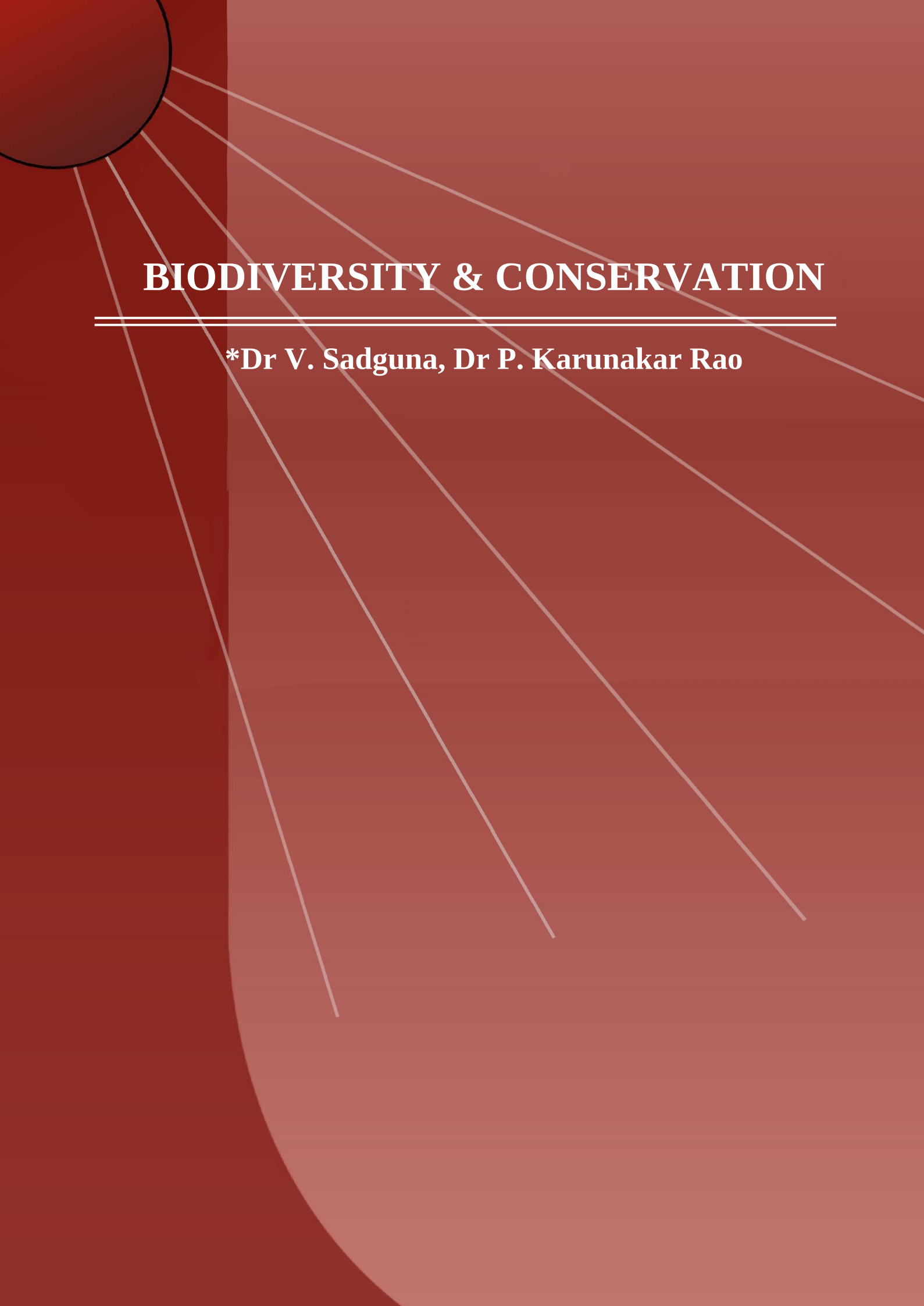




BIODIVERSITY & CONSERVATION

***Dr V. Sadguna, Dr P. Karunakar Rao**

BIODIVERSITY & CONSERVATION

**B.Sc. (Botany) III Year, Semester V
(For UG Courses in Indian Universities)**

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SEMESTER-V

PAPER-V: (A) BIODIVERSITY & CONSERVATION

Theory: 4 Hours/Week; (DSE-1: ELECTIVE)

Credence 4 Marks: 100 (Internal: 20; External: 80)

UNIT-1

1. Plant diversity and its scope: Genetic diversity, Species diversity, Plant diversity at the ecosystem level. Agrobiodiversity and cultivated plant taxa, wild taxa
2. Values and uses of Biodiversity: Ethical and aesthetic values, Precautionary principle, Methodologies for valuation, Uses of plants. Uses of microbes.

UNIT-11

3. Loss of Biodiversity: Loss of genetic diversity, Loss of species diversity, Loss of ecosystem diversity, Loss of agro-biodiversity, projected scenario for biodiversity loss.
4. Management of Plant Biodiversity: Organizations associated with biodiversity, management methodology for execution-IUCN, UNEP, UNESCO, WWF, NBPGR
5. Biodiversity legislation and conservation, Biodiversity information management and communication.

UNIT-III

6. Conservation of Biodiversity: Conservation of genetic diversity, species diversity ecosystem Diversity
7. Principles of conservation: In situ and Ex-situ conservation. Sacred grove, Botanical Garden, Biosphere reserve, Sanctuaries, National parks (In situ) and Tissue culture, Gene/seed/pollen banks and Cryopreservation (ex situ).

UNIT-IV

8. Role of places in relation to Human Welfare, Importance of forestry, their utilisation and commercial aspects, Avenue trees, Ornamental plants of India.
9. Alcoholic beverages through the ages. Fruits and nuts, Important fruit crops and their commercial importance. Wood and its uses

CONTENT

Chapter	Topics	Page number
I	1.1 Plant diversity and its scope: 1.1.1 Genetic diversity 1.1.2 Species diversity 1.1.3 Plant diversity at the ecosystem level. 1.1.4 Agrobiodiversity and cultivated plant taxa 1.1.5 Wild taxa 1.2 Values and uses of Biodiversity: 1.2.1 Ethical and aesthetic values 1.2.2 Precautionary principle 1.2.3 Methodologies for valuation 1.2.4 Uses of plants. 1.2.5 Uses of microbes	3-51
II	1.2 Plant diversity and its scope: 1.2.1 Genetic diversity 1.2.2 Species diversity 1.2.3 Plant diversity at the ecosystem level. 1.2.4 Agrobiodiversity and cultivated plant taxa 1.2.5 Wild taxa 1.2 Values and uses of Biodiversity: 1.2.1 Ethical and aesthetic values 1.2.2 Precautionary principle 1.2.3 Methodologies for valuation 1.2.4 Uses of plants 1.2.5 Uses of microbes 2.1 Loss of Biodiversity: 2.1.1 Loss of genetic diversity 2.1.2 Loss of species diversity 2.1.3 Loss of ecosystem diversity 2.1.4 Loss of agro-biodiversity 2.2 Projected scenario for biodiversity loss. 2.2.1 Management of Plant Biodiversity: 2.2.2 Organisations associated with biodiversity 2.2.3 Management methodology for execution 2.2.3.1 IUCN, 2.2.3.2 UNEP, 2.2.3.3 UNESCO, 2.2.3.4 WWF, 2.2.3.5 NBPGR 2.3. Biodiversity legislation and conservation, 2.3.1 Biodiversity information management and communication.	52-80
III	3.1 Conservation of Biodiversity: 3.1.1 Conservation of genetic diversity, 3.1.2 Species diversity, 3.1.2 Ecosystem Diversity 3.2. Principles of conservation: 3.2.1 In situ and Ex-situ conservation.	81-122

	3.2.1.1 Sacred grove, 3.2.1.2 Botanical Garden, 3.2.1.3 Biosphere reserve, 3.2.1.4 Sanctuaries, 3.2.1.5 National parks (In situ) and 3.2.1.6 Tissue culture, 3.2.1.7 Gene/seed/pollen banks and 3.2.1.8 Cryopreservation (Ex-situ).	
IV	4.1 Role of places in relation to Human Welfare, 4.1.1 Importance of forestry, its utilisation and commercial aspects, 4.1.2 Avenue trees, 4.1.3 Ornamental plants of India. 4.2 Alcoholic beverages through the ages. 4.2.1 Fruits and nuts: 4.2.2 Important fruit crops and their commercial importance. 4.2.3 Wood and its uses	123-153

PREFACE

Biodiversity is the foundation of life on Earth and encompasses the remarkable variety of genes, species, plants, animals, microorganisms and ecosystems. Biological diversity provides essential resources such as food, medicines, fibres, timber, fuel and industrial raw materials, while also maintaining ecological balance and supporting human well-being. Its conservation and sustainable utilisation are therefore essential for present and future generations.

This textbook, **Semester-V, Paper-V (A): Biodiversity & Conservation**, has been prepared primarily for undergraduate students of Botany. It presents the subject in a simple, systematic and student-friendly manner, covering the major concepts of plant diversity, biodiversity values, biodiversity loss, management, conservation and the utilisation of plant resources for human welfare.

Chapter I introduces the **scope and levels of plant diversity**, including genetic, species and ecosystem diversity, agrobiodiversity, cultivated plant taxa and wild taxa. It also discusses the ethical, aesthetic, ecological and economic values of biodiversity, the precautionary principle, biodiversity valuation, and the important uses of plants and microorganisms.

Chapter II deals with the **loss and management of biodiversity**. Genetic erosion, species extinction, ecosystem degradation and loss of agrobiodiversity are discussed along with their causes, consequences and projected future scenarios. The chapter also introduces major organizations such as **IUCN, UNEP, UNESCO, WWF and NBPGR**, together with biodiversity legislation, information management and communication.

Chapter III focuses on the **conservation of biodiversity** at genetic, species and ecosystem levels. The principles of **in situ and ex situ conservation** are explained through sacred groves, botanical gardens, biosphere reserves, wildlife sanctuaries, national parks, tissue culture, gene banks, seed banks, pollen banks and cryopreservation.

Chapter IV highlights the **role of plants and plant resources in human welfare**, with special emphasis on forestry, its utilization and commercial importance, avenue trees and ornamental plants of India. The ecological, economic and aesthetic contributions of forests and ornamental vegetation are discussed, along with the importance of sustainable utilization and conservation.

The textbook aims not only to support students in their academic studies and examinations but also to develop an appreciation of the enormous value of plant diversity and a sense of responsibility toward its protection. It is hoped that this book will encourage students to understand the close relationship between biodiversity, human welfare and sustainable development.

I sincerely hope that this textbook will serve as a useful academic resource for students and teachers and inspire greater interest in **biodiversity conservation, sustainable utilisation and the protection of our valuable plant resources**.

UNIT-1

Introduction to Plant Diversity

Plant diversity is also called biodiversity. It is critical to the health of an ecosystem. In a biodiverse ecosystem, each organism plays an important role and helps to regulate natural processes and growth cycles. The term “Diversity” generally refers to the variety and variability of life of both plants and animals on the Earth. According to the United Nations Environment Program (UNEP), plant diversity measures variation at the genetic, species and ecosystem level. Terrestrial diversity of plant species is higher near the equator due to warm climate and primary productivity. Plant diversity is not constant on Earth; it is richest in the tropics because the tropical forest ecosystem covers < 10% of Earth’s surface and contains 90% of the world’s species. Along the western Pacific Ocean coast, marine plant diversity is high due to high sea surface temperature.

The term Biodiversity was introduced in biological sciences in 1986. It became more significant since the United Nations Convention on Biodiversity was held during the Earth Summit in Rio de Janeiro in 1992. Biodiversity constitutes the vital life support for the survival of the human race. Biodiversity has been referred to as the planet’s most valuable resource. It is believed that about 10 to 80 million species (1 to 8 billion species) exist on the Earth. However, only 1.5 million species have been identified and enlisted so far. The term Biodiversity was coined by Walter G. Rosen in 1986, including genetic and ecological diversity. It is defined as the richness and evenness of species in a given area.

Our biological system is constantly affected by human activities. Human beings are mostly responsible for the destruction of habitats through intensive agricultural development, overexploitation of resources, urbanisation, industrialization, overpopulation, deforestation, pollution, environmental degradation and ethical degradation.

Plant diversity means differences among the plants and variety of characters observed within them. The plant kingdom has huge varietal diversity among all groups of plants. Plant diversity is greater in tropical regions than temperate region.

Biodiversity - Concept and Definition

Concept of Biodiversity: The word biodiversity is extensively used by scientists, environmentalists, conservationists, economists, industries, governments and the general public. It is the variety and variability of living species on Earth. Biodiversity is a wide-

ranging and complicated term that comprises living beings, their genetic differences, the species they belong to and the environments in which they are found. In general terms, biodiversity is defined as “the variety of life and its processes on Earth.

Biodiversity: An Umbrella Term: Biodiversity is sometimes used as an umbrella term for the amount, variety and variability of living creatures. It covers all living organisms such as plants, animals, microbes and their relationships with the environment. Biodiversity is the essence of life and is directly associated with ecological processes and human actions in this manner.

Major Levels of Biodiversity: Biodiversity is often investigated at three basic levels of biological organization: genetic diversity, species diversity and ecological diversity. Genetic diversity is within a species. Species diversity is between species. Ecosystem diversity is the variety of ecosystems and habitats in an area.

Genetic diversity: Genetic diversity is the variance in genes between individuals and between populations of the same species. It is responsible for changes in features including size, colour, disease resistance, productivity and environmental tolerance. For example, diverse kinds of rice, wheat and mango are examples of genetic diversity.

Diversity of species: Species diversity: The presence of a range of distinct species in a particular location. It includes the number of species and their relative abundance. The forest with different species of trees, herbs, birds, mammals, insects, fungi and microbes demonstrates tremendous species variety.

Diversity of Ecosystems: Ecosystem diversity is the variety of ecosystems, habitats and ecological populations in a region. Examples of diverse ecosystems are forests, grasslands, marshes, deserts, rivers, lakes and marine environments. Every ecosystem has its own creatures, ambient circumstances and ecological processes.

Diversity of Landscape: A few scientists have acknowledged the landscape variety as a fourth dimension of biodiversity. A landscape is a heterogeneous area composed by the interaction of ecosystems or habitats. For example, a landscape may include woods, grasslands, agricultural areas, ponds, streams, wetlands and shrublands. Thus, landscape diversity refers to the spatial pattern and configuration of diverse habitats and ecosystems.

Convention on Biological Diversity Definition: One of the most frequently acknowledged definitions of biodiversity is offered by the Convention on Biological Diversity (CBD), 1992. Biodiversity means the difference between living species of all sources including land, marine and other water environments and the ecological systems of which they are part. It encompasses within species diversity, between species and between ecosystems.

Global Biodiversity Strategy: The Global Biodiversity Strategy (1992) defines biodiversity as the “variability among living organisms from any source including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” This term points to the three main layers of biodiversity: genetic, species and ecosystem diversity.

Hierarchical Concept of Biodiversity: Biodiversity is more than a bunch of diverse organisms. It is a complex, hierarchical system of interacting genes, people, populations, species, communities and ecosystems. Di Castri and Younès (1996) define biodiversity as the whole and hierarchical interplay of genetic, taxonomic and ecological scales of organisation at various levels of integration. (Fig 1.1, 1.2 & 1.3).

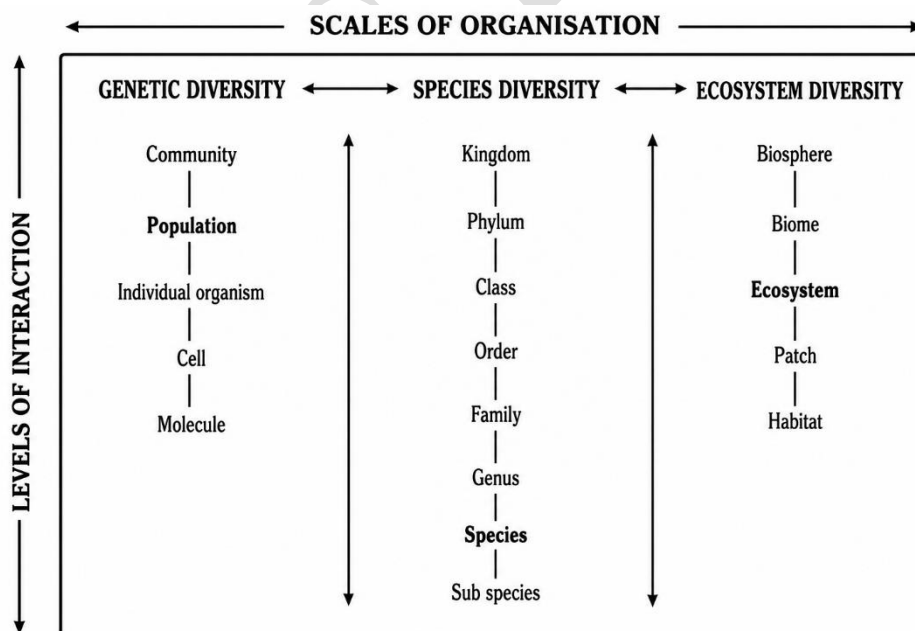


Fig 1.1: The Scales of Organisation and Levels of Interaction of Biodiversity (adapted from Di Castri and Younès, 1996).

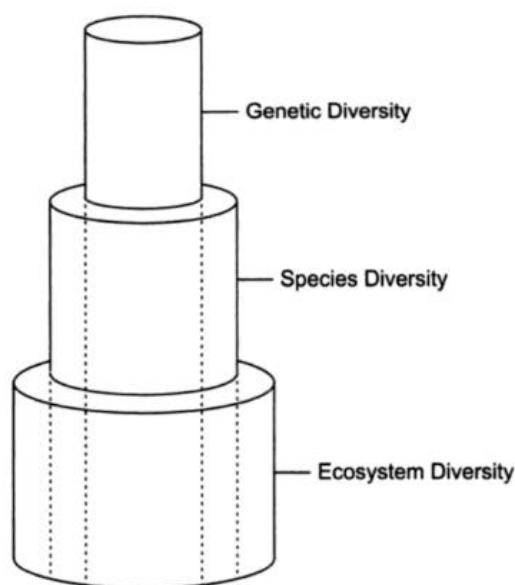


Fig. 1.2. The three hierarchical scales of biodiversity and their interrelationships.

