be preserved for later use after slicing and drying; they are also canned and jams and jellies are made from them. The juice extracted from the fruits is fermentation into cider wine and vinegar; apple brandy is obtained by distilling cider. Apples are rich in pectin and are useful in diarrhoea. Apple juice, syrup and vinegar reduce curd tension of milk used in infant feeding. Applemurabba, a preserve popular in India, is regarded as a stimulant for the heart; it is reported to relieve physical heaviness and mental strain. The vitamins, salts and organic acids are concentrated particularly in and just below the skin. and the fruit should be eaten unpeeled. Apple is considered as a good source of potassium. The edible portion of fresh apples contains Ca, Mg, K, Na, P, Cl, S and Fe. The mineral constituents of the apple are considered valuable for human nutrition.

Pear

Pyrus communis **L.;** Family-Rosaceae; Eng.-Pear; Hindi-Nakh, Bengali-Nashpati. (Fig. 13.)

Uses. The fruits are edible. They are eaten as such or canned. The fruits are rich in sugars, salts, and vitamins.

Plum

Prunus domestica ssp. insititia **(L.) Schneid.;** Family-Rosaceae; Eng.-Plum; Hindi-Alucha, alubukhara.

Uses. Plums are used as fresh fruit, for cooking, canning, and used in jams.

Sweet Cherry

Prunus avium **L.;** Family-Rosaceae; Eng.-Sweet Cherry; Hindi-Gilas.

Sour Cherry

Prunus cerasus **L.;** Family-Rosaceae; Eng.-Sour Cherry; Hindi-Alubalu.

Uses. Cherries are used as table fruits and in canning. Cherry brandy is distilled from cherry juice. The

Peach

Prunus persica **(L.) Stokes;** Family-Rosaceae; Eng.-Peach; Hindi-Aru.

Uses. The fruits are edible. They are the most popular fruit for canning. The oil obtained from the seeds, is used for cooking and as illuminant.

Apricot

***Prunus armeniaca* L.;** Family-Rosaceae; Eng.-Apricot; Hindi- Khubani. (Fig.13.12)

Uses. They are used as a table fruit in the regions where they are grown. They are also canned and candied. used for cooking, burning and for the hair. The seed is also known to possess anticancer properties.

Strawberry

***Fragaria vesca* L.;** Eng.-Perpetual strawberry (Fig. 13.13)

Uses. Strawberries are a dessert fruit primarily, but are also canned and used in jams and preserves, and as a flavouring material.

Raspberry (Fig. 13.154)

***Rubus ellipticus* Smith;** Family-Rosaceae; Eng.- Himalayan yellow raspberry; Hindi-Lal anchu, hisalu.

Uses. It is used fresh or cooked, and is utilized for jams, jellies, vinegar and as flavouring material.

Blueberry

Vaccinium sp. Family- Ericaceae. Eng.- Blueberry

They are generally prostrate shrubs common in N America and Canada with purple or indigo coloured berries and prized for their sweet edible fruits. Hailed as a superfood, blueberries are an excellent source of antioxidants like anthocyanins, dietary fibre, vitamin C, vitamin K, manganese and iron. They are commonly eaten fresh as a dessert fruit, can be added to many dishes, such as oatmeal, yogurt, pancakes, smoothies, salads, or baked foods. Blueberries are closely related to cranberries and bilberries, which are also members of the genus *Vaccinium*.

Mulberry

***Morus alba* L.;** Family-Moraceae; Eng.-White mulberry; Hindi-Tut; Bengali-Tut. (Fig. 13.15)

***Morus australis* Poir.;** Eng.-Common mulberry; Hindi-Tut.

Uses. The fruits are edible. The leaves are the source of food of silkworms. The fruits are refrigerant, used also for sore throat, dyspepsia and melancholia. The leaves are rich in calcium and vitamin C, and eaten as vegetable. The fruits are also used in the form of juices, stews and tarts, and fermented to yield spirituous liqueurs.

Fig 13.12 Apricot Fig. 13.13 StrawberryFig. 13.14 RaspberryFig. 13. 15 Mulberry

Grapes

***Vitis vinifera* L.;** Family-Vitaceae; Eng.-Wine grape; Hindi-Angur, Bengali-Angurphal. (Fig. 13.)

Uses. Grape is a delicious, refreshing and nourishing fruit. It is classed as a protective food, is easily digestible and has large quantities of sugar, minerals like calcium and iron, and vitamin B. The stilbenoid polyphenol resveratrol found in red grapes and certain berries is known to stall hyperlipidemia, prevent fatty livers and has potential anti-ageing effects. The flavone naringin and its aglycone naringenin present in grapes exhibit strong anti-inflammatory and antioxidant activities. Grapes ideal for eating fresh are called “table grapes”. Some varieties are known as ‘raisins’, can better be dried and preserved, while others are used in making juices and wines. Black grapes are also dried and preserved like raisins. They are available in plenty in South India.

Almond (Fig. 13.16)

***Prunus dulcis* (Mill.) D.A.Webb;** Family- Rosaceae; Eng. Almond,Sweet almond; Hindi-Badam; Beng- Baadaam, Desi Baadaam.

They are beneficial to the overall health of the body, being used especially in the treatment of kidney stones, gallstones and constipation. Externally, the oil is applied to dry skins and is also often used as carrier oil in aromatherapy. The seed is demulcent, emollient, laxative, nutritive and pectoral. The seed contains 'laetrile', a substance that has also been called vitamin B17. The plant contains the antitumour compound taxifolin (Duke JA and Ayensu ES 1985.Medicinal Plants of China Reference Publications, Inc. 1985 ISBN 0-917256-20-4)

Walnut (Fig. 13.17)

***Juglans regia* L.** Family- Juglandaceae; Eng- Common/Persian/English walnut; Beng, Hindi & Urdu –Akhrot.

The walnut is an important food crop, often cultivated on a commercial basis for its seed and for its valuable wood. The plant is also harvested from the wild for use as a food, as a popular traditional medicine. The walnut kernel is a popular, nutritious food high in protein, fat, vitamins, and minerals. It is eaten fresh or toasted, or used in confectioneries, pastries, salad toppings and sauces. China is the world's leading producer of walnuts, followed by the United States, Iran, and Turkey. Walnuts are a good source of essential omega-3 fatty acids like alpha-linolenic acid.

Hazelnut (Fig. 13.18)

***Corylus avellana* L.:** Family- Betulaceae; Eng- Common hazel;

Hazelnut trees are native to Europe and Western Asia. It is found to grow wild in Shimla, Kinnaur, and Chamba districts of Himachal Pradesh. It is rich in monounsaturated fatty acids, high in vitamin E, and is commonly eaten as food. Hazelnut contains oil, protein, fibre, and antioxidants. They are used in spreads (like Nutella), chocolates, and baked goods. Hazelnut oil is used in cooking and skincare.



Figure 13.16 Almond Figure 13.17 Walnut Figure 13.18 Hazelnut

SAQ II.

(a) State the primary climatic requirements for cultivating tropical fruits like mango and papaya.

(b) Name two temperate fruits of our country and mention their preferred growing conditions.

(c) State the main health benefits of eating avocados.

(d) Fill in the blanks:

(i) A major phytochemical found in blueberries is __________, which is known for its antioxidant property.

(ii) Tropical fruits such as mangoes and pineapples thrive in regions with temperatures ranging from _____ to ___ degrees Celsius.

(iii) Oranges are a rich source of vitamin ___, which boosts collagen production and immune function.

(iv) The stilbenoid polyphenol __________ found in red grapes and certain berries is known to stall hyperlipidemia, prevent fatty livers and potential anti-ageing effects.

(v) The carotenoid __________ is a powerful antioxidant found in tomatoes and certain red fruits, is known to lower the risk of prostate cancer.

13.7 Commerce in Fruits & Nuts

With fruits, the country ranks first in the production of Bananas (25.56%), Mangoes including mangosteens and guavas (44.46%), and Papayas (38.64%).As per National Horticulture Database (2nd Advance Estimates) published by National Horticulture Board, during 2023-24, India produced 112.62 million metric tonnes of fruits. Such a vast production base offers India tremendous opportunities for export. Grapes, Pomegranates, Mangoes, Bananas, and Oranges account for the larger portion of fruits exported from the country. Revenue in the Fruits & Nuts market amounts to US$134.90bn in 2024. The market is expected to grow annually by 7.64% (CAGR 2024-2029). At a global level, most revenue is generated in India (US$135bn in 2024). India is the world's largest importer of *dry fruits*. In 2023, India imported dry fruits worth $2.85 billion. India's dry fruit market is growing at a rate of 10-12% per year, which is higher than any other country in the world. The market is projected to grow from $9.3 billion in 2024 to $12.7 billion by 2029. The fruit market in India is growing due to increasing consumer awareness of healthy eating and rising disposable income in urban areas (Agriculture and Processed Food Products Export Development Authority- APEDA, Ministry of Commerce and Industry, Government of India, 2024)

13.8 Alcoholic Beverages through the ages

A beverage is any fermented liquor, such as wine, beer, or distilled spirits, that contains ethyl alcohol, or ethanol (CH_3CH_2OH), as an intoxicating agent. After ingestion, the alcohol is rapidly absorbed in the gastrointestinal tract ; thus, alcohol quickly reaches high levels in the blood. The beverages are classified into two major categories as alcoholic and non-alcoholic beverages. Alcoholic beverages can be fermented (non-distilled) or distilled. They may be fermented from the sugars in fruits, berries, grains, and such other ingredients as plant saps, tubers, honey, and may be distilled to reduce the original watery liquid to a liquid of much greater alcoholic strength. As examples of fruit sap sources we have wine (fermented) and brandy (distilled). Examples of grains as sources include beer (fermented) and whiskey (distilled). According to alcohol content, they can be classified as low alcohol or high alcohol drinks. Low alcoholic beverages should have no than *1.2% alcohol by volume (ABV)*, fermentation products such as low –alcohol beer, tequila are examples. Distilled spirits, such as whiskey, vodka, rum, and gin, are well-known for their high alcohol content.

The history of alcoholic beverages goes back thousands of years. Discovery of late Stone Age jugs suggest that prepared fermented beverages existed at least as early as the Neolithic period (c. 10,000 BCE).

13.8.1 Fermented Beverages

Brewing or the production of malt beverages is the name given to the combined process of preparing beverages from infusion of grains that have undergone sprouting (*malting*), and the fermenting of the sugary solution by yeast, whereby a portion of the carbohydrate is changed to alcohol and carbon dioxide. It is an ancient industry and was probably invented by the Egyptians.

A. Beer : *Beer* is produced from fermentedgrains, primarily barley, but also from wheat, maize, and rice. They are consumed globally as a staple beverage; varieties include lagers, ales, stouts, and pilsners. Often paired with meals, they are used in cooking to add flavour to dishes.

Composition of beer : The substances found in a beer depend largely upon the nature of the quality of the raw materials, the treatment of the sprouted grain or malt used in mashing, and the character of the ensuing fermentation, but storage and finishing operations affect the final composition. In normal beer carbohydrates

– such as dextrin, maltose and glucose – and protein derivatives – such as peptones, amino acids and amides are present. The products are produced mainly as the result of the action of the enzymes of the malt. Hops contribute bitter substances such as resins, essential oils and tannins. As a result of alcoholic fermentation, the sugars of the wort are being converted, in part to ethyl alcohol and carbon dioxide. Some of the amino acids are being transformed to higher alcohols and acids. Salts and traces of oil are always found. The finished beer contains 82 to 92 percent water by volume.