Cultural Diversity and Biodiversity

Human cultures and communities also interact vitally with biodiversity. Different groups have their own traditional knowledge, values, beliefs, resource use practices and conservation approaches. Thus, cultural diversity influences the protection and sustainable use of biological resources.

Table 1.1: Composition and Scales of Biodiversity (adapted from UNEP, 1995).

Scale of Biodiversity	Levels of Organisation
Genetic Diversity	Populations → Individuals → Chromosomes → Genes → Nucleotides
Organismal Diversity	Kingdoms → Phyla → Orders → Families → Genera → Species → Subspecies → Populations
Ecological Diversity	Biomes → Bioregions → Landscapes → Ecosystems → Habitats → Populations
Cultural Diversity & Human Interactions	Occur across all levels of biodiversity

Noss's holistic strategy: Noss (1990, 1994) suggested a broad approach to biodiversity including genetic, species, ecological and landscape diversity. He added that biodiversity at various levels can be explored through three primary components, namely composition, structure and function. Composition is about what parts are there, structure is about how they are arranged, and function is about how these components interact and work.

1.1 Plant diversity and its scope

Biodiversity plays a vital role in the sustainable development and welfare of human society. It provides valuable resources and opportunities in various fields such as medicine, industry, agriculture, research, education, environmental conservation, and employment generation. The diversity of plants, animals, and microorganisms contributes significantly to human well-being and economic development.

Scope of Biodiversity

1. Medicinal Field

- Biodiversity is an important source of medicines.
- Many drugs are obtained from plants, animals, and microorganisms.
- Knowledge of medicinal organisms helps in identifying their distribution, conservation, and utilisation.
- Biodiversity contributes to the discovery of new medicines for treating various diseases.

Ex: Cinchona source of quinine. *Rauvolfia* source of reserpine. Neem medicinal and antimicrobial properties.

2. Industrial Field

- Many industries depend directly or indirectly on biological resources.
- Plants and animals provide raw materials for manufacturing various products.
- Biodiversity supports industries such as the pharmaceutical industry, Textile industry, Paper industry, Food processing industry and Cosmetic industry.

3. Agriculture

- Biodiversity is the foundation of agriculture.
- It provides a wide variety of crops, fruits, vegetables, and livestock breeds.
- Genetic diversity helps in developing high-yielding, disease-resistant, and climate-resilient varieties.
- It contributes to food security and sustainable agriculture.

4. Research and Education

- Biodiversity provides immense opportunities for scientific research and study.
- It serves as a valuable resource for: Taxonomy, Genetics, Ecology, Biotechnology, Conservation biology
- It facilitates laboratory experiments, field studies, and classroom teaching.

5. Environmental Conservation

- Living organisms interact with environmental factors to maintain ecosystem stability.
- Biodiversity helps in: Nutrient cycling, Pollination, Soil conservation, Water purification
Climate regulation. Therefore, biodiversity is essential for maintaining ecological balance and conserving the environment.

6. Employment Opportunities

- Biodiversity conservation programs generate employment.
- Jobs are created in: Forestry, Wildlife management, Environmental consultancy, Ecotourism
Botanical and zoological surveys, Research institutions and Conservation projects.

Educational Importance

- Biodiversity enhances environmental awareness.
- It promotes scientific knowledge and conservation ethics among students and society.

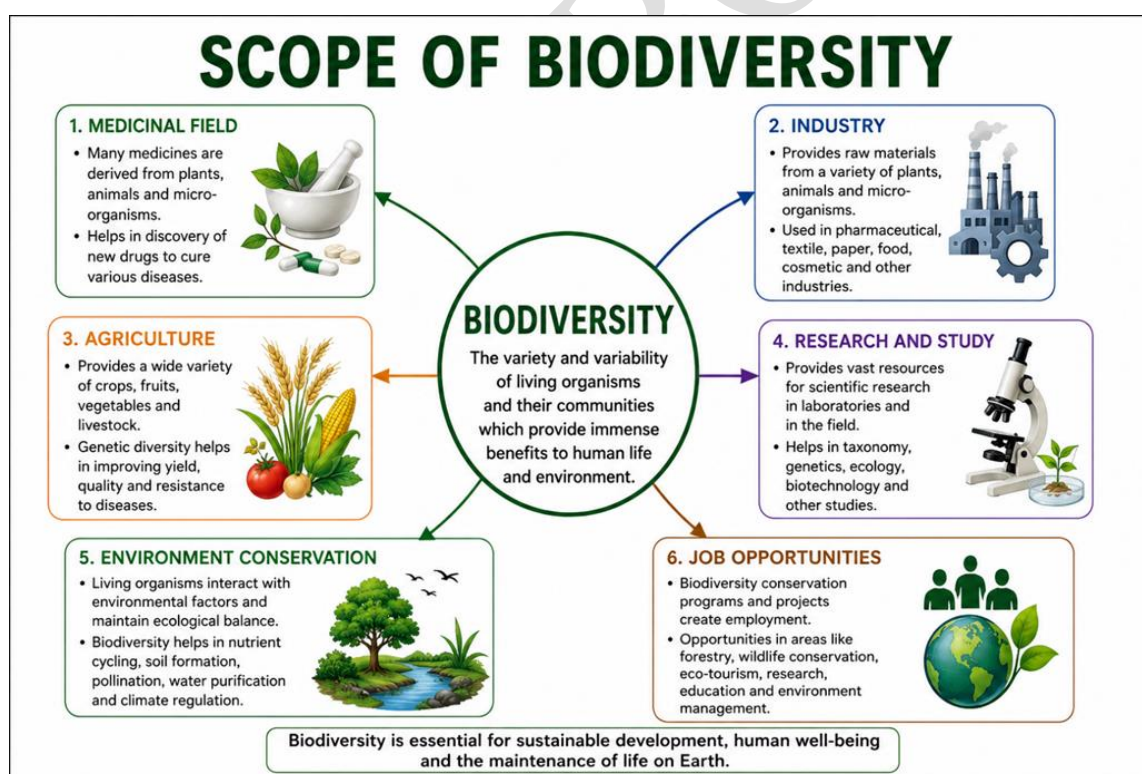


Fig. 1.4: Scope of Biodiversity.

Table-1.2 Comparison of plant species diversity in the world and India.

S. No	Plant group	Total plant species in the world	Total plant species in India
1	Algae	27,000	2,500
2	Fungi	75,000	23,000
3	Lichens	13,000	2,450
4	Bryophytes	17,000	2,584
5	Pteridophytes	10,500	1,082
6	Gymnosperms	720	64
7	Angiosperms	30,000	17,500

Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be designed as the number of different items and their relative frequency for biological diversity; these items are organized at many levels ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term explains different ecosystems, species, genes and their relative richness and abundance.

The presence of numerous organisms, plants, or biodiversity makes our life successful. There are about 320,000 plant species; most of these plants produce seeds. Green plants provide the majority of the world's oxygen molecules and form the basis of Earth's ecosystems. Biodiversity describes the richness and variety of life on Earth. It is the most complex and important feature of our planet; without biodiversity, life would not be sustained. Biodiversity is important in natural as well as artificial ecosystems. Plant which grows rapidly and produces a crop in one season were probably the first plants to be cultivated. Thus, cereals are the important plants of the different civilizations. They continue to provide the human population with the basic energy requirements. Many other plants were domesticated during the progress of the human race. Besides food plants, nature has provided man with plenty of diverse plants which serve as the raw material for various industries and also provide energy as fuel. The most important aspect of this role of plants revolves around the ability of the green plants to transform light energy into chemical energy. The sugars produced during photosynthesis serve as the building blocks for the synthesis of a wide variety of natural raw materials, including starch, fibres, vegetables, oils, gums and other organic compounds.

Man has depended on biomass, primarily wood, for a very long period in the history of the earth. However, the gradual transition to fossil energy sources, coal, mineral oil, and natural gas became important in the age of industrialization. This resulted in a greater demand for

fossil raw materials. In recent years, there is a worldwide search for alternative sources of energy for both nutritional and industrial requirements. Thus, plants serve as very useful gifts of nature.

The main scope of biodiversity includes the conservation and sustainable use of flora and fauna. The purposes of biodiversity are to sustain life and livelihoods, while the scope includes conservation practice, dependence on biodiversity for various resources and threats to biodiversity.

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Types of Biodiversity: Biodiversity, or biological diversity, is the diversity and variability of life on Earth. It encompasses the differences between living beings, the genes they have, the species they belong to and the environments they live in. Biodiversity is not just the number

of species in a certain area, but also the genetic differences within species and the diversity of ecosystems and biological processes.

Biodiversity can be investigated at three main levels: Genetic Variation, Variety of species.

Ecosystem biodiversity.

The three levels are intimately interrelated. Genetic diversity is the variance within species, species diversity is the variety of creatures in a region, and ecological diversity is the range of habitats, ecosystems, and ecological processes. Together they are the basis of life on Earth.

1.1.1 Genetic diversity

Genetic biodiversity, or genetic variety, refers to the variation of the genetic composition of individuals within a species. Every organism has a different set of genes, save for genetically identical animals, such as identical twins or organisms created asexually. These genetic variances are responsible for the differences in features such as size, colour, shape, growth rate, resistance to illnesses, tolerance to environmental circumstances and reproductive capabilities.

Genes are the primary components of inheritance. They are pieces of DNA that convey information that determines the qualities of living things. Genetic diversity can therefore be defined as the variation of genes or gene combinations within a species or community.

Genetic variety is illustrated by numerous types of rice, wheat, maize, cotton, mango, tomato, chilli and other crops. The various varieties of dogs, cattle, sheep, goats and poultry also show the genetic variety that exists among the species of domesticated animals.

Examples of Genetic Variation: In crops, genetic diversity is very easily seen. Farmers grow several distinct kinds of the same crop because various kinds have different qualities.

For example, Maize comes in variants with varying colours, forms, sizes and textures of kernels. Some types can be used for food, some for animal feed or for industrial reasons.

Similarly, different types of rice may vary in: Shape and size of grains, Colour and smell, Length of cultivation, production, resistance to pests and diseases, Drought or salinity tolerance **Adaptability to varied soils and climates** There is also plenty of genetic variation among household animals. There is a huge difference across dog breeds in body size, coat

colour, body form and behaviour. Cattle breeds vary in milk output, resistance to disease, and climatic adaptation.

Natural populations have genetic diversity because people have diverse alleles of genes. These differences are generated by mutation, genetic recombination, gene flow and other evolutionary processes.

Genetic diversity is important: Genetic diversity is crucial for species survival and long-term adaptability. The environment is always in a state of flux. Temperature, rainfall, illnesses, pests, soil conditions and other ecological elements are subject to change over time. Populations with genetic diversity are more likely to contain individuals that can survive such changes.

1. Response to Environmental Change: Genetic variety in populations allows adaptation to changing environmental conditions. Those with beneficial genetic traits may be more likely to live and reproduce under the changing environment.

2. Disease and Pest Resistance: Genetic variety offers the raw material for the development of disease-resistant and pest-resistant types of crops and livestock breeds. This is particularly essential in agriculture since a disease in one variety may not impact another variety to the same degree.

3. Food and Agriculture Security: A major genetic resource for plant breeding is provided by varied crop kinds. Breeders can draw on favourable genes from conventional varieties and wild relatives to generate superior crops with higher yield, better nutritional quality and tolerance to environmental challenges.

4. Evolutionary ability: Genetic variety is the basic material of evolution. Genetic variety is the raw material for natural selection. Populations can evolve from one generation to the next, becoming better adapted to their environment.

5. Conservation of Genetic Resources: Valuable genes that may be beneficial in the future are found in old kinds of crops, indigenous breeds of animals and wild populations. Therefore, their conservation is crucial for agriculture, medicine, biotechnology and stability of ecosystems.

Threats to Genetic Diversity: A loss of genetic variety can occur in populations that are particularly tiny or isolated. Genetic erosion is caused by habitat degradation, over-exploitation, replacement of traditional types of crops by a few contemporary varieties, intensive breeding, pollution, climate change and loss of wild relatives.

Reduced genetic variety decreases animals' ability to adapt to illnesses and environmental changes. Thus, conservation programs should aim to conserve not just the wild populations but also the traditional varieties.

Genetic Diversity Conservation: Genetic resources can be preserved by: In situ conservation - protection of creatures in their natural settings.

Ex situ conservation — the conservation of genetic resources beyond their natural settings. Seed and gene banks, Gene banks in the field, Gardens (botanical), Collections of germplasm.

Preservation of traditional crop varieties, Breeding programs.

Conservation of Wild Relatives of Cultivated Plants. Therefore, genetic biodiversity is the main level of biodiversity as it offers the variation needed for adaptation, evolution and survival.

1.1.2 Species diversity

Species biodiversity (also termed species diversity) is the number of distinct species found in a certain geographic area, habitat, ecosystem or on the planet as a whole.

A species is commonly defined as a group of creatures that have common features and may reproduce to generate fertile offspring under natural conditions. Thus, species diversity is a measure of the number of species present and their relative abundance in a community.

A forest can have many species of trees, bushes, herbs, birds, mammals, insects, fungi and microorganisms. A grassland may have a different variety of species; a pond has aquatic plants, algae, fish, amphibians, insects and microbes. Differences in species composition also contribute to species biodiversity.

Species Richness and Species Evenness: Two important concepts are used to define species diversity: species richness and species evenness.

Species Richness: Species richness is the number of different species found in a certain location. For example, Forest A may have 100 species of plants while Forest B may have just 50 species of plants. Now Forest A has more species richness in terms of plants.

Species Equitability: Species evenness is the relative abundance of the different species in a group. The number of species in two ecosystems may be the same, but the number of individuals in each species may range widely. When there is generally even numbers of individuals among species in a community, it is more even than one in which one or two species dominate. Thus, species diversity is a function of the number of species and the relative abundance of species.

Species Diversity Examples: Almost all natural ecosystems are characterised by species variety. A tropical forest may contain many species of Trees, Bushes, herbs, and climbers. Fowl Mammals, Reptiles, Amphibians: Bugs, Mycology, Micro-organisms, including bacteria.

Similarly, in aquatic ecosystems, there is a great diversity of algae, aquatic plants, fish, molluscs, crustaceans, amphibians and microorganisms.

India is rich in species diversity because of its various climates, geographical area and habitats. The country is home to forests, grasslands, deserts, marshes, rivers, mountains, coastal habitats and marine settings. Each of these ecosystems supports characteristic assemblages of species.

Why Species Diversity Matters: Diversity of species is vital for the functioning of ecosystems and human well-being.

1. Ecosystem Stability: Distinct species play distinct ecological responsibilities. Plants are the primary producers, herbivores eat plants, carnivores regulate animal populations, decomposers break down organic waste, and microbes are involved in nutrient cycling . The interaction of these creatures leads to the ecosystem's stability.

2. Food Sources: Humans rely on a relatively small number of species for sustenance yet thousands of plants, animal and microbial species provide direct or indirect food supplies. Wild species also provide sources of new crops and useful genes.

3. Medicinal Plants: Medicinal chemicals have been provided by plants, fungi and microbes. Thus, species variety provides a vast natural resource for the discovery of new medicines and therapeutic molecules.

4. Pollination: Many flowering plants are pollinated by insects, birds, bats and other species. The diversity of the pollinators helps in plant reproduction and agricultural crop production.

5. Nutrient Cycling: Microorganisms, fungus and soil animals play key roles in decomposition and recycling nutrients. Without these creatures, vital nutrients would not be recycled back into ecosystems.

6. Ecological Interactions: Species interact by predation, competition, parasitism, mutualism, pollination and seed dispersal. These interactions support ecological processes and determine the development of biological communities.

Threats to diversity of species: Species diversity is in fast decline in many places of the planet. Major threats include Destruction and fragmentation of habitat, Tree Cutting, over-exploitation of bio-resources, Pollution, Climate change, Invasive alien species, Illegal hunting, wildlife trade, non-sustainable farming and development.

In addition to the loss of a species, the unique ecological responsibilities and genetic resources that species provide may be lost forever.

Species Diversity Conservation: Protection of species variety can be done by: establishing wildlife sanctuaries and national parks, establishing biosphere reserves protecting threatened species, restoring habitat, and sustainable use of natural resources. Invasive species management, Control of hunting and wildlife trading, Species recovery and captive breeding programs, Public Awareness and Participation. Species biodiversity is the observable and functional diversity of life. This is crucial for healthy ecosystems and the continuous availability of biological resources.

Types of Species Biodiversity: Species biodiversity, or species diversity, refers to the variety of species present in a particular area, community, ecosystem, landscape or geographical region. It is an important component of biodiversity and can be studied at different spatial scales. Based on the spatial scale at which species diversity is measured, it is commonly divided into **three types**.

a) Alpha (α) diversity

b) Beta (β) diversity

c) Gamma (γ) diversity

These three levels provide information about species diversity from a **local community to a larger geographical region**.

a) Alpha (α) Diversity: Alpha diversity is also called **local diversity**. It refers to the diversity of species present within a particular habitat, community or sampling area at a local scale.

In simple terms, alpha diversity tells us **how many different species occur in a particular community or area**. It may also take into consideration the relative abundance of the species present.

Species Richness: The simplest measure of alpha diversity is **species richness**, which refers to the total number of different species present in a given area.

For example, if a forest quadrat contains 15 species of plants, its species richness is 15.

Alpha diversity is influenced by several factors, including: Size of the area sampled, Availability of resources, Habitat complexity, Environmental conditions, Disturbance, Competition among species, Productivity of the ecosystem. A habitat containing a greater number of species generally has higher alpha diversity than a habitat containing fewer species.

However, **alpha diversity should not be understood simply as increasing with the total number of individuals**. Species richness depends primarily on the **number of different species**, whereas diversity indices may also consider the relative abundance and evenness of those species.

In some mature or highly competitive communities, a few species may become dominant. As a result, the abundance of other species may decline, and measures of diversity that consider evenness may decrease. Example: Consider two forest communities.

- **Forest A:** 10 species with relatively even numbers of individuals.
- **Forest B:** 10 species, but one species accounts for most of the individuals.

Both forests have the same species richness, but Forest A has greater **species evenness** and may therefore have greater overall alpha diversity.

Thus, alpha diversity describes the **within-community diversity** of a particular habitat or sampling site.

b) Beta (β) Diversity: Beta diversity refers to the **difference in species composition between two or more communities, habitats or ecosystems**. It is commonly described as

species turnover. While alpha diversity describes diversity **within a particular site**, beta diversity describes how species composition **changes from one site to another**.

For example, suppose a researcher studies three habitats: Forest, Grassland and Wetland.