> Wort is the sweet infusion of ground malt or other grain before fermentation, used to produce beer and distilled malt liquors. Yeastsare normally added to the wort to induce fermentation.

Kinds of beer :

Lager beer : It means literally, the stored beer. Larger beer is produced by bottom fermentation and is rather high in alcohol and extract with a relatively low proportion of hops.

Pilsner is a type of pale lager that originated in the Czech Republic. Named after the city of Pilsen (Plzen in Czech), where it was first brewed in 1842. Pilsner beers are known for their light colour, and crisp taste.

Bock beer : This is a heavy beer, dark in colour and high in alcohol. It is brewed for consumption in early spring.

Ale : It is produced by top fermentation. It is pale in colour, tart in taste, and high in alcohol and contains more hops than does beer.

Porter : It is dark ale, high in extract and sweeter than the usual ale in taste. It is brewed from dark or black malt (malt roasted at a high temperature) to produce a wort of high extract.

Stout : It is a strong porter that is high in alcohol and extract. It is dark in colour and possesses a sweet taste and strong flavour of malt. The flavour of hops is better than porter.

Weiss beer : A beer made mainly from wheat, is produced by top fermentation. It is rather light, possesses a distinct flavour of malt and hop, is tart and contains a large quantity of natural fermentation gas. It is somewhat turbid in appearance.

Ginger beer : It is characterized by its distinctly acid nature, the ginger flavour, and presence of a small amount of alcohol.

Root beer : It consists of an infusion of various roots, barks and herbs, with the addition of sugar and yeast. The herbs commonly used for the purpose are ginger, sarsaparilla and winter green. Fermentation sets and the beverage become charged with carbon dioxide.

Cereal beverage : This beer contains less than 0.5 % alcohol. It is sometimes called 'near beer'.

B. Wine : Wine is the product made by the normal alcoholic fermentation of the juice of healthy, ripe grapes (*Vitis vinifera*). However, wine can be produced from practically any fruit or flower rich in soluble sugars. Enjoyed worldwide as red, white, rosé, and sparkling wines, they are commonly served with meals, used in religious ceremonies, and as a base for culinary sauces. Relatively small amounts of wine are made from apples, raisins, berries, peaches, cherries, oranges, currants, apricots, pomegranates, raspberries, pears, honey and strawberries. The wine made from the fruit is named after the fruit, for example, 'apple wine'. Chardonnay is one of the most popular and widely planted white wine grape varieties in the world. It originated in the Burgundy region of France, but it is now grown in almost every wine-producing region globally.

Wine-making areas : A large part of the world's wine is made in the countries located near the Mediterranean Sea. France leads the world in wine making, followed by Italy, Spain, Algeria, Portugal, Rumania, Argentina, Russia, Hungary, Yugoslavia, United States, Chile, Greece, Bulgaria, South Africa, Germany and other countries. In France, the region around Bordeaux produces most of the wine. This district is the most outstanding single wine producing area in the world. Burgundy wines are produced in the hilly country of the Cote d'Or in east central France. *Champagnes* are produced in the vicinity of Reims and Epernay. Only wines made in this 'Champagne region' have a right to the name. Black and red grapes are used and the manufacture involves a series of elaborate processes which extend over a period of six or seven years.

Making of wine : Selected grapes of appropriate maturity are crushed and stemmed; treated with sulphur dioxide, or a sulphite, or pasteurized; and inoculated with a starter containing a pure culture of selected yeasts (strains of Saccharomyces cerevisiae). The sugar content varies from 12 to 18 per cent. After a short fermentation period the wine is drawn off, placed in storage tanks for further fermentation, racked, stored for aging and finally packaged. Wines vary considerably in their characteristics and in their alcohol content from 7 to 16 per cent. Fermentation of the fruit juice is carried out in vats at an optimum temperature of 200C. The aroma and flavours come from various aromatic compounds present in the fruit. The characteristic bouquet develops only after the wine has been aged from four or five years to several decades. White wines are made from white grapes, or expressed juice. *Red wines* are made from coloured grapes and derive their own colour from the pigments present in the skins of the fruits.

Types of commercial wines : Some of the common commercial wines are

Champagne – foaming wine with dissolved CO_2, its traditional origin being the Champagne region of northeastern France. Its alcohol content is 12%. Champagne is made from only three grapes varieties – the black varieties pinot and meunier, and white grape – chardonnay;

Sparkling wine – produced by carbonation, by injecting CO_2 into the wine;

Liqueur Wine – sweet to taste, with higher ethanol content;

Sherry – fortified wine that comes in two distinct styles: dry wine (without any sweet taste) consumed as an appetizer before meals and oloroso (fortified Spanish sweetened wine usually made from Palomino grapes) taken after meals.

Port – stored in a wooden cask or Hintage ports; during maturation, the type of barrel used for ageing contributes to the quality of wine;

Vermouth – fortified wine flavoured with botanicals in the form of different varieties of herbs and spices.

13.8.2 Other Fermented Alcoholic Beverages

Fermented alcoholic beverages are consumed all over the world. In some countries the use of a particular beverage has been passed down from ancient times. Some of them are :

Sake : the traditional Japanese beverage has been in use for the last 2600 years. It is prepared by fermenting rice and served warm or cold, often during special occasions and ceremonies. It is a yellow rice wine containing 14 to 24 % of alcohol.

Kuass : Quite common in Russia, it is prepared by mixing equal parts of barley malt, rye malt and rye flour, adding boiling water, and then inoculating with yeast to enable fermentation. Peppermint is added to the fermented product for flavouring.

Pulque : A common fermented alcoholic beverage in Mexico, it is prepared by allowing the sweet juice of agave to undergo fermentation with yeasts, a process which is usually completed in a day.

Hard cidar : Here, fresh apple juice is allowed to ferment for 24 hours, the alcohol content gradually increases and hard cider is obtained. Instead of apple juice, pear juice may also be used.

Taette : It is a common fermented alcoholic beverage in Scandinavia. It is an alcoholic beverage prepared from milk. Yeasts cause the characteristic changes in flavour. It has a pleasant acid taste.

Pombe : It is prepared by permitting millet grain to sprout and undergo conversion of the starch to sugars followed by spontaneous fermentation.

Palm wineor Toddy : The fermented juice obtained from the inflorescences of many palms has been a beverage of great antiquity. Palm wine or toddy (Tari) was known to Herodotus as early as 420 BC. The important species of palms which yield toddy include Phoenixdactylifera, Borassus flabellifer, Acrocomia mexicana, inflorescence of Cocos nucifera.

Mead : Wine prepared from honey.

Cider : Wine from apples.

Box13.1 Terroir.
It is a French word which means "land." It is a concept that refers to unique flavours acquired by certain plantation crops such as grapes, coffees, or even chocolates and cheese – under a set unique topographical and climatic factors. These conditions include soil type, climate, geography and human influence. Used in the context of wine manufacture, a terroir explains why the same grape variety can produce wines with vastly different flavours and aromas, when grown in different regions. For instance, a Chardonnay from Burgundy, France will taste different from a Chardonnay from California, USA – due to the distinct terroirs of each region.

13.8.3 Distilled Beverages

Whiskey : Whiskey is an alcohol distillate from a fermented mash of malted or unmalted grains of barley, corn, oats, rye and wheat or potatoes. After several distillations of the mash the "low wines" result. Further distillation yields the "high wines". A mixture of water and high wines makes straight whiskey. Initially, several principles are present which make whisky harsh and unpalatable. It must be aged to allow these principles to disappear. They are aged in charred oak containers. At first the whiskey is colourless; the colour develops during the aging process. A continued distillation of high wines results in the formation of 'neutral spirits' which are used in blended whiskies and cordials. The *Scotch whiskey* (produced in Scotland) is prepared from barley malt. *Irish whiskey* (prepared in Ireland) is made from malt or unmalted grains of barley, oats and maize. They are produced in countries like Scotland (Scotch), Ireland (Irish whiskey), the USA (Bourbon), and Canada. They are either enjoyed neat, on the rocks, or in cocktails such as the *Old Fashioned* and *Whiskey Sour*.

Vodka : It originated from Eastern Europe, and is produced from distilled grains or potatoes. Itis a versatile spirit used in various cocktails like the *Bloody Mary* and *Moscow Mule*, and consumed neat in many cultures. The Vodka is not aged and bottled immediately after distillation and therefore, it remains colourless.

Rum : Rum is an alcoholic distillate from the fermented juice of sugarcane, sugarcane syrup, sugarcane molasses or other sugarcane by-products. Rum is manufactured in general in the countries which grow sugarcane or import molasses or other sugarcane products. It possesses a characteristic flavour, aroma, and colour. The flavour and aroma, improve with aging. Rum contains about 40 % ethanol. It is usually aged in charred white-oak barrels. Rum may be used in the preparation of ice cream, candies and mincemeat; in the curing of tobacco; as a beverage; and as a medicinal. It is popular in the Caribbean and Latin America, used in cocktails like the *Mojito* and *Piña Colada*, and in cooking, especially in desserts and marinades.

Brandy : Brandy is distilled only from wine. It is also distilled from the fermented juice of various fruits. It contains about 65 to 70 % ethanol. The best brandy is made in France in the Charente district. Only this product is called *cognac*. The other French brandies are known as *armagnac*. The finest grades of brandy are prepared from white wines. The brown colour of brandy develops when it is stored in wooden casks. Sometimes the brandy is coloured with caramel. Apple brandy is known as *applejack*. Often enjoyed as an after-dinner digestif, it is commonly used in cocktails, and in cooking to flambé dishes (a cooking technique that involves pouring alcohol into a hot pan and setting it on fire): or to enhance sauces.

Gin : It is obtained by distillation from a fermented mash of malt or raw grain.

The finest gin is distilled from the malt of barley and rye and flavoured with juniper berries and other botanicals. Several distillations are often required. They are a keyingredient in cocktails like the *Martini* and *Gin & Tonic*.

Absinthe is distilled fromanise, fennel, and wormwood. They are traditionally diluted with water and sugar before consumption. They are historically popular in Europe, especially France.

Tequila is distilled fromthe blue agave (*Agave tequilana*) plant. It is the traditional Mexican spirit, consumed neat or in cocktails like the Margarita. It is also used in culinary dishes to impart a distinct flavour.

Mezcal, however, is distilled from various agave species. It is another Mexican spirit known for its smoky flavour, and consumed neat or in cocktails.

Pisco is distilled from fermented grape juice. A South American spirit, popular in Peru and Chile, it is commonly used in cocktails like the *Pisco Sour*.

Cachaça is distilled fromfermented sugarcane juice. A Brazilian spirit, it is used in cocktails like the *Caipirinha*.

Baijiu is produced from distilledsorghum, rice, or other grains. It is a traditional Chinese spirit, often consumed during formal occasions and celebrations.

Soju is obtained from distilled rice,barley, or sweet potatoes. A Korean spirit, it is commonly consumed neat, often with meals.