If most species are common to all three habitats, beta diversity is relatively low because the communities are similar. If each habitat contains many different species, beta diversity is high because species turnover between habitats is substantial.

Species Turnover: Beta diversity therefore indicates the **similarity or dissimilarity of species composition** between communities.

- **High beta diversity** → greater difference in species composition and greater species turnover.
- **Low beta diversity** → greater similarity in species composition and lower species turnover. Beta diversity can be measured between pairs of sampling sites or among multiple communities.

Measures of Beta Diversity: Several similarity and dissimilarity indices are used to analyse beta diversity. Important measures include: Jaccard index, Sørensen index, Bray–Curtis dissimilarity, Morisita–Horn index.

These indices differ in the type of data they use and in the way species presence, absence and abundance are incorporated.

Bray–Curtis Dissimilarity: The **Bray–Curtis’s index** is widely used in ecological studies to compare the composition of communities. It is based on species abundance and is **not a phylogenetic measure**. Its dissimilarity value generally ranges from **0 to 1**.

- **0** indicates that the two samples have identical species composition and abundances.
- **1** indicates that the two samples have completely different species composition and abundances.

Therefore, Bray–Curtis’s dissimilarity is useful for comparing biological communities and determining the extent of species turnover between sites.

Relationship Between Alpha and Beta Diversity: Beta diversity can also be expressed conceptually as the differentiation among local communities. In some ecological frameworks,

it is related to the relationship between **regional diversity (gamma)** and **local diversity (alpha)**. Thus, beta diversity helps answer the question.

How much does species composition change from one community or habitat to another?

Example: If a plant community on the lower slope of a mountain contains many species that are replaced by different species on the upper slope, the change in species composition along the slope represents **beta diversity**.

c) Gamma (γ) Diversity: Gamma diversity refers to the **total species diversity of a larger geographical area, landscape or region**. It is also called **regional diversity** or **landscape-level diversity**.

Gamma diversity combines the diversity of several local communities occurring within a region. Therefore, it reflects the overall variety of species present across a broader geographical area. For example, a mountain region may contain forests, grasslands, shrublands and alpine habitats. The total number and diversity of species occurring throughout the entire mountain region represent its gamma diversity.

Factors Determining Gamma Diversity: Gamma diversity is influenced by two major components.

1. **The average diversity of local communities (alpha diversity)**
2. **The degree of differentiation among those communities (beta diversity)**

Conceptually, the relationship can be expressed as.

$\gamma = \alpha \times \beta$, where: γ = Gamma diversity, α = Average alpha diversity of the local communities
 β = Beta diversity or differentiation among the communities

The exact mathematical formulation may vary depending on the method used to quantify alpha, beta and gamma diversity (Table 1.3).

Factors Affecting Gamma Diversity: Gamma diversity is influenced by both natural and human-induced factors, including: Geographic area, Climate, Topography, Habitat heterogeneity, Historical evolutionary processes, Geological history, Species migration and dispersal, Environmental variation, Habitat fragmentation, Vegetation changes, Land-use changes and Human activities.

Large and environmentally heterogeneous regions generally provide a greater variety of habitats and may therefore support high gamma diversity.

Example: Consider a mountain slope extending from a low-elevation valley to a high-elevation region. The lower region may contain tropical or subtropical vegetation, the middle region may contain forests, and the higher region may contain grassland or alpine vegetation.

The **total variety of species occurring along the entire mountain slope** represents the gamma diversity of that landscape.

Table-1.3: Difference Between Alpha, Beta and Gamma Diversity.

Feature	Alpha (α) Diversity	Beta (β) Diversity	Gamma (γ) Diversity
Definition	Diversity of species within a particular habitat or community.	Diversity between habitats or communities.	Total diversity of species in a large geographical region.
Also Called	Local Diversity	Species Turnover Diversity	Regional Diversity
Level of Study	Single ecosystem or habitat	Between two or more ecosystems	Landscape or regional level
Measures	Species richness within a habitat	Change in species composition between habitats	Overall species richness of a region
Scale	Small scale	Intermediate scale	Large scale
Indicates	Number of species in one area	Similarity or dissimilarity between areas	Total biodiversity of a region
Example	Number of plant species in a grassland.	Difference in species between a forest and a grassland.	Total species diversity in an entire mountain range.
Importance	Indicates local ecosystem health.	Shows habitat variation and species turnover.	Reflects overall biodiversity of a region.

1.1.3 Plant diversity at the ecosystem level.

Ecological biodiversity, often referred to as ecosystem diversity, is the range of ecosystems, habitats, ecological communities, and ecological processes in a geographic area or throughout the planet. An ecosystem is made up of living species interacting among themselves and with their physical environment. Ecosystems have varied combinations of climate, soil, water, vegetation, animals and micro-organisms. These variances provide a diverse set of biological conditions and habitats.

Ecosystem examples include: Forest ecosystems, Grassland habitats, are Deserts ecosystems.

Freshwater ecosystems, Wetland ecosystems, Mountain ecosystems, Coastal ecosystems, Marine environments, and agricultural ecosystems.

Each ecosystem has characteristic communities of species. Each ecosystem has specific ecological purposes.

Types of Major Ecosystems

- 1. Forest Ecosystems:** Forests are dominated by trees and comprise many types of plants, animals, fungi, and microbes. They control climate, sequester carbon, safeguard soil and water resources, and offer habitat for species.
- 2. Grassland Ecosystems:** Grasslands are areas where grasses are the dominant flora. They provide habitat to herbivores, carnivores, insects, birds and microbes. Grasslands are vital for grazing, for soil protection and for carbon sequestration.
- 3. Desert Ecosystems:** Deserts receive relatively little rain and have species that are adapted to dry circumstances. Special adaptations are present in plants such as cactus and other xerophytes to help them conserve water.
- 4. Freshwater Ecosystems:** Freshwater ecosystems include rivers, lakes, ponds and streams are freshwater ecosystems. They support algae, aquatic plants, fish, amphibians, insects, micro-organisms and many other creatures. "Freshwater ecosystems are important water sources for human societies and agriculture.
- 5. Wetland Ecosystems:** Wetlands are locations where water is present part or all of the year and include places like marshes and swamps. They are very productive ecosystems, offering essential habitat for birds, fish, amphibians and aquatic plants.
- 6. Maritime Ecosystems:** Oceans encompass much of the surface of the Earth, and they are home to vast biological diversity. Marine and coastal ecosystems include coral reefs, mangroves, estuaries and open marine seas.
- 7. Ecosystems of Mountains:** Mountain ecosystems vary greatly in their altitude, temperature, rainfall and flora. They are typically home to strange and unusual species and are essential sources of fresh water.

The Importance of Ecological Diversity: The diversity of life within the biosphere is crucial to the general health and functioning of the biosphere.

- 1. Maintenance of Ecological Processes:** Different ecosystems execute crucial ecological activities such as nutrient cycling, decomposition, primary production, pollination, soil formation and water purification.
- 2. Control of Climate:** Forests, oceans, wetlands and other ecosystems contribute to the global climate by storing carbon, regulating temperature and cycling water.

3. Purification and Regulation of Water: Forests and wetlands also assist in controlling water flow, recharging groundwater and decreasing flooding. Wetlands may help purify water of contaminants and excess nutrients.

4. Soil Preservation: Vegetation protects soil against erosion. Roots hold soil fragments together, and organic matter increases soil structure and fertility.

5. Habitat of the Species: Various ecosystems provide habitats for the existence, feeding, breeding and movement of creatures. Therefore, the destruction of an ecosystem can lead to the decline of numerous species.

6. Economic and social advantages: Ecosystems supply food, fuel, lumber, fibres, pharmaceuticals, freshwater and other resources. They also encourage farming, fishing, forestry and tourism.

7. Educational and Cultural Values: Many ecosystems have cultural, spiritual, recreational and educational values. The natural environment offers chances for scientific inquiry and environmental education.

Threats to Ecological Diversity

Ecological diversity is threatened by: Felling trees, City-building, Industrialisation, Agricultural expansion, Mining, Contamination, Climate change, Over-utilisation of natural resources, Fragmentation of habitat, “Invading species” Growth that is not sustainable. The loss or degradation of ecosystems impacts not only individual species but also the natural processes upon which human society relies.

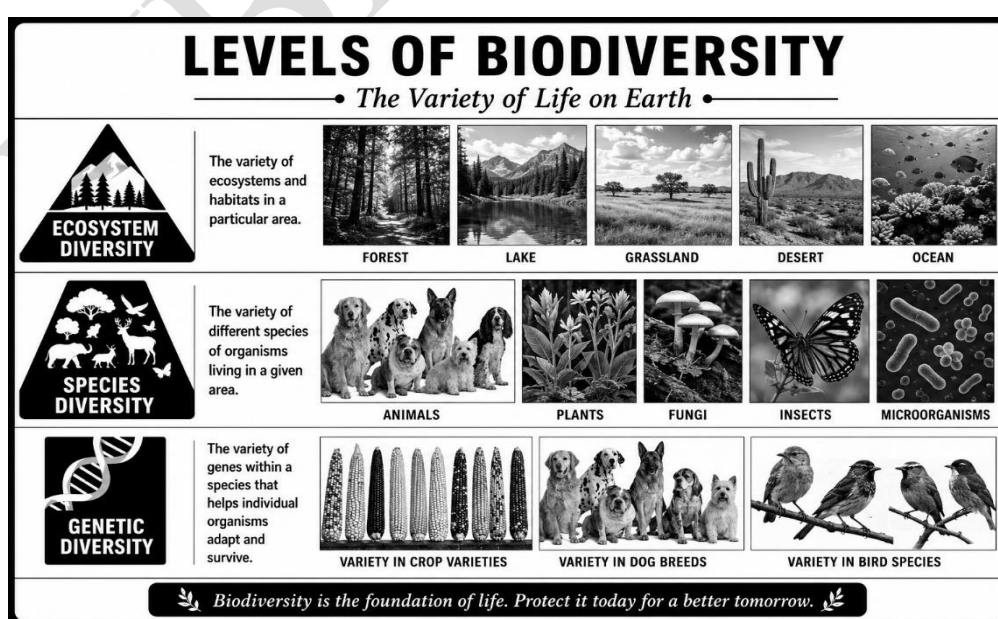


Fig. 1.5 (a) Levels of Biodiversity.

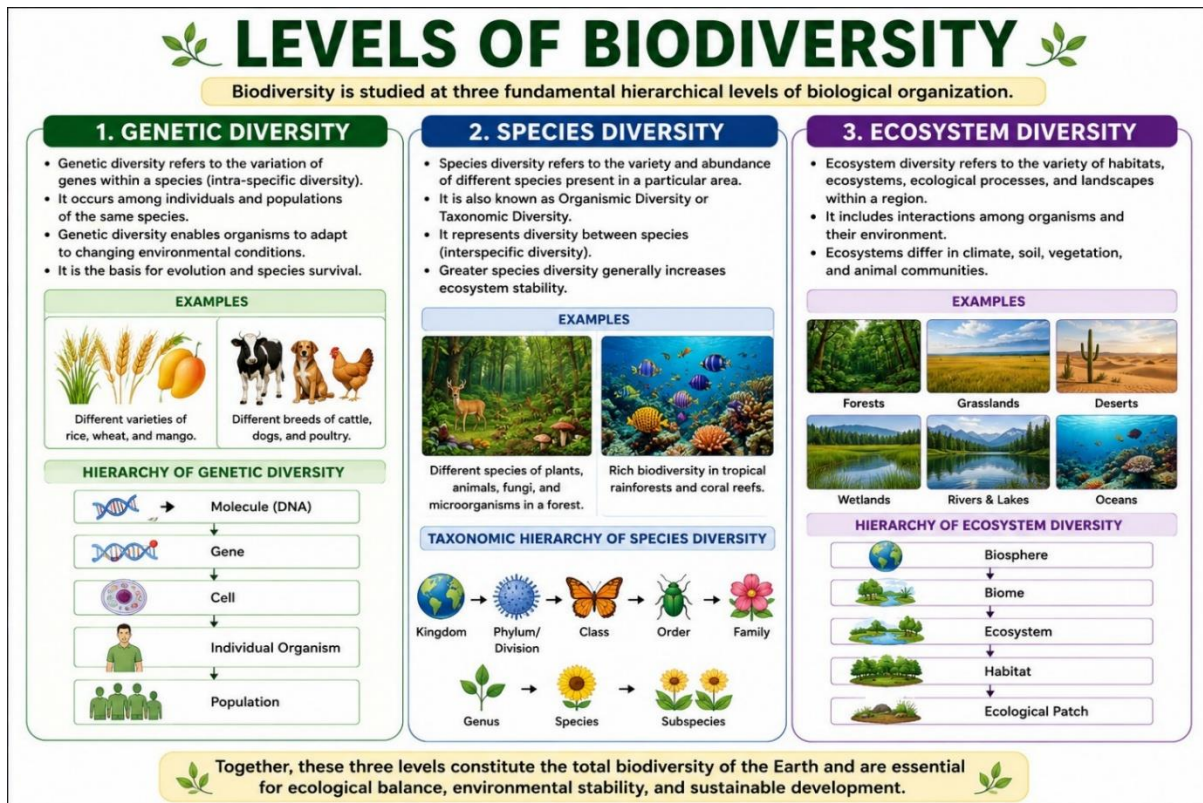


Fig 1.5 (b) Levels of Biodiversity.

Preservation of ecological diversity, protection, and appropriate management of natural habitats are important to conserve ecosystem diversity. Main measures are: Creating protected regions, restoring damaged ecosystems, planting and Restoring Forests, Conservation of Wetlands, Sustainable Forest management, Protection of rivers and their catchments, Coastal and marine habitat conservation, Pollution control and prevention, Adaptation and mitigation of climate change.

Community Conservation

In situ and ex situ measures for conservation may be employed; however, protection of ecosystems in their natural condition is especially crucial for preserving ecological interactions and evolutionary processes. Relationship between the Three Tiers of Biodiversity: Genetic, species and ecological diversity are interdependent. They are closely bound together. There is genetic variation within species. Species diversity is the relative number of species in a community or environment. Ecological diversity is the diversity of ecosystems and habitats on landscapes and regions.

Changes at one level may have effects at other levels. For example, the destruction of a forest environment can lead to a reduction in species populations. This can lead to the loss of

genetic diversity within those species. Therefore, effective biodiversity protection needs to examine all three levels at the same time.

1.1.1 Agrobiodiversity and cultivated plant taxa

Agrobiodiversity, or agricultural biodiversity, refers to the variety and variability of plants, animals and microorganisms that are directly or indirectly associated with food production and agriculture. It includes the diversity of crop varieties, livestock breeds, fish, beneficial insects, soil organisms, wild species and agricultural ecosystems.

Agrobiodiversity is an important subset of overall biodiversity. It has developed over thousands of years through the combined influence of natural selection and the selection, domestication, cultivation and management practices of farmers, pastoralists, herders and fishers. Agriculture is not simply the production of crops and animals. It is a complex interaction between genetic resources, organisms, ecosystems, environmental conditions and human knowledge. Therefore, local knowledge, traditional practices and cultural values are closely associated with agrobiodiversity.

Definition: Agrobiodiversity is the variety and variability of plants, animals and microorganisms that support food and agricultural production, together with the diversity of agricultural ecosystems and the organisms that maintain their functioning.

2. Components of Agrobiodiversity

Agrobiodiversity is broader than the crops and livestock that farmers harvest. It includes **three major components**.

A. Harvested Species and Genetic Resources

These are organisms that are directly used by humans for food, agriculture and other products.

They include

1. Crop plants: Examples include: Rice, Wheat, Maize, Sorghum, Millets, Pulses, Oilseed crops, Vegetables, Fruits, Spices, Medicinal plants. Different varieties of the same crop also constitute an important part of agrobiodiversity. For example, different varieties of rice may differ in: Grain size, Grain colour, Aroma, Nutritional quality, Yield, Duration, Drought tolerance, Salinity tolerance and Disease resistance.

2. Livestock: Agrobiodiversity includes different species and breeds of domesticated animals such as cattle, Buffalo, Sheep, Goats, Pigs, Poultry, Camels, Horses, and donkeys. Different breeds may possess different characteristics such as milk production, meat quality, disease resistance, body size and adaptation to local climatic conditions.

3. Fish and Aquatic Resources: Fish species and other aquatic organisms used for food and livelihood are also components of agrobiodiversity. These include: Freshwater fish, Marine fish, Shellfish, Aquatic plants, Other useful aquatic organisms.

4. Wild Biological Resources: Wild species occurring in agricultural landscapes, forests, grasslands and aquatic ecosystems may also contribute to food security.

Examples include: Wild edible plants, Wild fruits, Wild vegetables, Wild mushrooms, Wild fish, Edible insects.

- Wild relatives of cultivated crops: Wild relatives of crops are particularly important because they may contain genes for **disease resistance, drought tolerance, salinity tolerance and other desirable characteristics.**

3. Non-Harvested Organisms Supporting Agriculture: Many organisms present in agricultural ecosystems are not directly harvested but are essential for successful food production.

A. Soil Microorganisms: Soil contains enormous numbers of microorganisms, including bacteria, Fungi, Actinomycetes, Protozoa, and other microscopic organisms.

These organisms contribute to: Decomposition of organic matter, Nutrient cycling, Soil fertility, Nitrogen fixation, Phosphorus availability, Formation of soil structure, Plant growth promotion. For example, **Rhizobium** bacteria form symbiotic associations with leguminous plants and help in biological nitrogen fixation.

B. Pollinators: Pollinating organisms are essential for the reproduction of many flowering plants and crops. Important pollinators include: Honeybees, Wild bees, Butterflies, Moths, Beetles, Birds, and bats. Pollinators contribute directly to **fruit and seed production** and therefore play an important role in food security.

C. Natural Enemies of Pests: Many organisms naturally control agricultural pests.

These include: Ladybird beetles, Predatory bugs, lacewings, Spiders, Parasitoid wasps, Predatory birds, Beneficial microorganisms. They help reduce pest populations and may decrease dependence on chemical pesticides.

D. Decomposers: Fungi, bacteria and soil animals break down dead plant and animal material. They release nutrients back into the soil and maintain nutrient cycling.

4. Agrobiodiversity in the Wider Environment: Agrobiodiversity also includes organisms and ecosystems outside the immediate agricultural field that indirectly support food production.