SAQ III.

(a) From which fruit is the alcoholic beverage calvados prepared?

(b) Which region in France is famous for its red wines?

(c) Which country is the largest producer of beer?

(d) What is ABV? What is the maximum permissible limit of alcohol in low alcoholic beverages?

(e) What is the source of colour of red wines?

13.9 Summary

Now, let us summarize what we have learnt about the tropical and temperate fruits and nuts. Tropical fruits require a warm temperature between 20 and 30 degrees Celsius, high humidity and plenty of rainfall throughout the year. On the other hand, fruits of temperate climates such as apples and pears require cold winters for dormancy and moderate summer temperatures for growth. In India, in addition to a very large number of tropical fruits such as mangoes, papaya, pomegranate, watermelon, many temperate fruits and nuts are found in the northern latitudes – apples, pears, oranges, plums, almonds and so on. Fruits and nuts constitute a very important component of our diet. They contain many important vitamins such as vitamin A and C, essential minerals like potassium and magnesium, important carotenoids with antioxidant and other benefits, dietary fibres, digestive enzymes, anti-inflammatory constituents, all of which promote all-round health and well being.

Alcoholic beverages are integral to many cultures worldwide, each with unique sources, production methods, and uses. These beverages not only reflect the agricultural products of their regions but also play significant roles in social rituals, culinary traditions, and cultural identities. They may be fermented (non-distilled) products such as beer, wine, sake, hard cidar or distilled products such as whiskey, vodka, rum, brandy, gin. They are fermented commonly from the sugars in fruits, berries, grains, or from plant saps, tubers, and honey. Distillation reduces the original watery liquid to a liquid of much greater alcoholic strength. From fruit sap sources for instance, we obtain wine (fermented) and brandy (distilled). Examples of grains as sources include beer (fermented) and whiskey (distilled). According to alcohol content, they can be classified as low alcohol or high alcohol drinks. Low alcoholic beverages should have no more than 1.2% alcohol by volume (ABV), fermentation products such as low –alcohol beer, tequila are examples. Distilled spirits, such as whiskey, vodka, rum, and gin, are well-known for their high alcohol content.

13.10 Terminal Questions

1. Write a concise account of the important fruit crops of India.
2. Write 'True' or 'False'.

(a) India is the largest importer of dry fruits in the world.

(b) Walnuts are a good source of omega-3 fatty acids.

(c) Tropical fruits can be grown in regions with cold winters.

(d) Pineapples are a good source of bromelain, an enzyme that aids digestion.

(e) Pomegranates have anti-inflammatory properties owing to their high antioxidant content.

3. Match the columns I & II.

	Column I		Column II
(a)	Almonds	(i)	Alpha-linolenic acid (ALA)
(b)	Walnuts	(ii)	Taxifolin
(c)	Grape fruits	(iii)	Lutein
(d)	Pomegranates	(iv)	Acetogenins
(e)	Custard apples	(v)	Punicalagin
(f)	Pistachios	(vi)	Naringin
(g)	Guinness	(vii)	Japan
(h)	Prosecco	(viii)	Ireland
(i)	Sake	(ix)	Italy
(j)	Bourbon	(x)	USA

4. Fill in the blanks.

(a) Mangoes, cashew nuts and pistachios belong to the family ___________.

(b) Gin is traditionally flavoured with __________berries.

(c) Tequila is distilled fromthe plant ________ ___________ (scientific name).

(d) Whiskey is prepared from malted ________ and aged in oak barrels.

(e) Brandy is distilled from _____ or fermented fruit juice.

(f) Lager is a kind of _____.

(g) The alcoholic beverage obtained from sugarcane juice or molasses is _____.

(h) Vodka is distilled from _________, rye or wheat.

13.11 Answer key

SAQ I. A Look up sections 13.5 & 13.6.

B. (i) skin; (ii) omega-3 fatty acids; (iii) can; (iv) eye.

SAQ II.

(a) They require warm temperatures, high humidity and plenty of rainfall throughout the year.

(b) See Section 13.6. They require cold winters for dormancy and moderate summer temperatures for growth.

(c) Avocados are rich in healthy monounsaturated fats that help lower LDL. They contain fibres, high level of potassium and anti-oxidants like lutein which supports heart and eye health.

(d) Fill in the blanks :

(i) anthocyanins; (ii) 20 to 30; (iii) C; (iv) resveratrol; (v) lycopene.

SAQ III.

(a) Apples; (b) Bordeaux; (c) China; (d) Alcohol by volume, 1.2%; (e) Red wines are made from coloured grapes and become coloured from pigments present in the skins of the fruits.

Terminal Questions.

1. Look up Section 13.4
2. (a) True; (b) True; (c) False; (d) True; (e) True.
3. (a) (ii); (b) (i); (c) (vi); (d) (v); (e) (iii); (f) (iv); (g) (viii); (h) (ix); (i) (vii); (j) (x)
4. (a) Anacardiaceae; (b) Juniper; (c) Agave tequilana; (d) barley; (e) wine; (f) beer; (g) rum; (h) potatoes.

13.12 References and Further Readings

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Further reading

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Unit – 14 ❑ Wood and Timber-yielding plants

Structure

14.1 Objectives

After studying this unit, you should gain a clear idea about:

- Wood, its characteristics
- The important plants that are sources of timber and other wood
- Processing of various woods products for commercial use; and
- The process of paper manufacture.

14.2 Introduction

By now you know that plants are used for various purposes such as foods, beverages and medicines. In addition, several plant products provide us shelter and clothing. Since ages, food, clothing and shelter have been the cornerstone of humankind. Early human settlements as primordial log houses were built of wood. Navigation in waters was possible only with primitive canoes or boats made of wood. Barks of trees were used as primitive apparel. Different implements and utensils were carved out of wood. In this way you can go on adding to their uses.

Indeed, it is the most readily available and perhaps the most important and versatile of forest products.

Wood is produced as a result of secondary growth in gymnosperms and usually in dicotyledonous plants. Botanically, wood is nothing but secondary xylem. Several indigenous tree species from the natural forests are used in different ways -- as fuel, for construction, timber products, in the form of thin sheets or veneers, and as raw material in the paper industry. Besides timber and fuel, woody tissues yield many useful products such as gum, resin, turpentine, rayon, cork, and rubber. Plant fibres also provide raw material for various products such as cloth, mats, bags, and ropes. Lately, overexploitation and decline in the forest area and tree cover in general, threatens to endanger what was once an inexhaustible natural resource. Judicious utilization and care is needed to keep the forest plantations alive. In this unit we shall discuss the timber plants which are used in this country at a commercial scale, for various purposes.

The loss of tree cover loss is increasing globally, with tropical regions experiencing the most rapid loss. The main causes are agriculture, logging, and forest fires. Over the last 10,000 years the world has lost one-third of its forests. Since 1990, it is estimated that 420 million hectares (mha) of forest have been lost through conversion to other land uses. Nearly 95% of this deforestation occurs in the tropics. Total tropical primary forest loss in 2023 totaled 3.7 mha, the equivalent of losing almost 10 football fields of forest per minute. In 2023, this forest loss produced 2.4 gigatonnes (Gt) of CO_2 emissions. Globally, we deforest around 10 mha of forest each year -- an area the size of Portugal. This loss is only partially offset by afforestation programmes.

14.3 General considerations

Wood has many advantages over metals. It is cheap, light and may easily be worked with tools. It is very strong for its weight and it is embodiment of strength, toughness, and elasticity. It is a bad conductor of heat and electricity.

Timber plants are usually medium to large trees which are cut to extract the wood. It is also known as “lumber” in US and Canada. Timber is used for building houses, furniture, handicrafts, toys, musical instruments, and carving. Timber trees are broadly classified into trees of softwoods, *semi-hardwoods* and *hardwoods*.

Hardwood is derived from angiospermous (mainly dicotyledonous) plants. They are of superior quality that lasts for years. Hardwood plants provide the best quality wood as they possess more resistance and are used for construction of high-end furniture, floors, ceilings and even houses. Wood obtained from oak, birch, beech, is called hardwood. Softwoods are obtained from gymnosperms, mainly coniferous trees. Softwood is generally used in the manufacture of products such as crates for vegetables, crafts and even paper. Wood from the sturdy stems used in construction, furniture and paper pulp is timber and products produced or derived from them are timber products. Timber has a high strength to weight ratio. Products produced/ derived from other woody parts of plants are termed as *wood products*.

No less than 500 timber species are known whose trunk and branches provide wood. Some of the important timber trees are: Khair (*Acacia catechu*), Babla (*Acacianilotica*), Chatim (*Alstoniascholaris*), Itchri (*Anogeissus acuminata*), Kadam (*Neolamarckiacadamba*), Shimul (*Bombax ceiba*), Kamdeb (*Calophyllumpolyanthum*), Batna (*Castanopsis tribuloides*), Shisham/shishoo (*Dalbergia sissoo*), Garjan (*Dipterocarpus alatus*), Gamar (*Gmelina arborea*), Sundari (*Heritierafomes*), Telsur (*Hopea odorata*), Jarul/Sidha (*Lagerstroemia parviflora*), Aam (*Mangifera indica*), Tali (*Palaquiumpolyanthum*), Batna (*Quercus spicata*), Bilatishirish (*Samanea saman*), Sal (*Shorea robusta*), Dharmara (*Sterospermumpersonatum*), Mahogony (*Swietenia macrophylla and S. mahagony*), Teak (*Tectona grandis*), Toon (*Toona ciliata*).

The International trade code of flora and fauna governs the timber species suitable for commercialization and export.

Anatomical features of Wood

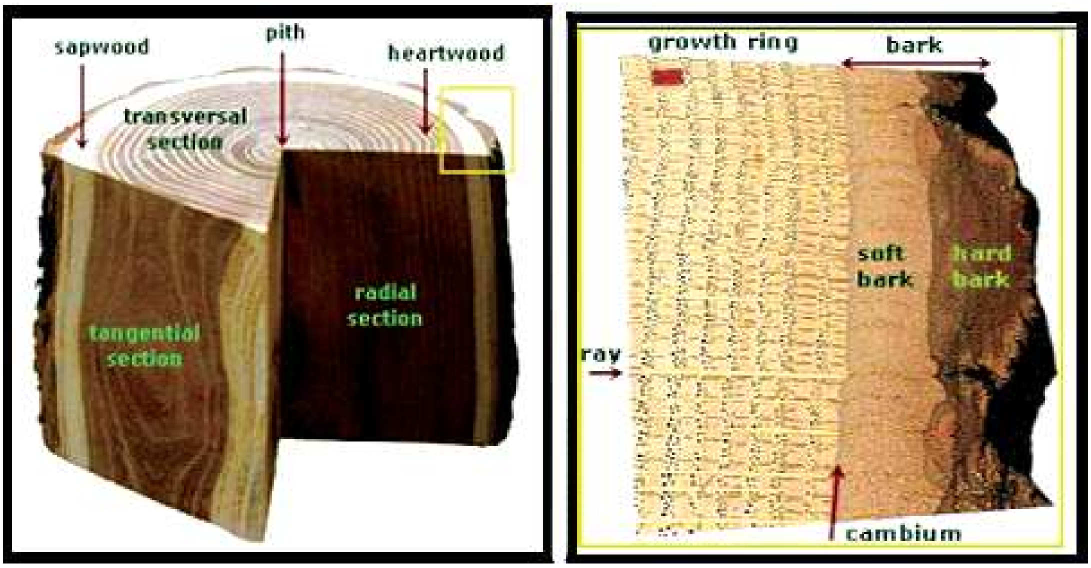
Commercial woods may be identified based on several important diagnostic features. Anatomical features are observed commonly in transverse sections, and in radial and tangential longitudinal sections (Fig. 14.1)

Porous and Nonporous woods

The presence or absence, and the nature and arrangement of *pores*, serve as a ready means of classifying woods. The coniferous woods do not possess pores, and are termed *nonporouswoods*, whereas the angiospermic woods possess numerous pores and are termed as porous woods. On the basis of the distribution of pores, the woods may be of two types-*ring porous* and *diffuse porous* woods. In ring porous woods (e.g., ash, elm, oak) the pores are found to be arranged in concentric circles, the outer and inner portions of which differ with regard to the number and size of the pores. In diffuse porous woods (e.g., beech maple, walnut) the pores are small and nearly of the same size and are found to be scattered uniformly throughout the wood. In some species (e.g. black walnut and butternut), pores are large in the early wood and smaller toward the latewood, but without the distinct zoning seen in ring-porous woods. We call them *semi-ring porous wood*. Moreover, some species that are usually ring-porous (e.g. cottonwood) occasionally tend toward semi-ring porous nature (Fig. 14.2).