Examples include: Forests, Wetlands, Rivers, Grasslands, Rangelands, Coastal ecosystems, watersheds, and Natural vegetation. These ecosystems provide important services such as: Water regulation, Pollination, Pest regulation, Soil conservation, Nutrient cycling, Climate regulation, Carbon storage and Habitat for beneficial organisms. Thus, agricultural production depends not only on cultivated fields but also on the surrounding natural environment.

5. Agrobiodiversity and Overall Biodiversity: Agrobiodiversity is **central to overall biodiversity** because agricultural landscapes contain a large variety of organisms and genetic resources. Agricultural systems are influenced by three major factors: **Environment + Genetic Resources + Human Management**: These three factors interact continuously. Farmers select particular crop varieties, animal breeds and management practices according to climate, Soil, Water availability, Local culture, Food preferences, Market demand, and traditional knowledge. Pest and disease conditions. Therefore, agrobiodiversity is not simply a natural phenomenon. It is the result of a long-term interaction between **nature and human activities**.

6. Role of Farmers and Traditional Knowledge: Farmers, herders and fishers have played a major role in developing and conserving agrobiodiversity over thousands of years.

Through repeated selection, farmers have identified and maintained varieties with desirable characteristics such as: High yield, better taste, Early maturity, Drought tolerance, Disease resistance, Pest resistance, better storage quality, Nutritional value, Adaptation to local soils and climate. Traditional agricultural knowledge is therefore an important part of agrobiodiversity.

Example: A farmer may maintain several varieties of the same crop rather than depending on a single variety. If rainfall is irregular or a particular disease occurs, some varieties may

survive better than others. This practice reduces risk and strengthens **food and livelihood security**.

7. Importance of Minor and Underutilised Crops: Many agricultural communities cultivate crops that are sometimes described as **minor or underutilised crops**. However, these crops may be extremely important at the local level. Examples include: Millets, Traditional pulses, Local vegetables, Wild edible plants, Indigenous fruit crops, Traditional oilseeds. Such crops may survive under conditions where major commercial crops perform poorly.

For example, some traditional crops can grow successfully under: Low rainfall, Poor soils, Drought, High temperatures, Marginal agricultural conditions. They can therefore contribute to **household nutrition, income and resilience**.

8. Wild Plants as Components of Agrobiodiversity

Wild plants can make an important contribution to household food security, particularly in rural communities. People may collect: Wild fruits, Leaves, Roots, Tubers, Seeds, Flowers, Edible shoots. These resources can supplement cultivated food crops.

For example, in parts of the African Sahel, rural communities traditionally collect edible plants such as **baobab (*Adansonia digitata*)**, red sorrel and other native species.

Such wild food resources can provide: Vitamins, Minerals, Dietary fibre, Proteins, Traditional medicines, Food during periods of crop failure. Therefore, wild biodiversity surrounding agricultural systems can be an important component of food security.

9. Distinctive Features of Agrobiodiversity

Agrobiodiversity has several characteristics that distinguish it from many other forms of biodiversity.

1. Active Human Management: Agrobiodiversity is actively managed by **farmers, pastoralists, livestock keepers and fishers**.

2. Dependence on Human Activities: Many domesticated crops and livestock breeds cannot survive effectively without human care and management.

3. Importance of Local Knowledge: Traditional knowledge and cultural practices are closely associated with the conservation and use of agricultural biodiversity.

4. International Interdependence: Many crops and livestock species have been introduced into regions outside their original areas of domestication. As a result, agricultural systems around the world depend on genetic resources originating from different countries and regions.

5. Diversity Within Species: In agriculture, **genetic diversity within a species can be as important as diversity between species**. For example, maintaining many varieties of rice may be as important as maintaining different crop species.

6. Conservation Through Sustainable Use: Agrobiodiversity is closely connected with **sustainable use**. Farmers conserve many crop varieties and animal breeds by continuing to cultivate, breed and use them.

7. Importance of Gene Banks: Modern agricultural systems also conserve genetic resources outside farms through: Seed banks, Gene banks, Germplasm collections, Breeding programmes, Field gene banks. However, **on-farm conservation** remains particularly important for maintaining traditional varieties and the knowledge associated with them.

10. Importance and Functions of Agrobiodiversity

Agrobiodiversity provides numerous ecological, economic and social benefits.

1. Increases Agricultural Productivity: Using diverse crops, varieties and livestock breeds can improve the productivity and efficiency of agricultural systems.

2. Improves Food Security: Diversity in food production reduces dependence on a single crop or livestock species. If one crop fails because of drought, disease or pests, other crops may still provide food.

3. Provides Nutritional Security: Different crops and food organisms provide different nutrients, including: Carbohydrates, Proteins, Fats, Vitamins, Minerals, Dietary fibre. A diverse agricultural system therefore supports a balanced diet.

4. Increases Economic Security: Farmers can diversify their sources of income by producing: Food crops, Fruits, Vegetables, Livestock products, Fish, Medicinal plants and Forest products. This reduces dependence on a single source of income.

5. Reduces Agricultural Risks: Diverse agricultural systems can reduce risks associated with drought, Floods, Pests, Diseases, Market fluctuations, crop failure, and climate variability

6. Supports Pest and Disease Management: Genetic and species diversity can reduce the rapid spread of pests and diseases. Different crop varieties may have different levels of resistance, while beneficial organisms can naturally control pests.

7. Improves Soil Health: Crop diversity, microorganisms, earthworms and other soil organisms contribute to decomposition, Nutrient cycling, Organic matter formation, Soil structure and Soil fertility

8. Reduces Dependence on External Inputs: Diverse farming systems can reduce dependence on chemical fertilisers, Pesticides, Purchased seed, Other external agricultural inputs. Biological processes such as nitrogen fixation and natural pest control can partly replace external inputs.

9. Supports Sustainable Agriculture: Agrobiodiversity promotes agricultural systems that are more resilient, Stable, Productive, and environmentally sustainable

10. Conserves Ecosystem Services: Agrobiodiversity supports important ecosystem services such as pollination, Nutrient cycling, soil formation, Water regulation, Pest regulation, and carbon storage

11. Provides Medicinal Resources: Many agricultural and wild plant species are sources of medicines, Vitamins, Nutraceuticals, and traditional remedies, Bioactive compounds

12. Supports Climate Resilience: Crop varieties and livestock breeds adapted to drought, heat, salinity and other environmental stresses can help agricultural communities respond to climate change.

11. Agrobiodiversity and Sustainable Agriculture: Agrobiodiversity is a foundation of **sustainable agriculture**. Sustainable agricultural systems aim to produce sufficient food while conserving natural resources and maintaining ecosystem health. Agrobiodiversity supports sustainable agriculture through: **Crop diversification → reduced risk → improved soil health → natural pest control → improved resilience → sustainable food production** Examples of practices that promote agrobiodiversity include: Crop rotation, Mixed cropping, Intercropping, Agroforestry, Integrated farming, Organic matter management, Conservation of traditional crop varieties, Integrated pest management, Conservation of beneficial organisms

12. Threats to Agrobiodiversity: Despite its importance, agrobiodiversity is declining in many regions. Major threats include.

1. Replacement of Traditional Varieties: Traditional crop varieties may be replaced by a small number of commercially popular varieties.

2. Monoculture: Large-scale cultivation of a single crop variety reduces genetic and species diversity.

3. Habitat Destruction: Conversion of forests, wetlands and grasslands to agricultural or urban land can destroy important biological resources.

4. Climate Change: Increasing temperatures, changing rainfall patterns, droughts and extreme weather events can threaten agricultural genetic resources.

5. Loss of Traditional Knowledge: When traditional farming practices are abandoned, valuable knowledge about local crops, livestock and natural resources may also disappear.

6. Excessive Use of Chemicals: Excessive use of pesticides and fertilizers can negatively affect soil organisms, pollinators and other beneficial organisms.

7. Invasive Species: Invasive species can compete with native organisms and alter agricultural ecosystems.

8. Socio-economic Changes: Changes in markets, food preferences, land ownership and farming practices may reduce the cultivation of traditional crops and breeds.

13. Conservation of Agrobiodiversity: Agrobiodiversity can be conserved through both **in situ/on-farm** and **ex situ** approaches.

A. On-Farm Conservation: Farmers continue to cultivate traditional crop varieties and maintain indigenous livestock breeds in their natural agricultural environments.

Advantages include: Maintains genetic variation, preserves traditional knowledge, allows continued adaptation, maintains cultural practices, supports local food systems

B. Ex Situ Conservation: Genetic resources are conserved outside their natural agricultural environment. Methods include: Seed banks, Gene banks, Germplasm collections, Field gene banks, Botanical gardens, Livestock conservation centres, Cryopreservation

C. Conservation of Wild Relatives: Wild relatives of crops should be protected because they may contain valuable genes for future crop improvement.

D. Promotion of Traditional Crops: Farmers should be encouraged to cultivate nutritionally valuable and climate-resilient traditional crops.

E. Documentation of Indigenous Knowledge: Traditional knowledge concerning crop selection, seed preservation, livestock management and wild food resources should be documented and transmitted to younger generations.

14. Agrobiodiversity and Food Security: Agrobiodiversity plays a central role in **food and livelihood security**. A farming household depending on only one crop is highly vulnerable to crop failure. In contrast, a household cultivating several crops and maintaining livestock, poultry or other biological resources has multiple sources of food and income.

For example: **Cereals + Pulses + Vegetables + Fruits + Livestock + Poultry + Fish**

Such diversification can provide greater nutritional security and economic stability. Agrobiodiversity therefore acts as a **biological safety net**, particularly for communities living in environmentally challenging regions.

15. Agrobiodiversity and Climate Change: Climate change is creating new challenges for agriculture, including rising temperatures, Irregular rainfall, Drought, Floods, Salinity, New pest outbreaks, and emerging diseases. Genetic diversity provides the raw material needed to develop crops and livestock capable of tolerating these stresses. For example, traditional varieties adapted to drought or poor soils may provide useful genetic traits for developing future climate-resilient crops. Therefore, conserving agrobiodiversity is an important strategy for climate adaptation and agricultural resilience.

16. Key Roles of Agrobiodiversity: The major roles of agrobiodiversity can be summarised as follows.

1. Increases agricultural productivity
2. Strengthens food security
3. Improves nutritional security
4. Diversifies farmers' income
5. Reduces agricultural risks
6. Improves resistance to pests and diseases
7. Supports natural pest control
8. Improves soil fertility and health
9. Promotes sustainable agriculture
10. Reduces dependence on external inputs
11. Supports pollinators and beneficial organisms
12. Conserves ecosystem services
13. Provides medicinal and nutritional resources
14. Supports adaptation to climate change
15. Conserves traditional knowledge and cultural heritage
16. Maintains genetic resources for future crop improvement
17. Protects ecosystem structure and stability
18. Supports the livelihoods of farming and rural communities

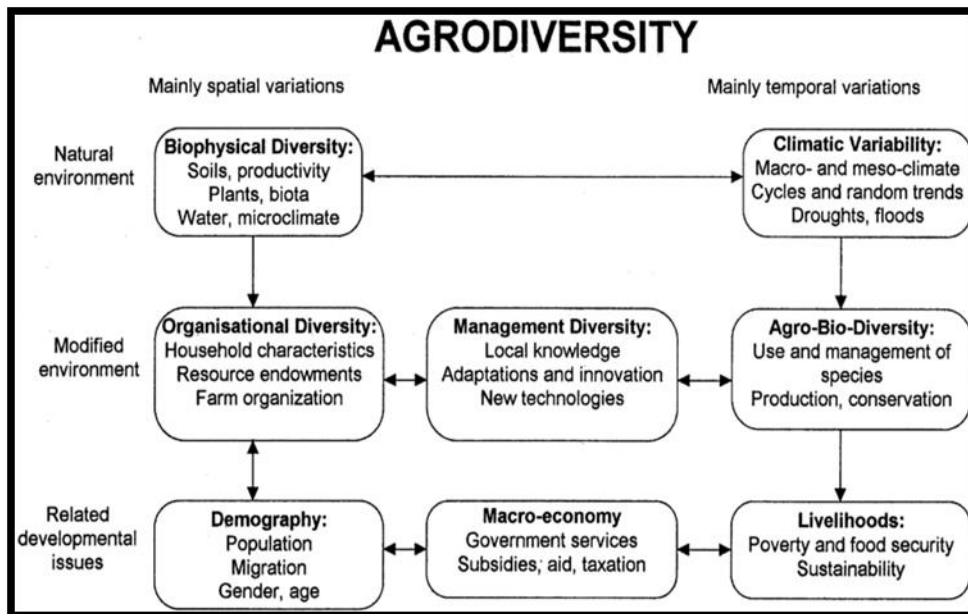


Fig. 1.6 Components and Dimensions of Agrodiversity.

Agrodiversity represents the diversity and variation within agricultural systems. It is influenced by both **spatial and temporal variations** and can be understood through the following major components (Fig.1. 6).

- **Biophysical Diversity:** Variation in soils, plant and biotic resources, water, productivity, and microclimate.
- **Climatic Variability:** Changes in macro- and meso-climates, climatic cycles, droughts, floods, and random trends.
- **Organisational Diversity:** Differences in household characteristics, resource availability, and farm organisation.
- **Management Diversity:** Local knowledge, adaptation, innovation, and use of new technologies.
- **Agro-biodiversity:** Diversity, use, management, production, and conservation of agricultural species.
- **Demography:** Population characteristics, migration, gender, and age structure.
- **Macro-economy:** Government services, subsidies, financial support, and taxation.
- **Livelihoods:** Poverty, food security, and sustainability.

Cultivated plant taxa

Cultivated taxa are plants that have been intentionally selected, propagated, or modified by humans to meet their needs. Cultivated plants are generally derived from wild plants that

were useful to early humans because they were edible, nutritious, productive, or had other valuable properties.

Cultivated Plant Taxonomy

Cultivated plant taxonomy deals with the identification, description, classification, and naming of cultivated plants. It is concerned particularly with the variation found in plants that have been influenced by human selection and cultivation.

The International Code of Nomenclature for Cultivated Plants (ICNCP) provides rules for naming cultivated plants. It helps maintain stability and uniformity in the names used for cultivated plants, particularly those important in agriculture, horticulture, forestry, and commercial production. Plant registration authorities also play an important role in registering new cultivated plant names and maintaining records of these names.

Cultivated plant taxonomy sometimes uses special categories that are different from the usual taxonomic hierarchy used for wild plants. Its main purpose is to provide clear and stable names for cultivated plants used by farmers, horticulturists, foresters, researchers, nurseries, and commercial organisations.

Cultivated plant taxonomy is an important part of horticultural botany. It is mainly studied and practiced in botanical gardens, universities, research institutions, large nurseries, herbaria, and government departments.

Areas of Special Interest: Cultivated plant taxonomists are involved in:

- Searching for and recording new plants suitable for cultivation.
- Identifying and classifying cultivated plants.
- Advising the public and professionals on the classification and nomenclature of cultivated plants.
- Conducting research on cultivated plant variation.
- Describing cultivated plants of particular regions.
- Preparing horticultural floras.
- Maintaining databases, herbaria, and other records of cultivated plants.

Major Groups of Cultivated Plants: Cultivated plants include.

- **Cereals and grains:** Wheat, rice, barley, rye, oats, maize, sorghum, millet and buckwheat.
- **Pulses and vegetables:** Beans, peas and other vegetable crops.

- **Root and tuber crops:** Potato and other tuber crops.
- **Fruit crops:** Various cultivated fruit-producing plants.
- **Commercial crops:** Cotton, jute, sugarcane, oilseed crops and tobacco.
- **Plantation crops:** Rubber, coffee, tea and coconut.

Uses of Cultivated Plants

1. Food Production: Many cultivated plants are grown as important sources of food. Cereals and grains such as **wheat, rice, barley, rye, oats, maize, sorghum and millet** provide carbohydrates and other nutrients. Vegetables, pulses, fruits and tuber crops also form important parts of the human diet.

2. Protein Production: Some cultivated plants, such as **maize and rice**, can be used as systems for producing **recombinant proteins** and other valuable biological products.

3. Commercial Production: Several cultivated plants are grown mainly for commercial purposes. Important examples include **cotton, jute, sugarcane, oilseed crops and tobacco**. These are commonly referred to as commercial crops.

4. Plantation Crops: Important plantation crops include **rubber, coffee, tea and coconut**. They are cultivated on a large scale and contribute significantly to agricultural and commercial activities.

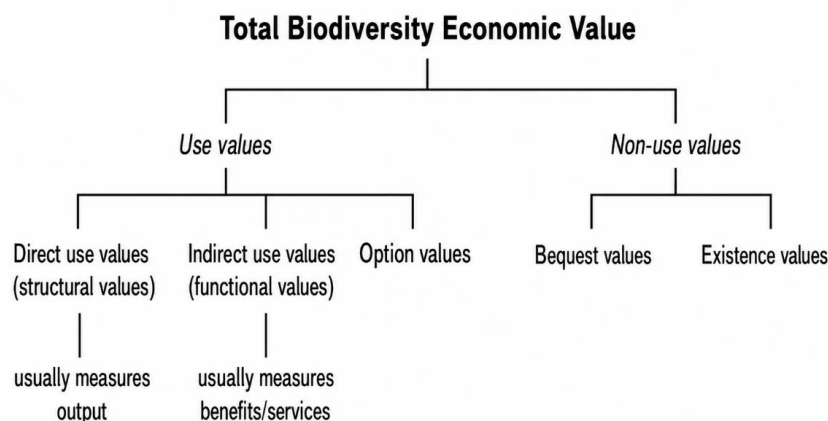
Major Crops in India: The major groups of crops in India include food grains, commercial crops, plantation crops, and horticultural crops. Among food crops, rice is one of the most widely cultivated crops in India. Wheat is one of the oldest crops domesticated by humans. Its early cultivation is associated with the Fertile Crescent of the Middle East, where wheat was domesticated approximately 10,000 years ago. Therefore, wheat is considered one of the earliest cultivated crops in human history. Cultivated plants are closely associated with human civilisation. Through selection, cultivation, propagation, and management, humans have developed a wide range of plants for food, nutrition, medicine, industry, and commerce. Cultivated plant taxonomy helps to identify, classify, name, document, and conserve this important diversity of cultivated plants.

1.1.5 Wild taxa

Crop wild relatives can be defined as wild plant species that are more or less genetically related to crops, but they have not been domesticated. (OR) Crop wild relatives (CWR) are species found growing in the wild and are genetically related to crops. These wild plants (CWR) are essential components of natural and agricultural ecosystems. Thus, they are very

important for maintaining ecosystem health. Their conservation and sustainable use is very important for improving agricultural production, increasing food security and maintaining a healthy environment.