Early wood and late wood

In temperate regions every year, new wood is formed in a limited growing season, with the result that definite *growth layers* develop, which shows two distinct areas within each layer. The wood formed in the spring is called the spring wood or early wood, and that formed in winter is called the *autumnwood* or *late wood*. There is a sharp contrast between the late autumn wood and the early spring wood, and this makes the successive rings distinct. The growth ring of a single year is called an annual ringand the number of these annual rings gives an indication of the age of tree. Annual rings of successive years may vary greatly in width. Wide rings are formed under favourable conditions of growth of the tree, and narrow ones are formed when conditions are unfavourable.



(a) Wood in different sectional views *(b) Inset: Growth rings and bark*

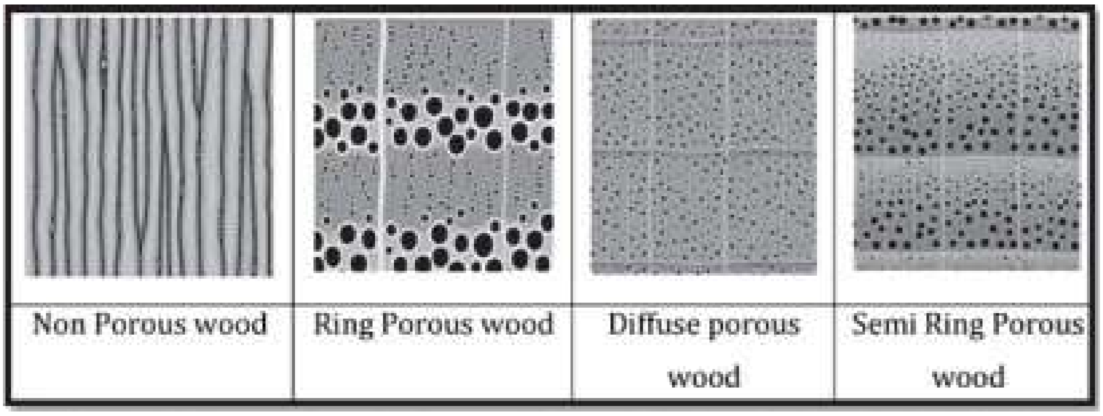
Figure 14.1

Sapwood and Heartwood

The outer region of the wood which is of lighter colour is known as the sapwood, and this alone is used for conduction of water and salt solutions. The cells of this region are alive and physiologically active. In old trees the central region of the secondary wood is filled up with tannin and other substances which make it hard and durable. This region is known as the heartwood. It looks black owing to the presence in it of tannins, oils, gums and resins. Heartwood gives mechanical support to the stem. The heartwood usually takes good polish and is used for cabinet work, furniture and other high-grade woodworking industries.

Texture, grain and figure

Texture refers to the relative size and quality of the various woods, while grain refers to their structural arrangement.



Rays

The rays are made of parenchyma cells that are oriented at right angles to the main axis of the stem. They vary greatly in width, height and arrangement.

Figure 14.2 Porous woods–classified according to the arrangement of pores

SAQ I. Give brief answers.

(a) In what ways is wood advantageous over metal as a raw material?

(b) What is hardwood? Give one example.

(c) What is softwood? Cite one Indian example.

(d) Mention two uses of wood in construction.

(e) What is 'early wood' and 'late wood'?

(f) How can you distinguish between 'sap wood' and 'hard wood'?

(g) Could you make a distinction between timber and wood products?

14.4 Important Wood and Timber-yielding plants

Let us now delve deeper into some of the important timber yielding trees of our country.

- Tectona grandis Family : Verbenaceae. Common names: Teak, Rangoon / Burma Teak.

Distribution : In India, teak forests are present in the states of Madhya Pradesh, Maharashtra, Gujarat, Karnataka, Rajasthan, Kerala, Tamil Nadu, and Andhra Pradesh (Fig. 14.3).

Characteristics : Teak is highly valued for its wood which is of superior quality. Wood - deep yellow to dark brown; moderately hard, does not split, warp or crack; density -- 639 kg/m^3 ; highly durable, not attacked by white ants and dry rot, even when unprotected by preservatives; fire- and water resistant. It can be easily seasoned and worked; takes up a good polish. It does not corrode iron fastenings and it shrinks little. The sapwood is whitish and rather susceptible to attack by termites and wood-rotting fungi. The heartwood is golden yellow to golden brown when freshly sawn, turning darker after exposure and is relatively immune to insect attack. The wood is greasy to touch and smells like old leather. The grain is normally straight, and the texture is coarse and uneven. It shows distinct growth rings. The wood is ring porous and is marked by the presence of large vessels (Fig. 14.4). The vessels of early wood are distinctly larger than those of the late wood. The pores seem to be arranged in concentric circles when seen in a transverse section. Tyloses are quite common.

Uses : It is among the most valuable timber trees of the world and its use is limited to superior works only. It is the chief source of timber for railway carriage and wagons in India. It is superior to oak in ship-building. Its wood is used in construction of houses; building bridges; making cabinets and boats; for veneer and carvings; plywood manufacture; for flooring; making toys, and in many other ways.

Figure 14.3. Teak plantations

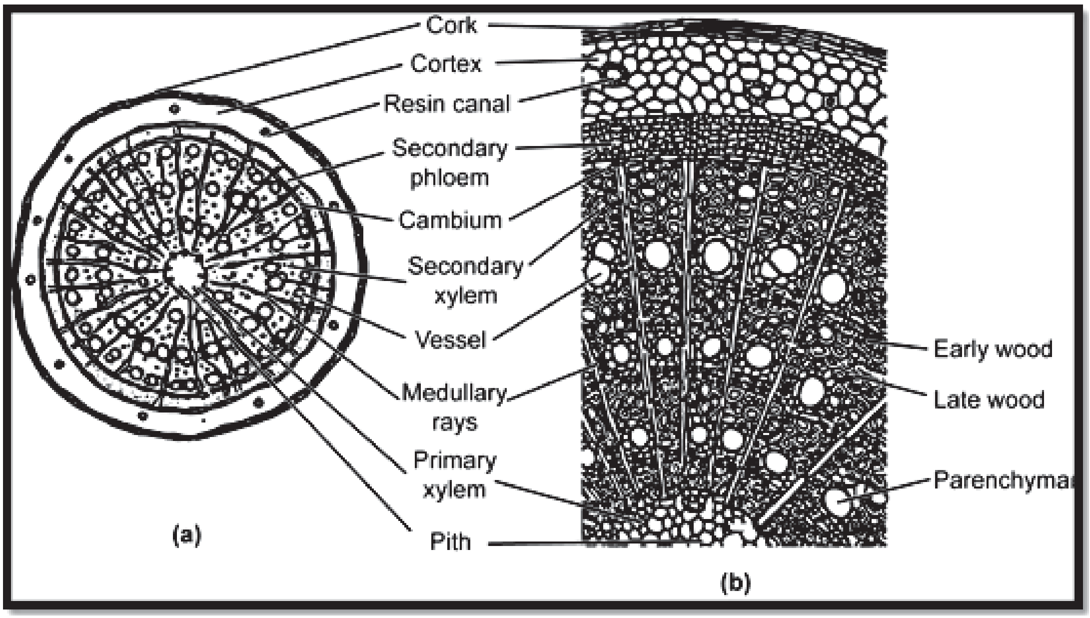


Figure 14.4. (a) A section of wood obtained from trunk of teak; (b) TS of Tectona stem.

- ***Shorea robusta*** Family *:* Dipterocarpaceae. Common names: Sal

Distribution : Indigenous to India and common in forests of India and Nepal. It is more common in West Bengal, Jharkhand, Bihar, Chhattisgarh, Orissa, Madhya Pradesh, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh.

Characteristics : It is one of India's most important sources of hardwood. When freshly cut, it is identified by its light color and coarse grain. However, exposure to sunlight darkens its wood. One of the toughest timbers available today, Sal wood is hard, fibrous and coarse grained with a density of ~ 880–1,050 kg/m3.This wood is strong enough to withstand water, making it ideal for use in cold climates. It requires slow and careful seasoning. It is also heavier and tougher than teak and is resistant to fungi, water and termites. It is best to season the wood before using it as this helps display the properties of sal wood better. It is highly resinous, durable, sturdy, resilient and termite-resistant. It does not take up a good polish. Sal wood's best quality is its ability to get stronger and tougher with age.

Uses : Sal wood is very strong and durable; hence it is ideal for making the body of a truck. It is also used in the construction industry and to make furniture and beams (Fig. 14.5). It is also frequently used for railway sleepers, shipbuilding, and bridges.

Figure 14.5 (a) Sal forest (b) Flowering shoot (c) Sal timber

- ***Dalbergia sissoo*** Roxb. Family: Fabaceae. Common names: Sishoo, Shisham, Rosewood, Tali.

Distribution : Sissoo occurs throughout the sub-Himalayan tracts to Assam, West Bengal and Orissa (Fig.14.6a & b). Indian rosewood (*Dalbergia latifolia*) is found in central and southern Indian states like Maharashtra and Mysore. Other common *Dalbergia* species are *D. nigra* (Brazilian rosewood), *D.melanoxylon* (African Blackwood), *D. retusa* (cocobolo) and *D. stevensonii* (Honduras rosewood).

Characteristics : It is a durable, heavy wood with yellowish white wood, strong and tough, density -- 770 kg/m^3. It is durable and handsome and it maintains its shape well. The wood is difficult to work but it takes on a fine polish. It can however be easily seasoned. The sapwood is white to brownish, and the heartwood is golden brown to dark brown. The pale, straw-colored sapwood is clearly demarcated from the heartwood.

Uses : It is used for high quality furniture, plywoods, bridge piles, sport goods, and railway sleepers, musical instruments, hammer handles, shoe heels and tobacco pipes. It is a very good material for decorative works, veneers and carvings. It is also good for manufacturing charcoals.