Importance of crop Wild relatives



They are a good source of plant genetic diversity. They constitute a vital resource in the efforts to globally secure food supply for human beings through improved agricultural production. The wild relatives can be found in many different habitats around the world. CWR collectively constitute an enormous reservoir of genetic variation useful for plant breeding initiatives and critical to meeting the challenge of global food security through enhanced agricultural production. CWR occur in a wide range of habitats but are at great risk as habitats continue to be degraded worldwide. There is an urgent need to conserve wild plants both in the wild (in situ) and in gene banks (ex situ) to ensure that genetic diversity remains available for future generations. Wild relatives of modern crops are the source of genes providing improved nutritional quality, resistance to pests and diseases and adaptation to drought and extreme temperatures.

Examples of wild taxa are

1. Wild lentil relatives – include *Lens ervoides* and *Lens orientalis*. They are closely related to cultivated lentils. *L. orientalis* is considered the progenitor of the cultivated lentil.
2. Brassica species – these species have diverse applications, including as vegetables, oil, condiments, fodder, green manure, lubricants and biodiesel
3. Papaya humans have cultivated papaya cultivars for millions of years for their commercial, medicinal and agronomic value. Wild taxa are plants that grow

spontaneously in natural or semi-natural ecosystems and can exist independently of direct human action.

4. *Avena sativa* (oats) – *Avena byzantia*.
5. *Chenopodium quinoa* (quinoa) - *Chenopodium berlandieri*.
6. Finger millet (*Eleusine coracana*) – *Eleusine africana*.
7. Barley (*Hordeum vulgare*) – *Hordeum arizonicum* and *Hordeum spontaneum*.
8. Rice (*Oryza sativa*) – *Oryza rufipogen*.

1. 2 Values and uses of Biodiversity

The values of biodiversity can be classified as direct and indirect values depending on the advantages it gives. Biological resources in many forms immediately contribute to human welfare by providing food, medicines, pharmaceuticals, lumber, fibre, fuel and shelter. Indirect ecosystem services such as air purification, soil formation, nutrient cycling, pollination, water regulation and climate control are also provided by biodiversity.

1. Direct use values

Direct use values refer to the enjoyment, satisfaction, or benefits that people receive directly from biological resources. These values are generally easier to observe and measure because they can often be assigned a monetary price.

There are **two major types of direct use values**.

1. **Consumptive use value** – non-market value
2. **Productive use value** – commercial value

1. Consumptive use value: Consumptive use value is the value of natural products that are directly consumed by people without passing through formal markets.

Humans are dependent on practically all life forms, directly or indirectly for their existence, food, shelter and other requirements, and this is a well recognised truth. The tiniest micro-organisms, by their biological activity, produce beneficial compounds and carry out crucial duties that promote human welfare and the biosphere. Some major utility values of various living forms are discussed below.

1. Viandes: The provision of food by plants is one of the most essential values of biodiversity. Originally, humans gathered food directly from wild plants. In many regions of the world, they still gather wild produce even now.

Currently, around 200 species of angiosperms have been domesticated for food production. Among these, only a few main crops, notably wheat, rice and maize, have reached substantial international economic significance. Similarly, a very limited number of domesticated species of animals and birds yield a large share of the food products used by man.

The number of plant species contributing significantly to total world food production is rather small, but at the local level a huge diversity of food products is provided by a large number of plants, especially in the tropics. But extensive farming of genetically similar crops has replaced many native varieties, some of which have become rare or disappeared altogether. There remains a great number of plant species and variations to be identified, appraised and studied for their potential food value.

2. Wood: Wood is one of the key natural resources which is utilised and traded all over the world. It has economic importance in national and international trade. Timber exports form an important component of the export profits of a number of tropical developing countries. Tropical timber, especially precious hardwoods like teak and mahogany, is a vital export for countries like Malaysia, Indonesia and Papua New Guinea.

Many tropical forests, however, have been substantially degraded by over-harvesting, illicit logging and poor forest management. Therefore, the sustainable management of forests and the responsible use of timber resources are vital for biodiversity conservation.

3. Medical Value: Many valuable treatments and therapies are derived from living organisms, especially from plants, fungus and bacteria. Many valuable medicinals have been derived from wild species.

For instance: Quinine is an important medication used in the treatment of malaria. It is extracted from species of Cinchona. Paclitaxel is a major anticancer medication (Taxol) and was first isolated from species of the genus Taxus. Several species of Digitalis, popularly called foxglove, are the source of digitalis glycosides like digoxin, which are used in the treatment of several cardiac diseases. Penicillin, one of the most important antibiotics, was first derived from fungi of the genus Penicillium.

Many more therapeutic chemicals have been obtained from plants and other species, especially those found in tropical woods. India is home to a number of native plants such as

Tulsi (*Ocimum tenuiflorum*) and Neem (*Azadirachta indica*) that are utilised in traditional medicine.

Many unexploited species may contain novel bioactive chemicals with potential applications in medicine, biotechnology and pharmaceutical research. Therefore, biodiversity protection is crucial for future discovery and development of medications.

Living organisms, including plants, animals and microorganisms, provide us with many useful drugs and medicines. For example, quinine, a drug used in the treatment of malaria, is obtained from the bark of Cinchona. Taxol (paclitaxel), an important anticancer drug, was originally obtained from species of Taxus. Digitalis glycosides, important in the treatment of certain heart conditions, are obtained from the purple foxglove (*Digitalis* spp.). Penicillin, an important antibiotic, was originally obtained from fungi belonging to the genus *Penicillium*.

Many other medicinal compounds have been obtained from organisms occurring in tropical forests, as shown in Table 1.4: Natural Medicinal Products. Several plants native to India, such as Tulsi (*Ocimum tenuiflorum*) and Neem (*Azadirachta indica*), have important medicinal applications.

There are still numerous organisms that may produce useful bioactive and medicinal compounds that are yet to be identified, evaluated and tested. Therefore, the conservation of biodiversity is essential for the discovery of new medicines and pharmaceutical products.

Table 1.4: Natural Medicinal Products.

S. No.	Medicinal Product	Natural Source	Major Use
1	Aspirin	Willow bark (<i>Salix</i> spp.)	Anti-inflammatory and pain relief
2	Allantoin	Blowfly larvae	Wound healing
3	Bacitracin	Bacterium (<i>Bacillus</i> spp.)	Antibiotic
4	Bee venom	Honeybee	Arthritis relief
5	Cytarabine	Marine sponge	Treatment of certain leukaemias
6	Cortisone	Mexican yam (<i>Dioscorea</i> spp.)	Anti-inflammatory
7	Digitalis	Foxglove (<i>Digitalis</i> spp.)	Cardiac stimulant
8	Diosgenin	Mexican yam (<i>Dioscorea</i> spp.)	Precursor for steroid and contraceptive drugs
9	Erythromycin	Bacterium (<i>Saccharopolyspora erythraea</i>)	Antibiotic
10	Morphine	Poppy (<i>Papaver somniferum</i>)	Analgesic
11	Penicillin	Fungus (<i>Penicillium</i> spp.)	Antibiotic
12	Quinine	Cinchona bark (<i>Cinchona</i> spp.)	Treatment of malaria
13	Reserpine	<i>Rauwolfia</i> (<i>Rauwolfia serpentina</i>)	Treatment of hypertension

14	Tetracycline	Bacterium (<i>Streptomyces</i> spp.)	Antibiotic
15	Vinblastine	Rosy periwinkle (<i>Catharanthus roseus</i>)	Anticancer drug
16	Vincristine	Rosy periwinkle (<i>Catharanthus roseus</i>)	Anticancer drug

Many plants native to India, such as **Tulsi (*Ocimum tenuiflorum*)** and **Neem (*Azadirachta indica*)**, have important medicinal applications. There are still numerous organisms that may produce useful medical compounds that are yet to be identified, evaluated and tested.

2. Productive use value: Productive use value refers to biological products that are commercially harvested, processed or exchanged in formal markets. These products have a market price and contribute to economic activity.

Examples: Animal skins, Ivory, Medicinal plants, Honey, Beeswax, Fibres, Gums and resins, Timber, commercially valuable plant and animal products.

Important Points

- Products are collected or produced for sale or commercial exchange.
 - They generate income and employment.
 - This is often the most visible economic value of biological resources.
 - Many species have potential economic importance to humans.
 - The global collection of genes, species, habitats and ecosystems is a valuable resource for meeting present and future human needs.
 - Productive-use values are more likely to be recorded in national income accounts.
- Example: The commercial collection and sale of medicinal plants, honey, timber or natural fibres represent productive use value.

2. Indirect Values of Biodiversity

Indirect values can be understood through several important categories.

A. Non-consumptive values

B. Social values

C. Ethical values

D. Aesthetic values

A. Non-consumptive values

Non-consumptive values are the indirect benefits obtained from ecosystem functions without directly consuming biological resources.

1. Genetic Value: Biological diversity represents a valuable **genetic resource**. Many improved and hybrid varieties of crops have been developed by incorporating useful genes from different species or varieties. Several examples illustrate the importance of genetic diversity in crop improvement.

- 1. Powdery mildew resistance:** Genes for resistance to powdery mildew obtained from a wild variety of watermelon grown in **Uttar Pradesh, India**, were transferred into muskmelon varieties grown in the USA to improve disease resistance.
- 2. Red rot resistance in sugarcane:** Genes from a grass species or variety originating from **Indonesia** were introduced into sugarcane to impart resistance to **red rot disease**.
- 3. Pest resistance in cotton:** A gene from the bacterium *Bacillus thuringiensis* was introduced into cotton plants to provide resistance against certain insect pests. Such genetically modified cotton is commonly known as **Bt cotton**.

These examples demonstrate the enormous potential of **plant breeding and biotechnology** for developing improved crop varieties with desirable characteristics such as disease resistance, pest resistance, improved yield and environmental adaptability. Therefore, maintaining and conserving **genetic diversity and gene pools** is essential for developing biologically diverse and improved forms of crops.

2. Ecotourism: Biodiversity is an important component of **landscape beauty and natural heritage**. It enhances the quality of life by providing aesthetically pleasing and attractive natural environments. Nowadays, increasing numbers of people spend considerable amounts of money on programmes associated with **ecotourism and nature-based tourism**.

In India, several ecotourism programmes have been developed in biodiversity-rich regions. Examples include ecotourism and boat trips along the **Godavari River in the Papikondalu region**. Wildlife and nature tourism in **Munnar, Kerala**.

- Ecotourism activities in forest and wildlife areas such as **Girnar**.
- Rafting and adventure tourism in the **Himalayan rivers**.

Such activities generate income and employment and thereby contribute to the economic development of local communities.

Many indigenous and local communities also attach great cultural and religious importance to mountains, forests and plants. The protection of **sacred groves**, forests and culturally important trees has traditionally contributed to biodiversity conservation and can also

promote tourism. The famous **Pillalamarri Banyan Tree** in Telangana is an example of a natural heritage site that attracts visitors.

3. Ecological Balance: Wild species often provide valuable but **under-recognised ecological services** that are essential for maintaining ecological balance.

For example, **frogs feed on large numbers of insects and other small organisms** and therefore help regulate insect populations. A decline in frog populations can contribute to an increase in insect pests and may disturb ecological balance. Frogs also form an important part of food webs and serve as indicators of environmental health.

Similarly, bats, birds and insects play important roles in pollination and seed dispersal. The disappearance or substantial reduction of any of these organisms can significantly affect crop production, plant regeneration, and biodiversity.

Certain species have a disproportionately large influence on an ecosystem's structure and functioning and are referred to as keystone species. However, not every important or abundant species is necessarily a keystone species. The banyan tree (*Ficus benghalensis*), for example, provides food, shelter and nesting sites for numerous birds, insects and other organisms and contributes significantly to the functioning of local ecosystems.

B. Social values: Biodiversity has important religious, spiritual, cultural and traditional values, particularly in India. Many plants, animals and natural ecosystems have special significance in local traditions and religious practices.

Examples from India

- **Hibiscus** flowers are traditionally offered to **Goddess Kali**.
- **Datura** flowers are associated with the worship of **Lord Shiva**.
- **Sami (*Prosopis spicigera*)** has been traditionally used in sacrificial fires.
- **Sacred groves** are patches of natural vegetation traditionally protected because they are believed to be associated with gods, ancestors or spirits.

Sacred Groves: Sacred groves are natural forest patches protected by local communities because of their religious and cultural significance. They also help conserve rare plant species, wildlife, genetic diversity, natural vegetation, and traditional ecological knowledge. Thus, biodiversity has a strong social and cultural value in addition to its economic value.

1.2.1 Ethical and aesthetic values

Ethical values: Biodiversity conservation can be justified not only on economic grounds but also on ethical grounds. Ethical values are based on the idea that living organisms have intrinsic value, regardless of their usefulness to humans.

Important Points

- Humans have a responsibility to protect other species.
- People do not have an unlimited right to destroy species or cause their extinction.
- The loss of one species may have far-reaching consequences for ecosystems and human society.
- Humans should learn to live within the ecological limits of the planet.
- Environmental damage should be minimised.
- People should take responsibility for their actions affecting nature.
- Present generations have a responsibility to protect natural resources for future generations.

Aesthetic values: Aesthetic value refers to the beauty, enjoyment, inspiration and emotional satisfaction that people obtain from nature and biodiversity. People enjoy natural landscapes, wildlife, forests, flowers, mountains, rivers and other elements of biodiversity. Examples: Beauty of wildflowers in national parks. Wildlife watching, Hiking, Canoeing, Mountain climbing, nature photography, and visiting forests and protected areas. These activities can provide **physical, intellectual and emotional satisfaction**.

Importance

- Nature provides inspiration and happiness.
- Natural beauty contributes to human well-being.
- Biodiversity can stimulate **creativity and knowledge**.
- Loss of biodiversity may reduce opportunities for future generations to experience and learn from nature.

Option value: Option value is the value of keeping the possibility of using biodiversity in the future. A species may have no known economic use today, but it may contain genes, chemicals or other properties that could become valuable in the future.

Important Points

- It represents the **potential future benefits** of biodiversity.
- It involves maintaining choices or **options for future generations**.
- The potential of a species to provide a future economic or social benefit is called its **option value**. As human needs change, new uses of biological resources may be discovered.

Examples: Pharmaceutical companies and health researchers study plants, microorganisms and animals to identify compounds that may help in treating diseases such as **cancer and other serious disorders**. A species that appears to have little value today may therefore become extremely important in the future.

4. Other Indirect Ecological Services: Diverse communities of plants, animals and microorganisms provide numerous **essential ecosystem services** that help maintain ecological stability and support life on Earth. Some important indirect ecological services include.

1. Absorption of solar energy through photosynthesis.
2. Fixation of carbon dioxide during photosynthesis and storage of carbon in living biomass and soils.
3. Purification of atmospheric air and water resources.
4. Regulation of biogeochemical and hydrological cycles.
5. Recycling of soil nutrients through decomposition and nutrient cycling.
6. Prevention of soil erosion by vegetation and plant root systems.
7. Regulation of local and global temperature and climate.
8. Pollination and seed dispersal by animals and other organisms.
9. Decomposition of organic matter and maintenance of soil fertility.
10. Regulation of water flow and groundwater recharge.

Thus, biodiversity provides a wide range of **indirect ecological services** that are fundamental to ecosystem stability, environmental sustainability and human well-being. Conservation of biodiversity is therefore essential not only for protecting individual species but also for maintaining the ecological processes on which life depends.

1.2.2 Precautionary principle: The Precautionary Principle is an important principle of environmental protection and biodiversity conservation. It states that preventive action should

be taken to protect the environment even when there is scientific uncertainty about the extent of possible damage.

Definition: “Lack of complete scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.”

1. **Prevention is better than cure:** Environmental damage should be prevented before it occurs rather than trying to restore the environment after damage has taken place.
2. **Scientific uncertainty is not an excuse:** Even when scientists do not have complete evidence about the harmful effects of an activity, appropriate preventive measures should be taken if there is a possibility of serious environmental damage.
3. **Protect biodiversity:** Activities that may threaten species, habitats or ecosystems should be carefully evaluated before they are permitted.
4. **Control potentially harmful activities:** Industrial pollution, deforestation, excessive use of pesticides, introduction of invasive species and other potentially damaging activities should be regulated.
5. **Burden of proof:** The person or organisation proposing a potentially harmful activity should demonstrate that reasonable environmental safeguards are in place.
6. **Protection of future generations:** Natural resources should be used responsibly so that future generations can also benefit from them.

Examples: Restricting the use of a **new chemical pesticide** until its environmental effects are adequately assessed. Conducting an **Environmental Impact Assessment (EIA)** before constructing a large dam, mine or industrial project. Preventing the introduction of a potentially **invasive species** until its ecological effects are understood. Protecting an endangered species when there is a reasonable possibility that a proposed activity could cause further population decline.

Importance in Biodiversity Conservation: The precautionary principle is particularly important because the extinction of a species or the destruction of an ecosystem may be irreversible. Therefore, conservation decisions should favour prevention and protection rather than waiting for complete scientific evidence.

In Simple Words: “If an activity may cause serious or irreversible environmental damage, take preventive action even when complete scientific evidence is not yet available.”

1.2.3 Methodologies for valuation

1. Valuation of Biodiversity: Biodiversity valuation is the process of assigning economic, ecological, social and environmental values to biological resources, including species, habitats, ecosystems and the services they provide. It helps society understand the benefits obtained from biodiversity and provides a basis for making decisions about conservation, sustainable use and development. The concept of **Total Economic Value (TEV)** is commonly used for biodiversity valuation. TEV includes direct-use values, indirect-use values, option values and non-use values such as existence and bequest values.

2. Market Price Method: The market price method estimates the value of biodiversity by using the actual prices of biological products traded in markets. Products such as timber, fish, medicinal plants, fruits, fibres, honey and other forest products have observable market prices. The quantity of the product sold and its market price can therefore be used to estimate its economic value. This method is relatively simple when reliable market information is available.

3. Replacement Cost Method: The replacement cost method estimates the value of an ecosystem service by calculating how much it would cost to replace that natural service with a human-made alternative. For example, a wetland naturally filters and purifies water. If the wetland were destroyed, a water-treatment facility might be required to perform a similar function. The cost of constructing and maintaining such a facility provides an estimate of the replacement value of the wetland service.

4. Restoration Cost Method: The restoration cost method estimates biodiversity value based on the expenditure required to restore a damaged ecosystem to its original or desired ecological condition. For example, the cost of restoring a degraded forest, wetland, river or grassland can provide an indication of the importance of maintaining that ecosystem. This method is particularly useful when ecosystems have already been damaged and restoration programmes are being considered.

5. Averted Damage Cost Method: The averted damage cost method measures the economic value of biodiversity by estimating the damage that is prevented because of natural ecosystem functions. For example, forests, wetlands and mangroves can reduce flooding and protect human settlements and agricultural land. The monetary value of the flood damage avoided because these ecosystems are present represents an important economic benefit of biodiversity.

6. Travel Cost Method: The travel cost method estimates the recreational value of natural areas by examining how much people spend to visit them. Travel expenses, entrance fees,

accommodation costs and the value of time spent travelling can be considered. For example, the number of visitors and their travel expenditure can help estimate the recreational value of a national park, wildlife sanctuary or ecotourism site.

7. Hedonic Pricing Method: The hedonic pricing method estimates the value of environmental amenities by examining their effect on the prices of related goods, particularly property. For example, houses located near clean lakes, forests, parks or attractive natural landscapes may have higher market prices than similar properties without such environmental advantages. The difference in property prices can therefore provide an indication of the value people place on environmental quality.

8. Contingent Valuation Method: The contingent valuation method uses surveys to ask people directly how much they are willing to pay for the protection, conservation or improvement of a biodiversity resource. For example, people may be asked how much they would be willing to contribute annually to protect an endangered species or conserve a forest. The resulting **willingness-to-pay (WTP)** estimates are used to calculate the economic value of biodiversity that may not have a direct market price.

9. Choice Modelling or Choice Experiment: Choice modelling is a stated-preference method in which people are presented with different environmental alternatives having different characteristics and costs. Respondents select their preferred option. Their choices allow researchers to estimate the value of individual biodiversity attributes, such as the number of species protected, area of habitat conserved or improvement in environmental quality. It is useful when researchers want to value different components of an ecosystem separately.

10. Benefit Transfer Method: The benefit transfer method uses economic values obtained from an existing biodiversity valuation study and applies them to another similar ecosystem or conservation site. For example, the recreational value estimated for one forest may be transferred and adapted to another forest with similar ecological and socio-economic characteristics. This method saves time and money, although the sites must be sufficiently similar for the transferred estimates to be reliable.

11. Participatory Environmental Valuation: Participatory Environmental Valuation involves local communities and other stakeholders in assessing the importance and value of biodiversity. Instead of relying entirely on monetary measurements, people may rank or score ecosystem services according to their ecological, cultural, social and livelihood importance. This approach is especially useful for understanding values such as sacred forests, traditional medicinal plants and community resources that may not have formal market prices.

12. Total Economic Value: The **Total Economic Value (TEV)** represents the overall value of biodiversity by combining its different forms of value. It includes **direct-use values**, such as food, timber and medicinal plants; **indirect-use values**, such as pollination, climate regulation and flood protection; **option value**, which represents potential future uses; and **non-use values**, including existence and bequest values. TEV provides a broader understanding of why biodiversity conservation is economically, ecologically and socially important.

1.2.4 Uses of plants

Plants are an essential part of life on Earth and play a vital role in maintaining ecological balance. They provide food, oxygen, medicines, timber, fibres, oils, beverages, and many other useful products. Plants are also important in agriculture, industries, environmental protection, and human health. Since ancient times, humans have depended on plants for their basic needs, economic activities, and cultural practices. Therefore, plants are often called the “foundation of life” and are invaluable natural resources that must be conserved and used sustainably.

Foundation of Life on Earth: Plant biodiversity forms the **foundation of life on Earth**. Plants provide essential food, oxygen, medicines and raw materials. A wide variety of plant species helps maintain ecological balance and supports the survival of humans, animals and microorganisms.

Food and Nutrition: Plants are the primary source of **food and nutrition** for humans and animals. They provide cereals, pulses, fruits, vegetables, nuts, roots, tubers and seeds. Plant diversity also provides animal fodder and helps maintain food security by offering a wide range of crops and genetic resources.

Medicinal Value: Plants are an important natural source of **medicines and pharmaceutical compounds**. Many traditional remedies and modern drugs are derived from plants. Plant biodiversity provides a valuable reservoir of chemical compounds that can be used for the prevention and treatment of diseases and for the development of new medicines.

Materials and Industrial Uses: Plants provide numerous **raw materials for construction, clothing and industries**. Wood is used for timber, furniture and construction, while fibres

such as **cotton and jute** are used for textiles and ropes. Plants also provide latex for rubber, gums, resins, oils, dyes and other industrial products.

Air Purification and Oxygen Production: Plants play a major role in maintaining **air quality**. Through photosynthesis, green plants absorb carbon dioxide and release oxygen into the atmosphere. Vegetation also helps remove certain air pollutants and dust particles, thereby contributing to a healthier environment.

Climate Regulation: Plant biodiversity contributes significantly to **climate regulation**. Plants absorb atmospheric carbon dioxide during photosynthesis and store carbon in their biomass and soils. Forests, grasslands and other plant communities therefore help reduce the accumulation of greenhouse gases and moderate local and global climate.

Soil Conservation and Fertility: Plants protect and improve **soil quality**. Their roots bind soil particles and reduce soil erosion caused by wind and water. Plant litter adds organic matter to the soil, improves soil structure and contributes to nutrient cycling and soil fertility.

Water Conservation: Plant communities play an important role in **water conservation and watershed protection**. Vegetation increases water infiltration into the soil, reduces surface runoff and helps maintain groundwater recharge. Forests and other plant ecosystems also help regulate water flow and reduce the risk of floods and droughts.

Habitat for Wildlife: Plants provide **food, shelter, nesting sites and breeding habitats** for animals, birds, insects and microorganisms. Different plant species create complex habitats that support a wide variety of organisms and help maintain ecosystem stability.

Ecological Stability and Resilience: High plant diversity increases the **stability and resilience of ecosystems**. When an ecosystem contains many different plant species, it is better able to withstand pests, diseases, droughts, climate change and other environmental stresses. Genetic and species diversity also provides opportunities for ecosystems to adapt to changing conditions.

1.2.5 Uses of microbes.

Microbes are microscopic organisms such as bacteria, fungi, algae, protozoa, and viruses that are found almost everywhere in nature. They play an important role in human health, agriculture, food production, industry, and environmental protection. Beneficial microbes are

used in the production of curd, bread, cheese, antibiotics, enzymes, biofertilizers, and biofuels. They also help in decomposition, nutrient cycling, nitrogen fixation, and bioremediation. Thus, microbes are essential for maintaining ecological balance and have great importance in science, medicine, agriculture, and biotechnology.

1. Microbial Biodiversity: Microbial biodiversity refers to the enormous variety of **bacteria, fungi, archaea, viruses and other microorganisms** found in different environments on Earth. Microorganisms are fundamental components of ecosystems and play essential roles in nutrient cycling, decomposition, soil fertility, environmental purification, agriculture, medicine and industry.

2. Nutrient Cycling: Microorganisms are major agents of **decomposition and nutrient cycling**. They break down dead plants, animals and organic wastes and release essential elements such as **carbon, nitrogen and phosphorus** back into the environment. This makes nutrients available again for plants and maintains the productivity and functioning of ecosystems.

3. Nitrogen Fixation: Certain microorganisms can convert atmospheric nitrogen into **usable nitrogen compounds** through biological nitrogen fixation. Nitrogen-fixing bacteria such as *Rhizobium* live in association with leguminous plants and improve soil nitrogen availability. This process is essential for plant growth and contributes significantly to soil fertility.

4. Bioremediation: Microbial biodiversity is important in **bioremediation**, in which microorganisms are used to remove, degrade or detoxify pollutants from contaminated environments. Specialized bacteria and fungi can break down petroleum hydrocarbons, pesticides and other organic pollutants, while certain microorganisms can transform or immobilise toxic metals. Thus, microbes help restore polluted soil and water.

5. Plastic Degradation: Some microorganisms and their enzymes have the ability to **degrade certain synthetic polymers and plastic components**. Research into microbial plastic degradation is providing new possibilities for managing plastic waste. Such organisms and their enzymes may contribute to future biological approaches for reducing persistent plastic pollution.

Agricultural uses

6. Soil Fertility and Plant Growth: Beneficial microorganisms are essential for maintaining **soil fertility and plant health**. Bacteria and fungi decompose organic matter, release

nutrients and improve nutrient availability. Mycorrhizal fungi form associations with plant roots and can enhance the uptake of water and minerals, particularly phosphorus.

7. Biofertilizers: Biofertilizers contain beneficial microorganisms that increase the availability of nutrients to plants. Examples include **nitrogen-fixing bacteria, phosphate-solubilizing microorganisms and mycorrhizal fungi**. They can reduce dependence on chemical fertilizers and support more sustainable agricultural production.

8. Biopesticides: Microorganisms can also be used as **biological control agents** against agricultural pests and plant pathogens. Microbial biopesticides, including certain bacteria, fungi and viruses, can suppress harmful insects or disease-causing organisms while generally reducing reliance on conventional chemical pesticides.

Industrial and medical uses

9. Medicine: Microorganisms are important sources of **medicines and pharmaceutical products**. They produce antibiotics, vitamins, enzymes and other biologically active compounds. Microbial biodiversity therefore provides a valuable reservoir for discovering new therapeutic substances and developing pharmaceutical products.

10. Food Production and Fermentation: Microorganisms are essential in the production of many **fermented foods and beverages**. Yeasts, bacteria and other microorganisms are used in the preparation of **bread, yoghurt, cheese and fermented beverages**. Fermentation improves food preservation, flavour, texture and nutritional properties.

11. Enzyme Technology: Microorganisms are important sources of **industrially useful enzymes**. Enzymes produced by bacteria, fungi and extremophilic microorganisms can function under unusual conditions of temperature, pH or salinity. They are used in industries such as **detergent production, food processing, textiles, pharmaceuticals and biotechnology**.

12. Industrial Biotechnology: Microbial biodiversity provides organisms capable of producing **organic acids, alcohols, enzymes, antibiotics, biofuels, vitamins and other commercially valuable products**. Because microorganisms can grow rapidly and can often be cultured under controlled conditions, they are valuable tools in modern industrial biotechnology.

Revision Questions

1. Explain the different levels of plant diversity with reference to genetic, species and ecosystem diversity.

2. Describe agrobiodiversity and explain the importance of cultivated and wild plant taxa.
3. Discuss the ethical and aesthetic values of biodiversity.
4. Explain the major uses of plants and microbes in human welfare.

Short-Answer Questions

1. What is genetic diversity?
2. Define species diversity.
3. What is meant by plant diversity at the ecosystem level?
4. Define agrobiodiversity.
5. What is the precautionary principle in biodiversity conservation?
6. Mention any four uses of microbes.

UNIT-2

Biodiversity refers to the variety and variability of life on Earth, including plants, animals, microorganisms, and the ecosystems in which they occur. It is essential for maintaining ecological balance and provides numerous benefits to humans, such as food, medicines, oxygen, pollination, soil fertility, clean water, and climate regulation. However, biodiversity is declining rapidly due to increasing human activities and environmental changes.

Loss of biodiversity means the reduction or disappearance of species, genetic diversity, and ecosystems. Major causes include deforestation, habitat destruction, overexploitation of natural resources, pollution, climate change, invasive species, urbanisation, and intensive agriculture. The disappearance of even a single species can disturb food chains and ecological interactions.

The loss of biodiversity poses serious threats to ecosystem stability, food security, human health, and sustainable development. Therefore, effective conservation measures, sustainable resource management, habitat restoration, and public awareness are essential to protect biodiversity for present and future generations.

2.1 Loss of Biodiversity

Biodiversity loss is the reduction in the number of species, genetic variation, diversity of creatures and biological communities in a given area. The loss of biodiversity can have a strong impact on the structure and functioning of ecosystems.

For example, removing trees from a forest affects several vital functions supplied by trees such as shade, regulation of temperature and moisture, wildlife habitat, and nutrient cycling. Therefore, the natural balance of the forest may be disrupted.

Natural Risks: Natural ecological disturbances such as wildfires, floods, droughts, storms, and volcanic eruptions can radically affect ecosystems. They can cause the extinction of some species locally and change entire biological communities.

Natural disturbances are generally transient and part of the dynamics of natural ecosystems (e.g., these events have happened many times in the course of evolution, and so many ecosystems and species have adaptations that allow them to rebound from such disturbances).

Human-caused loss of biodiversity

However, human activities tend to cause more serious, widespread and longer-lasting losses of biodiversity. The main factors include the loss of forest cover, damage to habitats, pollution, over-exploitation of natural resources, invasive species and climate change.

Researchers believe that the present rate of species extinction is 100-10,000 times the natural background extinction rate. In the fossil record as a whole, the background extinction rate is estimated to be around 1–5 species each year.

Thus, the present loss of biodiversity is a severe threat to ecosystem stability, ecological services and the long-term survival of many species.

The biological wealth of our planet is declining rapidly, mainly because of human activities. Biodiversity loss affects not only individual species but also the stability and functioning of ecosystems. For example, when predator populations decline, prey species such as pests may increase rapidly because of reduced biological control. This imbalance can place additional pressure on organisms at lower levels of the food chain.

Major Causes of Biodiversity Loss: The five major drivers of biodiversity loss are.

1. **Habitat loss and change in land use**
2. **Overexploitation of biological resources**
3. **Climate change**
4. **Pollution**
5. **Invasion by alien or invasive species**

Biodiversity loss refers to the decline in the number of organisms, genetic variability, species diversity, and biological communities in a particular region. Although biodiversity is commonly associated with species richness, the decline in the population of a species can also reduce the ecological role or niche that the species performs.

If a species performs an important ecological function, a substantial decline in its population can cause major changes in ecosystem structure and functioning. For example, **deforestation** removes trees that provide shade, regulate temperature and moisture, provide habitats for animals, and contribute to nutrient cycling.

Natural Biodiversity loss: Biodiversity naturally fluctuates over time as ecosystems respond to seasonal and environmental changes. For example, the arrival of spring creates favourable conditions for feeding, flowering, reproduction, and breeding, resulting in an increase in the populations of many organisms. During winter, however, biodiversity may temporarily decline because many insects become inactive or die, while migratory animals leave the region.

Seasonal changes in plants, insects, and other invertebrates can strongly influence the availability of food for other organisms and thereby affect local biodiversity.

Natural ecological disturbances such as wildfires, floods, droughts, storms, and volcanic eruptions can also dramatically alter ecosystems. They may eliminate local populations and temporarily transform entire biological communities.

However, natural disturbances are generally part of normal ecosystem dynamics. Since such disturbances have occurred throughout evolutionary history, many organisms and ecosystems have developed mechanisms to adapt, recover, and regenerate after these events.

In contrast, biodiversity loss caused by human activities is often more rapid, extensive, and long-lasting. Large-scale conversion of natural ecosystems into agricultural land has resulted in extensive loss and fragmentation of forests, wetlands, grasslands, and other habitats. Such changes have contributed substantially to declines in wildlife populations, particularly in freshwater ecosystems.

Major Effects of Biodiversity Loss: Loss of biodiversity in a region may result in.

1. **Reduced plant productivity and food production**
2. **Lower resistance and resilience to environmental stresses**, such as droughts and floods
3. **Greater instability in ecosystem processes**, including plant productivity, water use, pest outbreaks, and disease cycles
4. **Disruption of food webs and ecological interactions**
5. **Reduction in important ecosystem services**

Causes of Biodiversity Loss: The present-day acceleration of species extinction is largely associated with human activities and increasing pressure on natural resources. The major causes are described below.

1. Habitat Loss and Fragmentation

Habitat loss is one of the most important causes of biodiversity decline. It occurs when natural habitats are destroyed or converted for agriculture, settlements, industries, roads, mining, and other human activities.

Habitat fragmentation occurs when a large continuous habitat is divided into smaller, isolated patches. Fragmented habitats may not provide sufficient food, shelter, breeding sites, or migration routes for many species.

Tropical rainforests are particularly important because they support an enormous variety of organisms. Large areas of rainforest have been cleared for **agriculture, cattle ranching, plantations, mining, and infrastructure development**. The destruction and fragmentation of these habitats threaten numerous plant and animal species.

2. Overexploitation: Human beings depend on biological resources for **food, medicine, timber, fibres, fuel, and other materials**. However, when the rate of exploitation exceeds the natural capacity of populations to recover, it results in **overexploitation**.

Historical examples include the extinction of the **Steller's sea cow** and the **passenger pigeon** due largely to excessive human exploitation.

Today, many marine organisms are harvested faster than their populations can replace themselves. **Overfishing**, illegal hunting, excessive logging, and unsustainable collection of wild plants are important examples of overexploitation.

3. Invasion by Alien Species: An **alien species** is a species introduced outside its natural geographical range. Some introduced species become **invasive**, spread rapidly, compete with native organisms, alter habitats, and cause population declines.

A well-known example is the introduction of the Nile perch into Lake Victoria in East Africa, which contributed to severe declines and extinctions among many native cichlid fish species. In India, invasive plants such as ***Parthenium hysterophorus*** (Congress grass), *Lantana camara*, and *Eichhornia crassipes* (water hyacinth) can compete with native species and alter ecosystems. The introduction of the **African catfish (*Clarias gariepinus*)** for aquaculture has also raised concerns about its potential effects on indigenous freshwater fish.

4. Pollution: Pollution occurs when harmful substances or forms of energy enter the environment at levels that adversely affect living organisms and ecosystems.

Important pollutants include: Pesticides and herbicides, Toxic heavy metals, Industrial chemicals, Air pollutants, Plastic and other solid wastes and Excess nutrients.

Excessive use of fertilisers can cause eutrophication, resulting in excessive growth of algae and depletion of dissolved oxygen in water bodies. This can adversely affect fish and other aquatic organisms. Industrial pollutants such as sulfur dioxide (SO₂) and nitrogen oxides (NO_x) can contribute to acid deposition, which damages vegetation and aquatic ecosystems. Thus, air, water, and soil pollution can reduce species abundance, impair reproduction, damage habitats, and accelerate biodiversity loss.

5. Climate Change: Climate change is increasingly becoming an important driver of biodiversity loss. Human activities, particularly the burning of fossil fuels, release greenhouse gases such as carbon dioxide (CO₂) into the atmosphere.