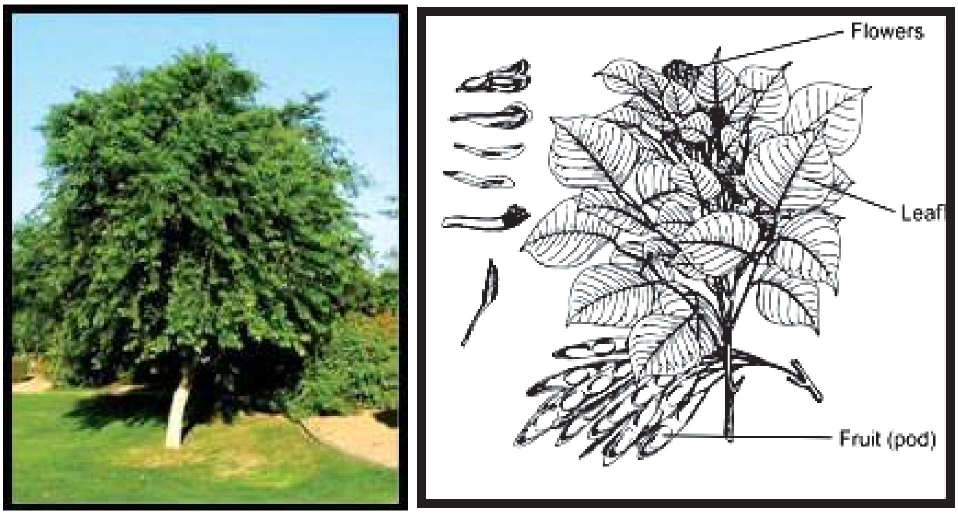


Figure 14.6 (a) *Dalbergia sissoo* (b) *Flowering twig of Dalbergia*

- *Pine* Family Pinaceae. The following *five* species are indigenous to the Indian Himalayas.

Pinus roxburghii Sarg. Common name : Chir pine.

Distribution : This pine is native to northern India, including Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Assam (Kameng district) and Arunachal Pradesh. It also grows in Nepal, Bhutan, and Myanmar. Chir pine grows at lower altitudes than other Himalayan pines, usually between 500–2,000 m (1,600–6,600 ft).

Pinus wallichiana AB Jackson. Common name : Himalayan Blue Pine, Kail

Distribution : Found at higher altitudes (1800m to 2500m or above) mostly in Himachal Pradesh, Jammu & Kashmir, and Uttarakhand. Blue pine occurs in slightly wet areas or moist areas and thus fire occurrence is less in Blue pine forests.

The pine needles in this species are borne in fascicles of 5, unlike most other species.

Pinus gerardiana Wall ex D Don Common name: Chilgoza pine

Distribution : Mostly in Himachal Pradesh and in parts of Jammu and Kashmir.

Pinus kesiya Royle ex Gordon; Syn.P. insularis Endl.

Distribution : Assam, Meghalaya, West khasi hills

Pinus merkusii Jungh& de Vriese. Common name: Merkus Pine, Tenasserim pine.

Distribution : Found in the northeastern part of India in the Anjaw district of Arunachal Pradesh and the Lohit district of the extreme northeast part of the Himalaya.

Characteristics : Pine wood is hard and tough except white pine which is soft. It decays easily if it comes into contact with soil. It is heavy and coarse grained. Pine timber falls into two broad categories - the *soft* or *white* pines, and the *hard, yellow or pitch pines*. The former have soft, light-colored wood-tinged pink in the heartwood and nearly white in the sapwood. The latter have a resinous, heavy, hard, strong, and durable wood, with a pronounced, grain pattern. The wood is light, easy to work but not durable. The timber is straight- grained and has little resin.

Figure 14.7a. Female cones of *Pinus wallichiana* (longest), of pine *P. roxburghii& P. gerardiana* (shortest), **Figure 14.7b.** Bark and wood

Figure14.8 Chir pine (a) tree (b) bark

Uses : It is used for pattern making, frames for doors and windows, and for paving material. White pine is light and straight grained and is used in the manufacture of matches. Soft pines are used for making matches, crates, boxes and rough carpentry work. Hard pine is used in construction of buildings, bridges and ships. The Chir pine plantations were raised by the Britishers mainly to obtain resin.

- Deodar. ***Cedrus deodara*** (Roxb. ex D. Don) G. Don. Family : Pinaceae Common name : Deodar, Himalayan cedar.

Cedrus has four species namely *C. atlantica* (atlas cedar), *C. brevifola* (Cyprian cedar), *C. libani* (Cedar of Lebanon), *C. deodara* (Deodar Cedar Tree, Himalayan Cedar). [Fig. 14.9 a & b].

Distribution : Distributed mostly in the North-Western Himalayas – in Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh and Punjab. The tree is actually native to mountainous areas of the Mediterranean region and one species to the western Himalaya.

Characteristics : Cedar is one of the most important and strongest Indian softwood. The wood has antifungal, antibacterial, and insect repellent properties. Cedarwood is light, soft, resinous, and durable. Its sapwood is white in colour and the heartwood is light yellow, turning brown on exposure to air. Wood is fine and uniform in texture. True cedars are evergreen and have aromatic, often red or red-tinged wood that is resistant to decay and insects.

Use : It is used in construction for railway coaches and sleepers, bridges, beams, floorboards, posts, door and window frames, and shingles. It is also used in making pencils, chests, closet linings, carving, fence posts and packing. Distilled oil from the wood is used in many toiletries.

Figure 14.9 (a) *Cedrus deodara* (b) *Female cones*

14.4 Wood – its diverse uses

Woods are being put to different uses and processed to make them suitable for the requisite purpose. Different woods are used for different purposes. Some of the common examples are discussed below.

Processing wood for use : Trees are felled by cutting across the trunk close to the ground. The side branches are then removed, and the trunks are cut into suitable lengths, known as *saw logs*. Today, powered saws are used instead of hand saws in several parts of the world. Wood is unique among the various raw materials and it is still irreplaceable. It has a number of uses such as for fuel, construction work, furniture, containers, mechanically reduced products, chemically derived products and so on.

1. Fuel

Wood is used as a fuel for heating and cooking from prehistoric times. Later of course, it was largely replaced by fossil fuels or electricity except for poor backward communities and certain rural households. Wood is an excellent fuel, since 90% of the oven dried wood is combustible. However, their value as fuel can vary. It depends mainly on their density, chemical composition, and the amount of moisture. The hardwoods such as beech, oak, maple, and birch are one of the best fuelwood. The average calorific value of seasoned wood is around 4600 cal/kg.

2. Construction and allied purposes

Certain kinds of timber are adjudged ideal for construction and related purposes. They include all parts of houses and buildings, bridges and similar structures not actually in contact with water or the earth. For such work, the timber should of course be strong and durable. Even the lightness of wood is sometimes an asset if strength and durability are not sacrificed. Three outstanding woods for such purposes (*building timbers*) are *Tectona grandis* (Teak- Segun), *Shorea robusta* (Sal) and *Cedrus deodara* (Deodar). The other important timbers used for this purpose are *Acacia* spp., *Toona ciliata* (toon), *Dalbergia* spp., *Mangifera indica* (Am), *Pinus* spp. and *Terminalia* spp. There are many items where appropriate timber are used. Some of them are mentioned here.

(a) *Poles* - Employed chiefly for telephone, telegraph, and electrical transmission lines. Durable wood, which is light, straight, and strong to resist stresses, is used. Coniferous trees are the principal source of wood for such uses -- *Pinus roxburghii* (Chir), *Cedrus deodara* (Deodar); other woods such as those of *Shorea robusta* (Sal), *Tectona grandis* (Teak), *Terminaliatomentosa* (Laurel) are also used frequently.

(b) *Pilings* - Used for the construction of docks, bridges, and wharves. These are straight, round timber, driven beneath water for construction work. Pines are commonly used and so is oak, the latter mainly for dock and harbour work and for marine pilings.

(c) *Posts* - Used for the erection and maintenance of fence lines along farm and ranch boundaries, railroads, and highways. Strength, lightness, and durability are the main requirements. Any available local species can be used.

(d) *Mine timbers* - Include a variety of wooden supports such as props or legs, crossbars or caps used in tile construction of mine tunnels to prevent debris from falling or where the underground formations are likely to cave in. Mostly those hardwoods that are durable and strong and resistant to decay and corrosion are employed for the purpose.

(e) *Railroad ties or sleepers or cross ties* - Used to support and hold railroad rails. The wood used need to be durable, treatable and able to withstand the impact and pressure of heavy and speedy traffic, hold spikes and screws and be easily available and inexpensive. Oak is the most widely used wood for this purpose. The wood is usually treated with preservatives and can last up to 30 years. For Railway sleepers, the most commonly used woods are- sal, deodar, teak, pyinkado (*Xylia xylocarpa*), and bijasal.

(f) *Boat and ship-building* -Timber used in all small boats and large ships is subjected to very great strains, and is often employed under circumstances which tax its durability to the utmost. For this reason, any timber used for ship and boat-building should be strong, elastic, durable and free from defects. *Tectona grandis* (Teak-Segun) is the best ship-building timber in the world, due to its relatively small co-efficient of expansion and contraction and to its durability. The other recommended timbers for this purpose are- *Acacia nilotica* (Babul), species of *Dalbergia, Dipterocarpus, Shorea, Xylia, Grewia, Morus, Terminalia, Bombax* and so on.

(g) *Railway carriage and wagon building* -- The wood to be used in railway carriage and wagon work should be sufficiently strong and durable. It should be free from bad seasoning defects, and at the same time be available in sufficient quantities. Teak complies with this specification better than any other timber, and for this reason it has been the main timber used by all the railway wagon and carriage works in India. The other important timbers used for this purpose are- *Shorea robusta, Pterocarpus* spp., *Adina cordifolia, Cedrus deodara, Dalbergia latifolia, Toona ciliata, Acacia nilotica, Dipterocarpus* spp., and several others.

(h) *Furniture, cabinet making and paneling* -- For high class furniture, cabinets and decorative panel work, there are several very ornamental and excellent woods in India. The chief characteristics required for these uses are resistance to crack and split, retention of shape, ease of working and good colour figure and grain. The most commonly used and recommended timbers for the purpose come from *Tectonagrandis* (teak), *Toonaciliata* (toona), *Terminalia tomentosa* (Laurel), *Juglans regia* (walnut) and species of *Albizia, Artocarpus, Dalbergia* and so on.

(i) *Veneers* - These are thin sheets of wood of uniform thickness, produced by peeling, slicing, or sawing logs. Commonly, their thickness is about 1/20 in. to 3/8 inches. Veneers are made by one of the following three methods - rotary cutting, slicing, or sawing. Of these, rotary cutting is the most common method.

Logs selected for this process are debarked and softened by steaming or steeping in hot water. This facilitates cutting and minimises the danger of splitting. They are then crosscut to desired lengths. Many woods like Douglas fir, Ponderosa pine and Poplars are used. Fine veneers are made from expensive woods like walnut, teak, and rosewood. The veneers are used in the manufacture of boxes, baskets, door panels, cooperage, trunks, mirrors, musical instruments and several other articles.