The increased concentration of greenhouse gases enhances the retention of heat in the Earth's atmosphere, resulting in changes in temperature, Rainfall patterns, Seasonal cycles, Ocean conditions, Sea level and the frequency and intensity of extreme weather events.

Species that cannot adapt or migrate quickly enough may experience population decline, range contraction, or extinction. Climate change can also interact with habitat loss, pollution, invasive species, and overexploitation, making their effects more severe.

6. Co-extinction: Co-extinction occurs when the extinction of one species causes the extinction of another species that depends on it. For example, some parasites are highly specialized to particular host species. If the host becomes extinct, its associated parasites may also disappear. Similarly, highly specialized plant–pollinator relationships can result in co-extinction. If a plant species disappears, a pollinator that depends exclusively on that plant may also face extinction (Table-2.1).

Table-2.1: Factors and their projected impacts.

Sl.No	Major Factor	Projected Impact
1	Climate Change	Changes in temperature and rainfall can alter habitats and reduce the geographical range of many species.
2	Land-Use Change	Conversion and fragmentation of natural habitats can cause population decline and biodiversity loss.
3	Deforestation	Destruction of forest habitats can threaten species that depend specifically on forest ecosystems.
4	Overharvesting	Excessive exploitation can reduce populations, deplete natural resources, and disturb ecological balance.
5	Pollution	Contaminated environments can cause health problems, reproductive failure, and mortality in organisms.
6	Invasive Species	Invasive organisms may outcompete native species and accelerate ecological changes and biodiversity decline.

Five Major Causes of Biodiversity Loss

- 1. Habitat Destruction & Fragmentation** – Loss and division of natural habitats reduce the space, food, shelter, and breeding sites available to species.
- 2. Overexploitation of Resources** – Excessive hunting, fishing, logging, and harvesting reduce populations faster than they can naturally recover.
- 3. Invasive Alien Species** – Non-native species may spread rapidly, compete with native species, alter habitats, and cause population declines.
- 4. Pollution** – Air, water, and soil pollution from chemicals, pesticides, plastics, heavy metals, and excess nutrients can harm organisms and ecosystems.
- 5. Climate Change** – Rising temperatures and changing rainfall, seasons, ocean conditions, and extreme weather events alter habitats and threaten species that cannot adapt or migrate.

Easy-to-Remember Formula

$$H \rightarrow O \rightarrow I \rightarrow P \rightarrow C$$

H – Habitat Loss

O – Overexploitation

I – Invasive Species

P – Pollution

C – Climate Change

2.1.1 Loss of genetic diversity

The conservation of the genetic diversity found in related wild strains is thus vital to the continuing development of crop plant cultivars, in terms of increased productivity and resistance against disease and pests. Loss of genetic diversity can have a number of consequences, which include-

1. Reduced ability to adapt: genetic diversity is essential for species to evolve and adapt to environmental changes; without it, populations are less able to survive in changing environments.
2. Increased risk of extinction: small isolated populations are more likely to lose genetic diversity, which increases their risk of extinction.
3. Inbreeding depression: inbreeding depression can increase the risk of extinction when genetic diversity is lost; for example, in the 1990's, the threatened with extinction due to low genetic diversity.
4. Harmful genetic variations: genetic variations lead to genetic drift. It can lead to the development of harmful genetic variations in small populations.
5. Disrupted adaptive processes: human activities can disrupt the adaptive processes of many species, which can reduce gene flow and genetic variation.
6. Monoculture agriculture: it can lead to a loss of genetic diversity, which can make crops more susceptible to disease and herbivores.

Low genetic diversity often occurs due to habitat loss. Inbreeding, genetic drift, restricted gene flow and small population size contribute to a reduction in genetic diversity. Loss of genetic diversity within a species is called genetic erosion. This genetic erosion is caused by anthropogenic or local variables, land clearing, overexploitation, population pressures, environmental degradation, changing agricultural systems, overgrazing, pests and diseases, and weeds. Loss of genetic diversity occurs quickly with catastrophic events or changes in land use that remove large numbers of individuals and their habitats.

2.1.2 Loss of species diversity

The loss of species diversity is a decline in the variety of life on Earth. It can include the death, extinction or destruction of species or the manual removal of organisms.

Causes of loss of species diversity are

1. Change in land use: e.g., deforestation, intensive monoculture, urbanisation.
2. Direct exploitation, such as hunting and overfishing

3. Climate change
4. Pollution
5. Invasive alien species, which cause competition between the new species and local species.

Loss of species diversity can affect ecosystems. Loss of species diversity undermines the ability of ecosystems to function effectively and efficiently and thus undermines nature's ability to support a healthy environment. It is important in a changing climate in which loss of species diversity reduces nature's resilience to change. Loss of species diversity threatens the structure and proper functioning of the ecosystem. All ecosystems are able to adapt to the stresses associated with reductions in biodiversity to some degree; biodiversity loss reduces an ecosystem's complexity by reducing the number of interacting individuals. With the loss of species, the ecosystem can become destabilised and collapse.

The biological wealth of our planet has been declining rapidly due to human activities. The colonisation of tropical Pacific islands by humans has led to the extinction of more than 2,000 species of native birds. The IUCN Red List (2004) documents the extinction of 784 species, including 338 vertebrates, 359 invertebrates and 87 plants in the last 500 years. The recent extinctions include the dodo (Mauritius), Quagga (Africa), Thylacine (Australia), Steller's Sea cow (Russia) and three subspecies of tiger such as Bali, Javan and Caspian. 27 species have disappeared in the last twenty years. Careful analysis of records shows that extinctions across taxa are not random. Some groups like amphibians appear to be more vulnerable to extinction. More than 15,500 species worldwide are facing the threat of extinction. Presently, 12% of all bird species, 23% of all mammal species, 32% of all amphibian species and 31% of all gymnosperm species in the world are facing the threat of extinction. During the long period of about >3 billion years, since the origin and diversification of life on Earth, there were five episodes of mass extinction of species. The sixth extinction presently in progress different from the previous episodes. The difference is the rates of extinction; the current species extinction rates are estimated to be 100 to 1,000 times faster than in pre-human times, and our activities are responsible for the faster rates. Ecologists warn that if the present trends continue, nearly half of all the species on Earth might be wiped out within the next 100 years

2.1.3 Loss of ecosystem diversity

Loss of ecological diversity refers to the decrease in the variety of life on Earth. It is caused by several factors, including.

1. Climate change affects species distribution, population dynamics, and ecosystem functioning.
2. Pollution encompasses automotive exhaust fumes, noise, and light pollution.
3. Habitat loss from deforestation, soil pollution, and urbanization.
4. Direct exploitation, which includes overfishing and hunting.
5. Invasive species can reduce ecosystem diversity and biodiversity.
6. Biodiversity loss can cause ecological instability, reducing ecosystem effectiveness and efficiency.
7. Loss of biodiversity can lead to reduced ecological services.
8. Economic impact: Loss of biodiversity or ecosystem diversity can affect the economy.
9. Decline of biodiversity or environmental diversity causes cultural decline.
10. Increased disease risk: Biodiversity in ecosystems can transmit diseases including monkeypox, COVID-19, AIDS, Ebola, Dengue fever, and chikungunya.
11. The loss of biodiversity and ecosystem diversity might bring wild animals closer to human communities, increasing the likelihood of conflict between humans and wildlife.
12. Increased carbon dioxide levels cause ocean acidification, making it difficult for marine species like corals, plankton, and shellfish to keep their protective coating. As a result, the populations of these species and those that rely on them for food and shelter are declining.
13. Simplifying ecosystems, such as monocultures or urban areas, diminishes species diversity and resilience.
14. Ecosystem services decline: Healthy, diverse ecosystems provide critical services like water and air filtration, soil formation, pollination, carbon sequestration, and climate regulation. Biodiversity loss can degrade these services, resulting in a reduction in environmental quality.
15. Biodiversity loss can alter the cycling of resources including carbon, nitrogen, and phosphorus in ecosystems. This can impact ecosystem production, water quality, and greenhouse gas emissions.

The loss of species and ecosystems can lead to the loss of cultural values.

2.1.4 Loss of agro-biodiversity

Agrobiodiversity refers to the variety of species used for food, animal feed, medicine, and other purposes, with the following patterns.

1. Approximately 75% of plant genetic diversity has occurred after 1900.
2. Livestock breeds: 30% are at risk of extinction.

3. Over 90% of crop kinds have perished due to agricultural practices.
4. Only 12 plant and five animal species currently provide 75% of the world's food supply.

Reasons for the decrease in agrobiodiversity include:

- a) Genetically modified varieties reduce agrobiodiversity.
- b) Modern agriculture's specialisation, rationalisation, and intensification have led to the loss of agrobiodiversity.
- c) Lack of economic incentives for biodiversity conservation has led to the decline of agrobiodiversity.
- d) Privatisation of genetic resources leads to significant loss of agricultural biodiversity.
- e) Urbanisation, deforestation, agricultural modernisation (including monocultures and abandonment of traditional techniques), westernisation of diets, and supply chains all pose threats to agrobiodiversity.
- f) Agrobiodiversity is lost due to loss of forest cover, coastal wetlands, and uncultivated areas, as well as aquatic environment damage.
- g) Environmental pollution, overgrazing, global warming, climate change, overharvesting, desertification, and natural disasters all contribute to the loss of agrobiodiversity.
- h) The conversion of native savannas to industrial agriculture results in the loss of national habitats, flora, and ecosystem services, contributing to the loss of agrobiodiversity.
- i) Unsustainable land use practices reduce productivity and contribute to the loss of agrobiodiversity.
- j) Growing novel crops for industrial purposes, such as sugarcane for bioethanol and soybeans for livestock feed.

2.2 Projected scenario for biodiversity loss.

Healthy ecosystems, rich in biodiversity, underpin the food that people eat and their livelihoods, health and well-being. But invasive species, pollution, overexploitation, habitat loss, land use changes, climate change and other human activities are fast eroding Earth's biological wealth.

If current pressures persist, the loss of biodiversity is projected to rise over the following decades.

1. Future: Looking ahead, projections suggest that, on current trajectories of resource use and environmental degradation, biodiversity will continue to diminish.

A significant loss of biodiversity is expected as a consequence of fast land change and deforestation. As demands for infrastructure and agriculture expand, natural forest cover in developing countries might be dramatically reduced. Although developed regions may have varied patterns of land-use change, pollution, climate change, urbanisation and high resource consumption may continue to threaten biodiversity.

All in all, continued human pressures are likely to result in a net loss of ecological health and biodiversity.

2. The current rate of loss of biodiversity: It is believed that the present rate of species extinction is far higher than the background rate of natural extinction. Human activities has contributed to the extinction and decline of many species. Continuing trends in biodiversity loss could increase the rate of loss and make conservation and sustainable management even more critical.

3. The importance of biodiversity loss

The implications of biodiversity loss go beyond the loss of individual species. It can affect the functioning of ecosystems and of human society as a whole. Important repercussions include: dangers to food security and livelihoods. Lower stability and resilience of the ecosystem. Increased probability of the species going extinct. Loss of ecosystem services. Breakdown of ecological links and food chains; negative impacts on human health and well-being. Decline of biodiversity: major factors are financial losses due to depletion of natural resources.

1. Climate change is real: Rising temperatures, changing rainfall patterns, increased frequency of extreme weather events and changes to seasonal cycles may affect species distribution and habitat. If a species does not adapt or move, it may go extinct in the local area, or its numbers may decline.

2. Land Use Change: Ecosystems are destroyed and altered when woods, marshes, grasslands and other natural habitats are transformed for infrastructure, industry, agriculture, urban development and roads. This limits the amount of space and resources many species require.

1. Lost trees: Forest removal causes widespread habitat deterioration and fragmentation. It also threatens species dependent on forest ecosystems, especially specialised and endemic species – and lowers carbon storage and disrupts water cycles.

2. Overharvesting and Overexploitation: Fish, plants, animals, timber and other biological resources can be overexploited, driving populations to unsustainable levels. Continued over-exploitation may eventually lead to a population collapse and extinction.

5) Contaminants: Pollution of soil, water, and air releases toxic compounds into ecosystems. Overeating, plastics, heavy metals, industrial toxins and pesticides can all cause disease, infertility, low survival and death in creatures.

3. Invasive alien species

An invasive species is a non-native species that invades a new environment. They can destroy ecosystems, carry illness, compete with native species for food, space and other resources and cause the extinction of native species.

2.2 Management of Plant Biodiversity

Management of plant biodiversity is essential for the conservation of the plant species, genetic resources, and the ecosystems necessary for the existence of life. Among many essential ecosystem services, plants are the source of food, medicines, raw materials, habitat, preservation of soil and storage of carbon. The reduction in plant diversity is being accelerated by factors such as habitat degradation, climate change, over-exploitation, pollution, invasive species and unsustainable agricultural methods. A complete plan, involving conservation, sustainable usage, restoration and surveillance over a long period of time, needs to be adopted if one wants to accomplish effective management. The conservation of the diversity of plants is necessary in situ (i.e., the protection of plants in their native habitats) and ex-situ (i.e., the conservation of plant genetic resources outside their natural environments). Sustainable agriculture practices and ecosystem-based management can further contribute to the preservation of genetic diversity, ecological stability, food security, and resilience to environmental change.

2.2.1 Organisations associated with biodiversity

The international organisations which are relevant to biodiversity are the International Union for Conservation of Nature (IUCN) and the Convention on Biological Diversity (CBD). Other organisations in this category are national-level organisations like the National Biodiversity Authority (NBA) of India. These organisations create policies, provide financing for conservation, and monitor endangered species. The Red List is produced by the International Union for Conservation of Nature (IUCN), which assesses the conservation

status of species around the world. UNEP is the United Nations' advocate for the environment and the world's environmental conscience. World Animal Fund (WWF) is a non-governmental organisation working to preserve animals all throughout the world. The CBD puts into action worldwide legal agreements for the conservation of biological diversity. The National Biodiversity Authority of India (NBA), regulates access to biological resources and equitable sharing of benefits, and ZSI will prepare an account and survey of the plant and animal life of India. The State Boards: National guidelines of conservation should be made specific to the locality. If you need this to be modified to a certain section or place, please tell me whether you are interested in information on international treaties or local Indian biodiversity committees.

2.2.2 Management methodology for execution

The management of plant biodiversity must be systematic, participative and scientific. The methodology should involve biodiversity assessment, conservation, restoration, sustainable usage, monitoring and community participation. To achieve successful execution, the following actions can be taken.

1. Baseline Evaluation.

Conduct a full inventory of the study area in terms of plant species, genetic resources, ecosystems, types of vegetation, rare and endangered species, and existing conservation measures. Prepare an inventory of important plant species and sites of high conservation value.

2. Identification of the Threat

Evaluate the main causes of biodiversity loss including habitat degradation, deforestation, invasive species, overexploitation, pollution, climate change, grazing pressure and unsustainable farming.

3. In-situ conservation

Create and manage protected areas, conservation zones, holy groves, forest reserves and community-managed ecosystems to conserve plant species in their natural habitats. Natural populations should be able to recover and maintain their ecological ties.

4. Conservation ex situ

Ex-situ conservation should be used for rare, imperilled or fragile species; this includes seed banks, botanical gardens, field gene banks, nurseries, tissue culture and living collections. Special care must be made to conserve the genetically diverse material.

5. Restoration of Habitat.

Restore degraded environments with native and locally adapted plant species. Activities can include reforestation, afforestation, invasive plant removal, soil conservation, wetland restoration, and natural regeneration.

6. Sustainable management of agriculture.

Encourage crop diversification, traditional varieties, agro-forestry, mixed cropping, intercropping, organic fertilisers and integrated pest management. These measures support not just agricultural biodiversity but also improve soil health and ecological resilience.

7. Invasive Species Management

Identify invasive alien plant species and apply appropriate strategies to prevent, detect, remove and control them over time. Management of invasive species should promote recovery of native species.

8. Involvement of the Community.

Biodiversity protection should involve active participation of local communities, farmers, students, forest dependent people and other stakeholders. The traditional ecological knowledge and local conservation practices should be recorded and, when applicable, put to use.

9. Monitoring and Evaluation

Develop regular monitoring systems to evaluate species abundance, population trends, regeneration, habitat condition, genetic diversity and effectiveness of conservation actions. Periodic assessment should be carried out and management techniques changed as required.

10. Documentation and Data Management

Keep systematic records of species inventories, photographs, herbarium specimens, seed collections, distribution maps, conservation activities and monitoring findings. Good documentation establishes a foundation for future research and management decisions.

11. Capacity building and knowledge

Organise training programs, workshops, field demonstrations, biodiversity awareness campaigns and educational activities for a better knowledge of plant conservation and promotion of sustainable use of biological resources.

12. Long Term Management Plan

Develop a practical site-specific management plan with properly defined objectives, activities, responsibilities, dates, resources, indicators and assessment procedures. Periodically review and adjust the approach to reflect ecological changes and new science.

The Management Arrangement

Assessment: Threat identification, conservation planning, in situ and ex situ conservation, restoration, sustainable use, community engagement, monitoring, evaluation and adaptive management. This comprehensive strategy guarantees that plant biodiversity is efficiently conserved, and regenerated when necessary and used sustainably for present and future generations.

2.2.2.1 IUCN International Union for Conservation of Nature and Natural Resources

Several governments, non-governmental, voluntary, national, and international organisations are actively engaged in biodiversity protection. Some important institutions include the principles of conservation (IUCN)

1. International Union for Conservation of Nature and Natural Resources (IUCN)
2. UN Environment Program (UNEP)
3. Worldwide Fund for Nature (WWF)
4. National Bureau of Plant Genetic Resources (NBPGR)

The International Union for Conservation of Nature and Natural Resources (IUCN), also known as the World Conservation Union (WCU), was created in 1948 and is headquartered in Gland, Switzerland. However, the organisation changed its name to WCU in 1990. However, it continues to be known as IUCN. The union is actively engaged in ecosystem management and restoration, as well as the improvement of people's lives and economies. The union elects a 32-member council at the worldwide level and is a multicultural, multilingual organization with 1,000 employees in 62 countries. Dr Ashok Khosla, an Indian scientist, currently heads this organization. As the world's largest environmental knowledge

network, the union has assisted countries in developing and implementing national conservation and biodiversity programs.