(j) *Plywood* - It is a thin board made up of an odd number of (usually three to nine) very thin sheets of veneers glued together under pressure, ranging in thickness from 3-25 mm. Successive veneers are positioned in such a way that the grain of each is at right angles to the adjoining sheet (in a cross-banded way), making the structure as strong and even stronger than the wood itself. The major advantage of plywood over solid woods is dimensional stability and that it is much less likely to warp or twist like ordinary wood. Since the strength of plywoods is redistributed, nails and screws can safely be driven close to their edge without splitting them. They can also be molded to larger sizes – suitable for making partitions, walls, flooring and roofs. Plywood is used for inner cabinet work, automobile body parts, boards, ceilings, counters, desks, drawers, and furniture.

(k) Laminboards – Laminboards are usually constructed from cheap inferior woods for the cores, and better quality decorative good for the faces. Wood from pine, spruce, fir, *Bombax ceiba, Ailanthus grandis, Tetramelesnudiflora* and *Kydiacalycina* are very suitable for core work, while superior timbers such as teak, rosewood, sissoo and toon make excellent face veneers. The laminboards are used for making doors and cabinets. (Fig. 14.10)

3. Containers

Cooperage – It is the art of making wood containers such as barrels, tubs, tanks, and the construction of wooden pipelines for transporting city water supplies. There are two principal divisions of the cooperage industry, namely, *slack (or dry) cooperage* made for packaging, storing, and transporting dry material such as cement and *tight (or wet) cooperage* for holding liquids such as beer, whisky, and wine syrups. Woods selected for slack cooperage must be cheap, light, easy to work, elastic and free from warping. Pine, beech, oak, maple, spruce, *Bombax ceiba* (Simul), mango are commonly employed. For making tight cooperage the inner walls are coated with an inert material such as paraffin, silicate of soda or glue to prevent leakage and contamination of liquids. Hardwoods, especially oak are commonly used because of their strength and durability, impenetrable nature, and thermal insulation properties. Woods of other trees used for the purpose include red gum, white ash, yellow birch, Douglas fir, *Grewia tiliifolia* (Dhaman).

Packing cases and boxes -- Wood for such use must be light, easily worked and cheap. Tea is now generally packed in plywood chests, which are strong, light and cheap. Hollock (*Terminalia myriocarpa*) is used for making good plywood tea chests. The commonest Indian woods for packing cases and boxes include those from species of *Dalbergia*, toon, teak, mango, siris, kadam, pine, *Terminalia chebula* and so on. Cigar boxes in South India are made from *Toona ciliata* and *Melia azedarach* and coffee boxes from *Terminaliachebula*. Wood from poplar (*Populus* spp.) is often for manufacturing fruit crates in Kashmir.

Figure 14.10. Major types of engineered wood products. [Source: Gong M. Wood and Engineered Wood Products: Stress and Deformation. Engineered Wood Products for Construction. IntechOpen; 2022. Available from: http://dx.doi.org/10.5772/intechopen.101199]

4. Chemical Products

Wood is mainly made up of cellulose, hemicellulose, lignin and varying amounts of tannins, resins, gums, and latex. It serves as a basic raw material for deriving several chemical products using various methods. Some examples are given below :

Wood distillation - This is an ancient process. One of the chief sources of wood for destructive distillation is the waste left by lumbering operations and sawmills. The wood is heated in a cast iron or steel retort or oven in the absence of air. Charcoal residue is left behind in the retort, and the escaping vapors are conducted through water-cooled condensers. The condensate (pyroligneous acid) is allowed to settle, and tar and oils are separated out from the liquid above. Meanwhile the non-condensable gases are trapped and are used to help heat the oven.

Based upon the kind of wood used, distillation can be classified into hardwood and *softwood distillation*. Denser and heavier woods like sugar maple, birch, oak, and beech are employed in hardwood distillation and the products are:

(i) Charcoal - the solid residue,

(ii) Pyroligneous acid - a yellowish green, ill smelling liquor or condensate consisting of water, acetic acid, methanol, and dissolved tar,

(iii) Wood tar - the water-insoluble fraction that settles at the bottom of the aqueous pyroligneous acid,

(iv) Non-condensable wood gas -- used as fuel or for illumination purposes.

On the other hand, *softwood distillation* utilises resinous pinewoods, chiefly of long leaf and slash pines. The principal distillation products are charcoal, wood turpentine, pine oil, dipentine, pine tar, tar oils, wood gas and a small amount of wood alcohol (methanol) and acetic acid.

Tapping for naval stores industry - The term 'Naval Stores' was initially used to designate the pitch obtained by tapping pine trees. Pitch and its derivatives were used extensively by the European maritime industry in the late 16th century for caulking the planks of wooden sailing ships and for water proofing riggings and hawsers. The species used today are the long leaf and slash pines in the USA, maritime pine (*Pinus pinaster*) in Europe, and *Pinus roxburghii* in India. Besides pines, Douglas fir, spruces and larches are the other conifers tapped for the purpose.

Three different types of products are obtained by this industry: (i) gum turpentine and gum rosin, derived from the gum (oleoresin) bled from living trees; (ii) wood turpentine and wood rosin, obtained by the action of steam and suitable solvents on macerated or chipped stumps and roots left behind after lumbering; and (iii) sulphate turpentine and sulphate rosin, important byproducts of pulp mills employing the sulphate process for pulping resinous woods.

Crude turpentine is collected by tapping when the trees have attained a girth of 23 cm or more. The crude turpentine contains about 20% spirit of turpentine, 65% rosin, 5 to 10% water, some plant tissues and dust. It is distilled in steam distillation plants to isolate its useful components. The distillate consists of water and spirits of turpentine while the hot molten amber to dark-red residue that remains behind is the rosin of commerce.

Spirit of turpentine is used as a thinning material in the paint and varnish industry, as a solvent for rubber and gutta-percha, and for the manufacture of printing cloth, waters proofing compounds, leather dressings, synthetic camphor, many pharmaceuticals such as liniments and many other chemicals. Rosin is used for preparing paints and varnishes, polishes, waxes, soaps, oil cloth, 'linoleum', sealing wax, printing ink, roofing and floor covering adhesives, plastics, rubber, wood preservatives, disinfectants, drugs, and chemicals. Rosin is also used in the paper industry for sizing, i.e., for imparting luster and weight, and hindering absorption of ink or moisture. Rosin oil is used in the manufacture of greases, lubricants, and solvents.

SAQ II.

(a) Why is teakwood highly valued?

(b) State one important advantage of working with plywoods.

(c) State whether the statements are 'True' or 'False'

(i) Laminboards are commonly used for making doors and cabinets.

(ii) The most valuable timber in our country is obtained from Sal.

(iii) Plywood is made from common timber.

(iv) Timber from Himalayan Cedar is rarely attacked by white ants or fungi.

(v) Seasoning of timber is done to increase its moisture content.

(vi) The heart wood represents the central core which is surrounded by annual rings.

(vii) Charcoal, pyroligneous acid and wood tar are the principal products of hardwood distillation.

5. Cellulose Derived Products

Cellulose is a carbohydrate [$(C_6H_{10}O_5)$,] and is an important component of cell walls. Cotton was originally used as a source of cellulose, but now wood pulp is generally employed. It is used in the manufacture of such products as paper and rayon.

Manufacture of Papers from wood pulp

The global paper production capacity is projected to reach 510 million tons by 2025, driven by rising demand for packaging, printing, and writing paper products.

Cotton and linen rags were the principal sources till the last century and are still used for the manufacture of the finest grade paper. Manila and sisal hemp, crop wastes and rejects from textile factories or cotton linter recovered during the processing of cotton seed are also used. Rags, hemp ropes, jute wastes, and wastepaper are also converted into pulp. Presently, wood fibers are the most important raw materials used. About 97% of the world's paper and paperboard is made from wood pulp, of which nearly 85% is derived from coniferous woods like spruces (*Picea* spp.), firs (*Abies* spp.) and pines (*Pinus* spp.). The hardwoods used in paper manufacture are mostly poplar (*Populus* spp.), birch (*Betula* spp.), beech (*Fagus* spp.) and eucalyptus (*Eucalyptus* spp). In India, the raw fibres are sourced from bamboos (especially *Bambusa arundinacea* and *Dendrocalamusstrictus*), sabai-grass (*Eulaliopsisbinata*), bagasse and salai-wood (*Boswellia serrata*). The paper manufacturing process is a complex and resource-intensive process that involves converting raw materials such as wood, recycled paper, or other plant-based fibers into high-quality paper products. Paper is a ubiquitous product that is used in a variety of applications, from printing and packaging to hygiene and personal care products.

We shall concentrate on the process of manufacture of paper from wood pulps. The entire process of paper manufacture from wood pulp is a blend of both art and science, with meticulous control over every step to ensure the quality and consistency of the final product. The paper manufacturing process is a complex and resource-intensive process that involves converting raw materials such as wood, recycled paper, or other plant-based fibers into high-quality paper products. Paper is a ubiquitous product that is used in a variety of applications, from printing and packaging to hygiene and personal care products. Paper manufacturing from wood pulp involves several steps. Here is an outline of the major steps.

(a) *Preparation of Raw Materials*

The process begins with sourcing suitable wood. The trees harvested and transported to a mill, where they are debarked and chipped into small pieces. Debarking is carried out with mechanical drum debarkers or hydraulic bark removers. Mechanical chippers are used for cutting the debarked logs into small wood chips.

(b) *Pulping Process*

Wood chips are ground into pulp by *mechanical* forces (e.g., stone groundwood or refiner mechanical pulp) or they are digested with chemicals (e.g., kraft or sulfite process) to dissolve lignin and separate the fibres. With mechanical pulping, lignin and other non-cellulose products are not removed; the pulp and its products deteriorate in strength and turn yellow with age. But the paper has good opacity, bulk, and printing quality. Such pulp is largely used for newsprint, wrapping and wall papers. Only the light-colored and long-fibred coniferous woods especially spruce are used. In India, Salaiwood (*Boswellia serrata*) is most widely used for mechanical pulping (Fig 14.11).

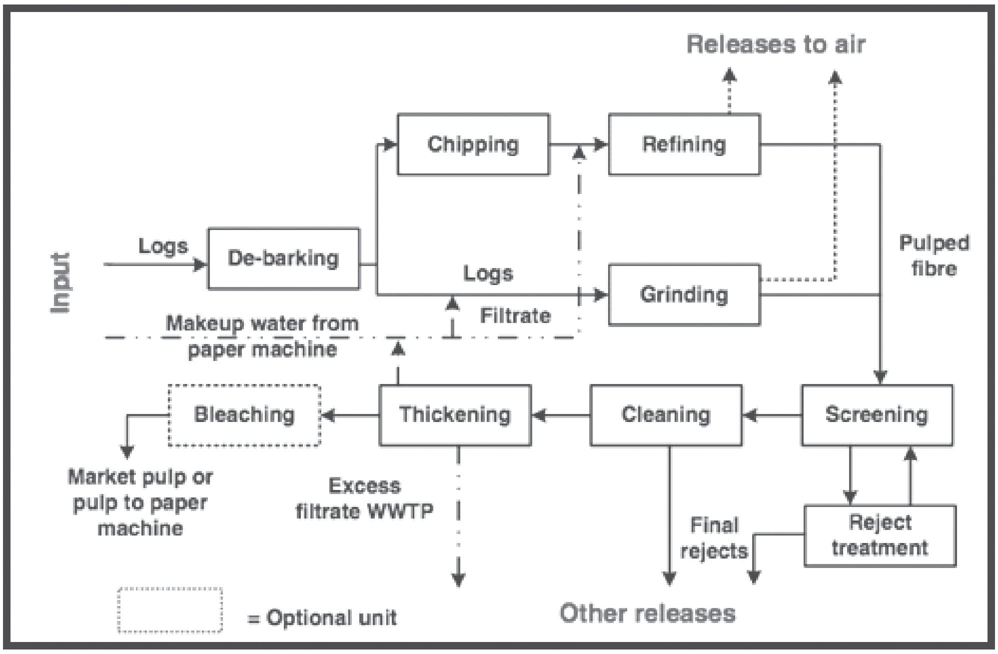


Figure 14.11 Mechanical processing of wood to make paper

Chemical pulping is often preferred for producing high-quality paper. Softwoods with little or no resin (spruce, fir, hemlock) and some hardwoods are used in this process. The sulphite pulp is used in the manufacture of printing, bond, tissue and wrapping papers, in rayon and newsprint. *Soda pulp* (*mixed with sulphite pulp*) is used in the manufacture of printing paper for books, and better grade magazines. *Sulphate pulp* is used for making a strong brown kraft wrapping paper (used in craft work and as cover paper), paper bags and paper board. Sometimes mechanical and chemical pulping may be combined (*semi-chemical*) for specific applications. Hardwoods are generally used in this process. Wood chips are at first softened by mild chemical action and thereafter defibration is accomplished by mechanical action. This method yields 65- 85% pulp of the dry weight of wood. The higher yield in comparison to chemical pulping is because of the retention of about 50% of the lignin and 30-40% of the hemi-cellulose. Optionally, used paper products are processed into pulp through deinking and cleaning.

Pulp obtained from chemical and semi-chemical processes is subjected to a treatment called *beating* (Fig. 14.12) which separates the fibres from one another, shortens and bruises them. Consequently, they cling firmly forming a uniform sheet on the paper-making machine later. The degree of beating influences the texture of the paper obtained. A variety of materials are added to the pulp stock in the beater to improve the quality of the paper. Mineral fillers give weight and opacity to the paper by filling the interstices. China clay, talc, calcium sulphate, zinc sulfide, titanium oxide and calcium carbonate are some important fillers. Sizings such as rosin, soap, wax, and starch make the surface smooth and impervious to ink. Currently, emulsions like polyvinyl acetate, polyesters, vinyl chloride and acrylic resins are also being used for sizing (Fig. 14.12).

(c) *Pulp Washing and Screening*

Washing removes residual chemicals and impurities while screening filters out large or unwanted particles using screens.

(d) *Bleaching (Optional)*

It removes remaining lignin to produce white paper. Common bleaching agents include chlorine dioxide, oxygen, or hydrogen peroxide.

(e) *Papermaking Process*

Stock Preparation involves using additives such as fillers (e.g., clay, calcium carbonate) and sizing agents (e.g., rosin, starch) are mixed into the pulp.

Forming – the pulp slurry is spread over a wire mesh to form a continuous sheet.

Pressing – Water is removed from the sheet by pressing it through rollers.

Drying – more water is removed with heated rollers or by air drying.

Calendering – It smoothes and finishes the paper surface.

Finishing and Packaging – It involves :

(i) Coating (Optional) : A layer of coating is applied to improve surface properties for specific uses.

(ii) Cutting and Reeling : The paper is cut to size and wound into rolls or sheets.

(iii) Packaging : The finished paper products are packaged for shipping and distribution.

(f) *Quality Control*

Tests are carried out for paper properties such as weight, thickness, strength, and brightness. Some adjustments may be necessary to meet specifications.

The process of paper manufacture generates considerable wastes, including water, chemicals, and paper sludge, which can have a significant environmental impact if not managed properly. The industry in recent times is under increasing pressure to adopt more sustainable and efficient practices – to reduce waste, conserve natural resources, and minimize environmental impact.

6. Agricultural implements

Agricultural implements refers to the appliances as ploughs, harrows, rollers and clod crushers. A strong, hard tough timber is required for this type of work. Plants such as *Acacia nilotica* (Babul), *Anogeissus latifolia* (axle wood), *Syzygiumcumini* (Jaman), *Grewia tiliifolia* (Dhaman), *Shorea robusta* (Sal), *Xyliaxylocarpa* (Irul), are used for agricultural implements of different kinds.

7. Axe helves and tool handles

Woods for helves and tool handles must be strong and tough and must also possess great shock resisting abilities. Species such as those of *Dalbergia* (Shisham), *Grewia* (Dhaman), *Diospyros* (ebony) are recommended for this purpose.

8. Boot lasts and shoe heels

There is a considerable demand in India for boot and shoe lasts, and recently demand for shoe heels, and especially ladies' shoe heels, has grown enormously. For boot lasts and shoe heels, a tough wood which is not too hard is required. The important woods used for the purpose are- *Dalbergia sissoo* (Shisham), *Gardenia* spp., *Mitragynaparvifrora* (Kaim), *Mangifera indica* (Am).

9. Cart and carriage building

The various parts of a cart or carriage are subjected to different kinds of stresses and strains, and require different qualities of wood for real efficiency. The important woods recommended include species of *Dalbergia, Shorea, Dipterocarpus, Syzygium, Acacia, Grewia, Terminalia* and several others.

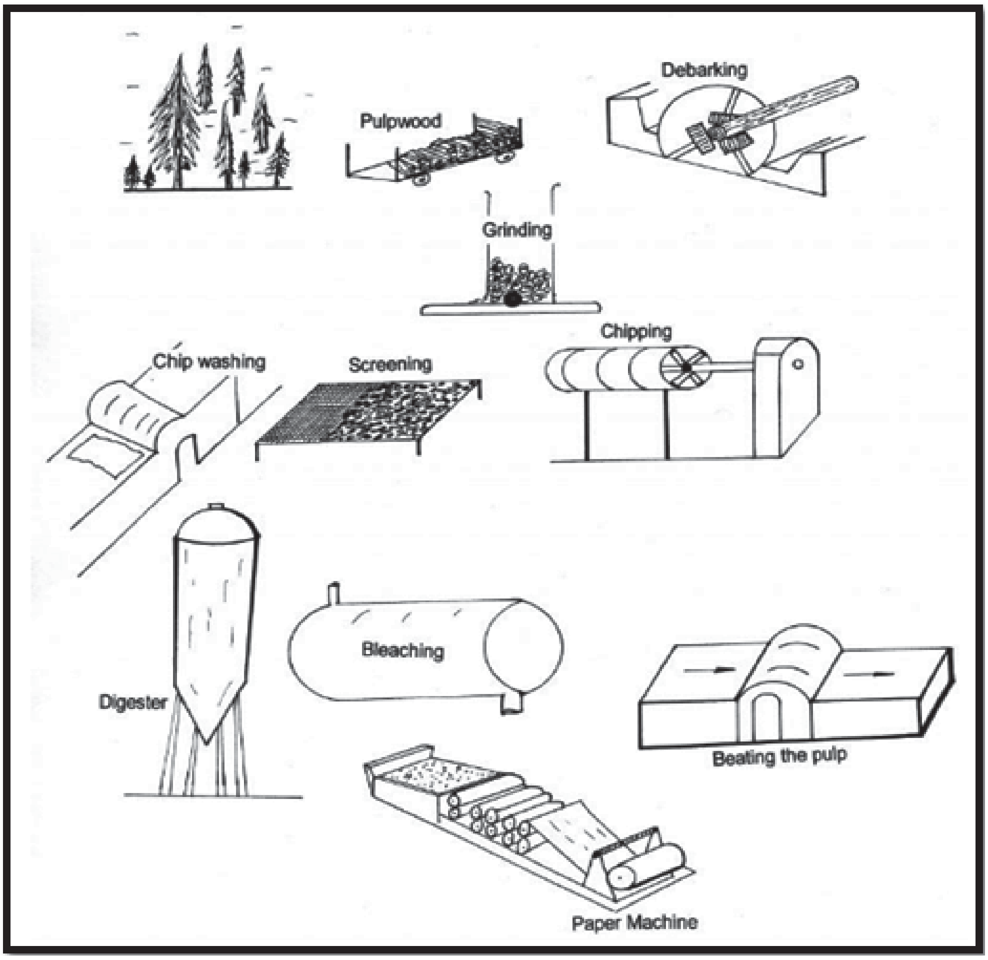


Figure 14.12 Chemical process of paper manufacture

10. Engraving and printing blocks

Dalbergia sissoo (Shisham) in North India, and *Dalbergia latifolia* (Rosewood) in South India, are the most popular woods for calico-printing blocks. Sissoo (Shisham) is considered to be excellent for the purpose. *Toona ciliata* (toon) and *Tectona grandis* (teak) are also sometimes used.

11. Match splints and boxes

A good match wood for splint manufacture must be soft, straight grained, white and cheap. India possesses many woods which are suitable for box making and splints. The woods are- *Bombax ceiba* (simul), *Anthocephalusindicus* (kadam), *Salix* spp., etc.

12. Mathematical instruments

The better class of mathematical instruments such as set squares, rulers, etc., are usually made of *Buxus wallichiana* (box wood), *Juglans regia* (walnut) and *Aesculus indica* (horse chestnut), but cheaper instruments intended for school use are often made of *Adina cordifolia* (Haldu), *Toona ciliate* (Toon), *Gardenia* spp., etc.

13. Musical instruments

In India, many woods are used for making musical instruments such as tanpura, sitars, violins, etc., teak, toon, sissoo, mulberry, haldu being among the commonest. For sitars, teak is used for the long neck and deodar or shisham for keys. Toon is almost universally used for the bodies. For banjos, teak is most commonly used. For drums, mulberry, sissoo, siris etc, are used. *Canariumeuphyllum* (Dhup) is used for guitars. In Western countries, maple and spruce are commonly used in the construction of various stringed musical instruments due to their excellent tonal and structural properties. They are used in violins, violas, cellos, double basses, guitars, pianos, mandolins and harps.

14. Sporting equipments

Billiard cue shafts in India are made from *Diospyros melanoxylon* (ebony), *Grewia tiliifolia* (dhaman), and *Polyalthia fragrans*. For the buttsof cues ebony, *Hardwickia pinnata* and *Dysoxylumglandulosumare* used. More than 200 manufacturers in India are involved in the production and exportof world-class sports goods. Such goods are of such superior quality that over 70 countries import from India. There are several good reasons for the tremendouspopularity of Indian sports goods abroad: excellent quality, superb finish, carefullyselected raw material, and enhanced durability.Cricket bats are made of *Salix* spp. (Willows, Especially Kashmir Willows). *Populus* spp. has also been used for cheap types of bat. Golf clubs are made of *Terminalia* spp., *Grewia* spp., *Anogeissus* spp., and *Pyinma*. Hockey sticks are madeof *Morus alba* (mulberry). Hockey sticks from India are known the world over fortheir balance and strong drive. The timbers employed for the skis are *Dalbergia sissoo* (shisham) and *Anogeissus latifolia* (axle wood). Stumps and bales are madeof *Morus* spp. (mulberry) and *Grewia tiliifolia* (dhaman). In India, tennis and badmintonrackets are made of mahogany and maple wood. The racket frames are made of *Prunus padus*, *Dalbergia sissoo*, *Toona ciliata*. *Melia azedarach* and so on.

15. Cork

Most commercial cork is obtained from the cork oak (*Quercus suber*). Cork or “corkwood” consists of the outer bark of the tree. This can be removed without injury to the tree. At the age of about 20 years, when the tree is about 40 cm in circumference, this outer layer, known as virgin cork, is removed by stripping. The operation consists of making vertical and horizontal cuts with knives or saws, and then prying off large pieces of the bark. After stripping the pieces of cork are dried for several days and then boiled in large copper vats. The rough edges are then trimmed off and the flat pieces are sorted and baled. The natural cork is used to make stoppers, hats, helmets, cigarette tips, handles of golf clubs, pen holders, fishing rods, floats, life preservers, life jackets, baseballs mats, tiles, and several other such products. Composition of cork is utilized for the lining of crown caps, the metal tops for sealing bottles, gaskets, toes, counters and innersoles for shoes.

16. Turnery, carving, combs and toys

A turnery is used for constructing and carving wooden articles on a lathe. Very close-grained woods are acquired for high class turnery and carving. Walnut is much in demand in North India and Kashmir for this purpose. The sandalwood carvings of Mysore are equally well known. Sissoo and ebony are also used high class carving and inlay work in North India. *Dalbergialatifolia* is commonly used in Kerala for carvings of idols, animals, birds, etc. Wood carving is an ancient craft in which the state of West Bengal excels. The items include are dolls and toys, owl, horse, etc. Recently many piece goods including stands for table lamps are being manufactured. Shishamwood is used in abundance. *Erythrina* spp., *Gyrocarpusspp*., *Bauhinia malabarica* are used for making toys in Karnataka. *Hymenodictyonorixense* (Kuthan) is the best toy wood in U.P. Indian combs such as those used by Sikhs in the hair are made of *Buxus* spp. (boxwood), *Adina cordifolia* (Haldu), ebony and sandal-wood.

17. Pencils and pen-holders

The timbers used in India for manufacture of pencils include Cypress, blue pine or kail, simul, toon, *Salix tetrasperma* and *Melia* species. Pen-holders may be made of Haldu (*Adina cordifolia*), *Gardenia* spp., Kaim and in North India spruce and fir.

18. Picture frames

No very special qualities are required for picture framing, so long as the wood used is well seasoned and not liable to warp. For picture framing in India, the most commonly used wood is teak, sissoo, rosewood, ebony and haldu. However, light conifer woods such as fir and spruce are the best. School slate frames can be made from a variety of woods, e.g. *Trewianudiflora* (gutel), *Teramelesnudiflora* (maina), *Terminalia chebula*, *Mangifera indica* (Am), and so on.

19. Rifle parts

Walnut (*Juglans regia*) is the chief timber used for the manufacture of rifle work all over the world, as it stands up exceptionally well when worked to a fine finish on high speed cutting and drilling machines. The wood is also very steady and is not prone to excessive shrinking, swelling, warping or splitting, once it is properly seasoned.

20. Shuttles

All cotton, jute, wool and other textile mills use wooden shuttles in large quantities. The wood for shuttles ordinarily comes from *Diospyros melanoxylon* (ebony), *Gardenialatifolia, Acacia nilotica, Mitragyna parviflora, Dalbergia latifolia and Dalbergia sissoo.*

14.5 Summary

Hardwoods *come from angiosperms*. Typically they have vessels (pores) and are more complex than softwoods which come from gymnosperms with a profusion of tracheids and parenchyma cells. Hardwoods constitute the best quality wood as they are more resistant and commonly used for construction of high-end furniture, floors, ceilings or even houses. To a botanist, wood is secondary xylem. In most trees two types of wood can be recognised, sapwood and heartwood. Sapwood is the outer, pale-coloured wood are alive and active in conducting water, mineral nutrients while translocating photosynthates to the various parts. Over time, they can shrink or crack and are also susceptible to attacks by fungi and insects. The wood from this region is also generally inferior to heartwoods, although by appropriate preservative their quality can be considerably enhanced. As a tree ages, the cells in the sapwood stop conducting and die, turning into the inner darker heartwood which has little or no moisture. Heartwood is preferred for woodworking and is generally used for structural wooden works and wooden home-building products or other construction materials. Anatomy of woods are commonly examined in transverse sections and radial or tangential longitudinal sections. Wood may be non-porous (softwoods), ring-porous, diffuse porous or semi ring porous (hardwoods). The parameters usually employed in identifying woods include grain pattern. colour (darkens with age), hardness, texture, weight, aroma, vessels (arrangement, size, distribution), unique figures or patterns (a bird’s eye or curls or tiger stripes in maple, ray flecks in oak or beech) and growth rings. In India, teak, sal and sissoo (among hardwoods) and pine and deodar (among softwoods) are widely used for timber and a variety of products.

Each type of wood however, has its unique features, making it suitable for specific applications based on its strength, durability, appearance, and workability. Whether you are crafting a delicate piece of furniture or building a sturdy structure, there is always a perfect type of wood to suit your purpose.

Paper manufacture is a complex and resource-intensive process that involves converting raw materials such as wood, recycled paper, or other plant-based fibers into high-quality paper products. Paper is a ubiquitous product that is used in a variety of applications, from printing and packaging to hygiene and personal care products. The paper manufacturing process involves several stages, including pulping, refining, screening, and drying, each of which plays a crucial role in determining the quality and properties of the end product. The process also generates significant waste, including water, chemicals, and paper sludge, which can have a significant environmental impact if not managed properly.

The loss of tree cover has seen a steep increase. Most of this occurs in the tropics. Agriculture, logging and raging forest fires -- which has increased in intensity, frequency and range over the last few years, is cause for deep concern. This not only depletes one of the most valuable and versatile natural resources but also vanquishes the global carbon sink.

14.6 Terminal Questions

1. Give brief answers to the following :

(a) Name two woods commonly used in making Western musical instruments.

(b) What role does wood play in paper production?

(c) Why softwoods are non-porous?

(d) Name two woods commonly used in making Western musical instruments.

2. Write answers to the following (in 150-200 words):

(a) Which species of pine and deodar are common in our country? Characterise the wood that you obtain from them.

(b) Outline the steps in manufacture of paper from wood pulps.

(c) Give a brief account of the pulping process in paper manufacture.

3. Match the items in Column I with those of Column II.

	Column I		Column II
1.	Shisham	(i)	Verbenaceae
2.	Teak	(ii)	Pinaceae
3.	Dalbergia melanoxylon	(iii)	Pinus sylvestris
4.	Kail	(iv)	African Blackwood
5.	Scots pine	(v)	Pinus wallichiana
6.	Pine	(vi)	Strongest Indian soft wood
7.	Cedrus deodara	(vii)	Fabaceae

4. Fill in the blanks

(a) Woodis a bad conductor of ______ and _______.

(b) Wood is secondary ________.

(c) The needles in Himalayan Blue Pine are borne in fascicles of ______.

(d) The wood for cricket bats in our country mostly comes from species of _______ and ________.

(e) Most commercial cork is obtained from the outer bark of _________ ________ (scientific name).

(f) In paper manufacture, ________ is the process where the pressed dry sheet is passed through a series of rollers to smooth and finish the paper to the desired thickness and texture.

5. Name one major source of wood for each of the following purposes :

(a) Furniture making

(b) For making of musical instruments

(c) Construction of houses and bridges

(d) Making matches

(e) For carpentry work

(f) Making beams, posts, door and window frames.

14.7 Answer key

SAQ I

(a) Wood has several advantages over metals. Wood is cheap, light and may easily be worked with tools. It is very strong for its weight and it is embodiment of strength, toughness, and elasticity. Moreover, it is a bad conductor of heat and electricity.

(b) Hardwood is derived from angiospermous deciduous trees and is dense, durable, and often used in furniture. An example is teak.

(c) Softwood comes from gymnospermous trees, paler in colour and is less dense than hardwood. An example is pine – Pinus roxburghii.

(d) In construction work, wood is frequently used in making doors and other pieces of furniture.

(e) The wood formed in the spring is called the ‘early wood’ (spring wood), and that formed in winter months is called the ‘late wood’ (autumn wood).

(f) Sap wood is the outer pale-coloured living part of the trees which is less durable and prone to attacks by fungi or insects. On the other hand, heart wood in the inner, darker dead part of the tree that is the source of hard and durable timber.

(g) Timber products are derived from timbers -- wood from the sturdy stems used in construction, furniture and paper pulp. Timber has a high strength to weight ratio. Products produced/derived from other woody parts of plants are termed as wood products.

SAQ II

(a) Teakwood is highly valued for its durability, resistance to termites, and ability to withstand harsh weather conditions.

(b) One major advantage of using plywood is that its tensile strength is equal in all directions.

(c) (i) True; (ii) False; (iii) True; (iv) True; (v) False; (vi) True; (vii) False.

Terminal Questions

1. (a) Maple and spruce. They are commonly used in the construction of various stringed musical instruments due to their excellent tonal and structural properties.

(b) Wood pulp, commonly derived from softwoods, is a primary raw material used in the production of paper.

(c) Softwoods derived from gymnosperms do not possess vessels (pores). That is why they are non-porous.

(d) Maple and spruce.

2. (a) See Section 14.3

(b) The basic steps in the process of paper manufacture from wood pulp are as follows.

Harvesting and Debarking : Wood logs are harvested and the bark is removed.

Chipping : The debarked logs are fed into chippers that transform them into wood chips.

Pulping : Wood chips are chemically or mechanically broken down into pulp.

Mechanical Pulping : Uses mechanical grinding to break down the wood into pulp.

Chemical Pulping : Uses chemicals like sodium hydroxide and sodium sulfide to break down the wood.

Cleaning and Screening : The pulp is washed and screened to remove any remaining wood particles and contaminants.

Bleaching : The pulp is bleached to achieve the desired whiteness and purity.

Mixing with Additives : Various additives (like starch, clay, or calcium carbonate) are mixed with the pulp to improve paper properties.

Sheet Formation : The pulp mixture is sprayed onto a moving mesh screen, allowing water to drain away, forming a mat of fibers.

Pressing : The wet mat is pressed through rollers to remove excess water.

Drying : The pressed mat is passed through heated rollers to dry it completely.

Calendaring : The dry sheet is passed through a series of rollers to smooth and finish the paper to the desired thickness and texture.

Reeling : The finished paper is rolled onto large reels and then cut into desired sizes.

(c) See Section 14.4, 5b.

3. 1. (vii), 2. (i), 3. (iv), 4. (v), 5. (iii), 6. (ii), 7. (vi)

4. (a) heat & electricity; (b) xylem; (c) five; (d) Salix & Populus; (e) Quercus suber; (f) calendaring.

5. (a) to (f) Look up Section 14.4.

14.8 References and Further Readings

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Further readings

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