Functions of the IUCN

The following are some of the most important functions of the IUCN

1. Monitoring the status of the world's living forms using the IUCN-Red list of Threatened Species.
2. Providing policy advice and technical support to governments, United Nations organisations, international agreements, and others such as the G-8 and G-77.
3. Developing rules and tactics for maintaining environmental equilibrium, as well as providing legal punishments and authority for those norms.
4. Evaluating all new sites nominated for Natural World Heritage designation while conserving existing sites.
5. The IUCN thinks that maintaining biodiversity is everyone's duty, not only locals'. As a result, it serves as a forum for environmentalists from various sectors to collaborate and brainstorm solutions.

Table-2.2: IUCN Categories of Threatened Species.

S. No.	IUCN Category	Abbreviation	Meaning
1	Extinct	EX	Species that no longer exist anywhere in the world.
2	Extinct in the Wild	EW	Species surviving only in captivity or cultivation, and not in their natural habitat.
3	Critically Endangered	CR	Species facing an extremely high risk of extinction in the wild.
4	Endangered	EN	Species facing a very high risk of extinction in the wild.
5	Vulnerable	VU	Species facing a high risk of extinction in the wild.
6	Near Threatened	NT	Species close to qualifying for a threatened category and likely to become threatened.
7	Least Concern	LC	Species currently at low risk of extinction.
8	Data Deficient	DD	Species for which there is insufficient information to assess extinction risk.
9	Not Evaluated	NE	Species that have not yet been assessed according to IUCN criteria.

2.2.2.2 UNEP: United Nations Environment Programme

The United Nations Environment Programme (UNEP) was founded after the United Nations Conference on the Human Environment, held in Stockholm, Sweden, in 1972. Its headquarters are in Nairobi, Kenya.

The Stockholm Conference was a momentous event in which countries from all over the world gathered under the subject "Only One Earth". It generated optimism for a new period of international collaboration and worldwide engagement in the protection of the environment.

The then Prime Minister of India, Mrs Indira Gandhi, addressed the conference and stressed the need for linking environmental conservation with economic development at the global level. She also pointed to poverty as a key driver of environmental degradation.

UNEP functions

1. **Environmental Activities Coordination:** UNEP supervises the environmental activities of the United Nations and aids developing nations in implementing environmentally sound policies.
2. **Tackling Global Environmental Problems:** It is the leading UN body for global and regional environmental issues.
3. **Environmental Protection:** UNEP is working on developing solutions to environmental challenges in the marine, terrestrial and atmospheric environments.
4. **Biodiversity Information:** Provides data and information on biodiversity and endangered species in a range of publications, reports and databases.
5. **International Collaboration:** UNEP promotes and assists in the convening of international conferences, conventions, seminars and research programs on environmental protection.
6. **Conservation of Biodiversity:** It is an essential source of information on biodiversity, conservation and sustainable use of natural resources.
7. **Research and information dissemination:** "UNEP encourages scientific research, environmental assessment, and the gathering and dissemination of environmental information and conservation strategies to countries and organizations."
8. **Financial and Technical Assistance:** UNEP assists governments, institutions and other organisations with funding, technical cooperation and capacity-building programs for environmental protection and sustainable development.

2.2.2.3 UNESCO: United Nations Educational, Scientific and Cultural Organisation

UNESCO is a United Nations specialised agency that promotes global peace through education, culture, and science.

1. It works to achieve the Sustainable Development Goals (SDGs) through its many programs.

UNESCO creates educational resources to help humanity live in a world free of bigotry and hatred.

2. It works to preserve the cultural heritage of the world's various cultures while simultaneously promoting equal dignity for all cultures.
3. It also works to advance scientific programs and policies as platforms for collaboration and development.
4. UNESCO is also recognised for campaigning for free expression and condemning journalist killings.
5. Despite being officially established as UNESCO in 1945, the organisation had its roots in the League of Nations itself.
6. The UNESCO Constitution entered into force in 1946.
7. UNESCO is headquartered in Paris and is a member of the United Nations Development Program (UNDP). Currently, UNESCO has 193 members.
8. The United States, Israel, and Liechtenstein are UN members; however, they are not UNESCO members.
9. The United States and Israel withdrew in 2019, citing bias in the organisation on the Palestine problem.
10. The United States previously left UNESCO in 1984 before rejoining in 2003. Palestine, Niue, and the Cook Islands are members of UNESCO but not the United Nations.
11. UNESCO supports a wide range of programs, including teacher education, science, the promotion of media and press freedom, regional and cultural history, cultural diversity, natural and cultural heritage, world literature translation, human rights, and others.

UNESCO is led by its Director-General.

1. Cultural Conventions of UNESCO: These conventions have served to conserve and preserve the world's natural and cultural heritage.
2. Convention on the Means of Prohibiting and Preventing the Illicit Traffic in Cultural Property (1970).

3. Convention for the Protection of the World's Cultural and Natural Heritage (1972)
Convention for the Protection of Underwater Cultural Heritage (2001).
4. Universal Declaration of Cultural Diversity (2001).
5. Convention for the Safeguarding of Intangible Cultural Heritage (2003).
6. Convention to Protect and Promote the Diversity of Cultural Expressions (2005)

Table -2.3 Important UNESCO Conventions.

Year	Convention / Declaration
1970	Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property
1972	Convention Concerning the Protection of the World Cultural and Natural Heritage
2001	Convention on the Protection of the Underwater Cultural Heritage
2003	Convention for the Safeguarding of the Intangible Cultural Heritage
2005	Convention on the Protection and Promotion of the Diversity of Cultural Expressions

UNESCO World Heritage Sites

A **UNESCO World Heritage Site** is a place recognised for its **outstanding cultural or natural value to humanity**. World Heritage Sites may include: Historical monuments

- Archaeological sites
- Cultural landscapes
- Natural ecosystems
- Forests and wildlife habitats
- Important geological formations

UNESCO works with countries to ensure the **protection, conservation and sustainable management** of these sites (Table 2.4).

Table 2.4: Important International Days and Their Observances.

Date	International Day
27-Jan	International Day of Commemoration in Memory of the Victims of the Holocaust
13-Feb	World Radio Day
08-Mar	International Women's Day
22-Mar	World Water Day
23-Apr	World Book and Copyright Day
03-May	World Press Freedom Day
05-Jun	World Environment Day
12-Aug	International Youth Day
15-Sep	International Day of Democracy

05-Oct	World Teachers' Day
16-Nov	International Day for Tolerance
01-Dec	World AIDS Day

UNESCO and India

India has a long-standing association with UNESCO and is a **founding member** of the organisation.

Indian National Commission for Cooperation with UNESCO

The **Indian National Commission for Cooperation with UNESCO (INCCU)** is India's national coordinating body for cooperation with UNESCO.

It facilitates cooperation between UNESCO and various Indian institutions in the fields of.

- Education
- Science
- Culture
- Communication
- Heritage conservation

UNESCO Office in India

UNESCO has maintained a presence in India since 1948 and works with the Government of India and various institutions on education, science, culture and heritage programmes.

Mahatma Gandhi Institute of Education for Peace and Sustainable Development.

The Mahatma Gandhi Institute of Education for Peace and Sustainable Development (MGIEP) was established in 2012 in New Delhi.

It focuses on education for peace and sustainable development, particularly in support of SDG 4 – Quality Education.

UNESCO and Indian Cultural Heritage

One of UNESCO's major areas of work in India is the **protection and promotion of India's cultural heritage**. UNESCO works with Indian authorities and institutions to conserve World Heritage Sites, intangible cultural heritage and other important cultural resources.

2.2.2.4 World Wildlife Fund (WWF)

The World-Wide Fund for Nature (WWF) is an international non-governmental organization focused on the conservation of nature, biodiversity and wildlife. It helps conserve natural ecosystems and reduce the biggest risks to the environment.

WWF Timeline: Established: 29 April 1961: This organisation was originally called the World Wildlife Fund.

Current Name: World Wide Fund for Nature; Headquarters: Gland, Switzerland; Precursor organisation: Conservation Foundation

WWF supports conservation programs and initiatives across the world.

WWF Mission: The mission of WWF is: Protect nature and lessen the most urgent threats to the diversity of life on Earth.”

Main areas of work: WWF’s work is mostly focused on: Forests, Climate change, Water Resources (Freshwater), coastal and ocean ecosystems, Animal conservation, Sustainable agriculture and food, and conservation of biodiversity. WWF collaborates with governments, local communities, scientists and other organisations to put conservation programs in place.

WWF’s Important Species Protection

WWF pays significant attention to threatened and endangered species such as: Major WWF Campaigns Bengal Tiger Asian Elephant Giant Panda Gorilla Rhinoceros Snow Leopard Polar Bear Sea Turtles Whales Red Panda Ganges River Dolphin,

Among the most prominent campaigns for WWF are: Earth Hour: A global movement to raise awareness about environmental issues by asking people to switch off superfluous lights for one hour. Debt-for-Nature Swaps instruments that help integrate debt relief with environmental conservation.

Living Planet Index: The Living Planet Report is a flagship publication of WWF. It comes out every two years and includes data regarding the state of biodiversity and the impact of human activities on nature.

The report employs the Living Planet Index (LPI) as one of its key metrics.

Living Planet Index: The Living Planet Index monitors trends in the population numbers of vertebrate species in terrestrial, freshwater and marine environments. It is an indicator of changes in world biodiversity.

Key findings of the Living Planet Report 2020: The survey found an average loss of observed vertebrate populations worldwide of 68% from 1970 to 2016. Average losses in freshwater vertebrate populations over the same period were very steep, at roughly 84%. Large animals or megafauna are especially susceptible to hunting, habitat loss, overexploitation and other pressures from people. The growing magnitude of the human ecological footprint exerts a significant stress upon the natural resources and ecosystems of the earth.

WWF India: WWF-India was founded in November 1969 as a charitable public trust. It works for the conservation of India's biodiversity, animals and natural environments.

WWF-India's primary goals are

12. To protect biological diversity.
13. For the promotion of the sustainable use of renewable natural resources.
14. To decrease pollution and over-consumption.
15. For the protection of critical habitats and threatened species.
16. To raise environmental awareness and promote conservation in communities.

Important Conservation Areas in India

WWF-India undertakes conservation programs in several major landscapes and areas that include: Satpura-Maikal, Nilgiris - Western Ghats. Sundarbans. Terai Arc. North Bank Kaziranga-Karbi Anglong, Kanchendzonga, Western Arunachal, Western India, Western Himalayas, Bharatpur. WWF-India's Priority Species

For conservation consideration, the key species are: Bengal Tiger, Asian Elephant, Indian One-horned Rhino, Ganges River Dolphin, Snow Leopard, Red Panda

2.2.2.5 National Bureau of Plant Genetic Resources (NBPGR)

The National Bureau of Plant Genetic Resources (NBPGR) is an important national institute responsible for the collection, conservation, evaluation and management of plant genetic resources in India. It plays an important role in conserving crop diversity and ensuring the availability of genetic resources for future agriculture.

National Gene Bank

- The National Gene Bank was established in 1996 to conserve the seeds and other forms of Plant Genetic Resources (PGR) for future generations.
- It has the capacity to conserve about one million germplasm accessions in seed form.
- It currently conserves about 4.52 lakh accessions, including approximately 2.7 lakh Indian germplasm accessions and the remaining accessions obtained from other countries.
- The Gene Bank helps conserve genetic diversity that can be used for crop improvement, food security and sustainable agriculture.

About NBPGR

- NBPGR was established in 1976 as the National Bureau of Plant Introduction.
- It was renamed the National Bureau of Plant Genetic Resources (NBPGR) in 1977.
- Its origins can be traced to the ICAR Scheme for Plant Introduction, initiated in the late 1940s.
- NBPGR functions under the Indian Council of Agricultural Research (ICAR).
- Headquarters: New Delhi.
- It has 10 Regional Stations located in different phyto-geographical regions of India.

Mandate of NBPGR

The main mandate of NBPGR is to serve as the nodal national institute for the acquisition, management, conservation and genomics-based characterization of indigenous and exotic plant genetic resources important for food and agriculture.

It also undertakes research and human-resource development for the sustainable development of Indian agriculture.

Objectives of NBPGR

1. Exploration and Collection

To plan, organise and coordinate the exploration and collection of **indigenous and exotic plant genetic resources**.

2. Introduction and Exchange: To undertake the **introduction, exchange and quarantine** of plant genetic resources.

3. **Characterisation and Evaluation:** To characterise and evaluate crop genetic resources and document their important characteristics.

4. **Conservation:** To conserve crop genetic resources and promote their utilisation in collaboration with other national organisations.

5. **Documentation and Information Network:** To develop information systems and networks related to **plant genetic resources**.
6. **Research and Training:** To conduct research, teaching and training programmes related to plant genetic resources.
7. **Development of Guidelines:** To prepare guidelines for the safe handling, conservation and utilisation of plant genetic resources.
8. **Public Awareness:** To create awareness about the **importance of plant genetic resources and their conservation**.

2.3 Biodiversity legislation and conservation

Biological Diversity Act, 2002

The Biological Diversity Act, 2002 was enacted by the Parliament of India to provide a legal framework for the conservation of biological diversity, the sustainable use of biological resources, and the fair and equitable sharing of benefits arising from their use.

The Act is particularly important for India because the country is one of the world's megadiverse countries, with a rich variety of plants, animals, microorganisms and traditional knowledge.

Objectives of the Biological Diversity Act, 2002

The major objectives of the Act are.

1. Conservation of biodiversity and biological resources.
2. Sustainable use of biological resources.
3. Fair and equitable sharing of benefits arising from the use of biological resources.
4. Regulation of access to India's biological resources.
5. Protection of the traditional knowledge of local and indigenous communities.
6. Protection and rehabilitation of threatened species.
7. Involvement of local communities in the conservation and sustainable management of biodiversity.

Important Features of the Act

- It regulates access to India's biological resources and associated traditional knowledge.
- It promotes the conservation and sustainable use of biodiversity.
- It recognises the contribution of local communities as conservers and holders of traditional knowledge.
- It provides mechanisms for benefit sharing with local communities.

- It provides for the establishment of the National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs) and Biodiversity Management Committees (BMCs).
- The Central Government may notify threatened species and regulate or prohibit their collection, conservation and rehabilitation.
- It provides for the designation of institutions as repositories of biological resources.

Exemptions

Certain activities and resources are exempted from the provisions of the Act, subject to the applicable conditions:

1. Biological resources that are **normally traded as commodities**, when used only as commodities.
2. Certain **traditional uses** of Indian biological resources and associated knowledge.
3. Certain **collaborative research projects** between Indian and foreign institutions approved by the Central Government.
4. Use of biological resources by **cultivators, farmers, livestock keepers, beekeepers and traditional healers**, such as vaid and hakims.

National Biodiversity Authority (NBA)

The **National Biodiversity Authority (NBA)** was established in **2003** under the Biological Diversity Act, 2002.

- **Headquarters:** Chennai, Tamil Nadu
- **Ministry:** Ministry of Environment, Forest and Climate Change, Government of India
- It is a **statutory body**.
- **State Biodiversity Boards (SBBs)** have been established at the state level.
- **Biodiversity Management Committees (BMCs)** function at the local-body level.

Functions of the National Biodiversity Authority

1. **Regulation and Monitoring:** To monitor activities regulated under the Biological Diversity Act and help prevent unauthorised access to biological resources.
2. **Advisory Role:** To advise the Central Government on matters relating to the **conservation and sustainable use of biodiversity**.
3. **Biodiversity Heritage Sites:** To advise on the identification and development of **Biological Heritage Sites**.

4. **Protection of Traditional Knowledge:** To help prevent the misuse or unauthorised acquisition of traditional knowledge associated with biological resources.
5. **Access and Benefit Sharing:** To regulate access to biological resources and ensure **fair and equitable sharing of benefits** arising from their utilisation.
6. **Threatened Species:** The Central Government, in consultation with the NBA, may notify threatened species and regulate or prohibit their collection, conservation and rehabilitation.
7. **Repositories:** Institutions may be designated as repositories for different categories of biological resources.

Structure of the NBA: The National Biodiversity Authority includes members appointed by the Central Government, including.

- **A Chairperson**
- Representatives of the Ministry dealing with **Tribal Affairs**
- Representatives of the Ministry dealing with **Environment, Forest and Climate Change**

Representatives from ministries dealing with: Agricultural Research and Education, Biotechnology, Ocean Development, Agriculture and Cooperation, Indian Systems of Medicine, Science and Technology, Scientific and Industrial Research.

Regulation of Access to Biological Resources

The Act regulates access to Indian biological resources and associated knowledge.

- **Foreign individuals and foreign companies** seeking biological resources or associated knowledge for research, survey or commercial utilisation generally require approval from the National Biodiversity Authority.
- Indian individuals and organisations are subject to the applicable provisions and benefit-sharing requirements administered through the State Biodiversity Boards and other authorities.
- Certain research and publication activities are subject to specific exemptions under the Act.

Table 2.5 Institutional Framework for Biodiversity Conservation in India.

Level	Institution	Major Role
National	National Biodiversity Authority (NBA)	Regulation, advice and benefit sharing
State	State Biodiversity Boards (SBBs)	Regulation and conservation at state level
Local	Biodiversity Management Committees (BMCs)	Conservation and documentation of local biodiversity and traditional knowledge

2.3.2 Biodiversity information management and communication.

Biodiversity Information Management (BIM) and communication is the systematic process of collecting, storing, organising, analysing, and sharing information about living organisms, genetic resources, species, habitats and ecosystems. It supports biodiversity conservation, scientific research, environmental planning and decision-making.

What is Biodiversity Information Management?

Definition: Biodiversity Information Management involves the use of databases, computer systems, geographic information systems (GIS) and other **digital tools** to manage information about biodiversity.

Types of Biodiversity Information: Biodiversity databases may contain: Scientific names and classification of organisms, Geographic distribution and locations, Population size and trends, Habitat information, Ecological characteristics, Genetic and genetic-resource information, Conservation status of species, Information about threats and conservation measures.

Main Purpose: BIM helps scientists, governments and conservation organisations to.

1. Monitor the status of biodiversity.
2. Identify threatened and endangered species.
3. Establish conservation priorities.
4. Support environmental impact assessments.
5. Plan land and natural-resource use.
6. Support scientific research and policy-making.
7. Share biodiversity information among institutions.

Components of Biodiversity Information Systems

- 1. Databases:** Databases are organised digital collections of biodiversity information. They may operate at **local, national and international levels** and contain information on flora, fauna, ecosystems and genetic resources.
- 2. Libraries and Information Networks:** Digital libraries, bibliographic databases and information networks provide access to: Research publications, Species catalogues, Taxonomic information, Biodiversity reports, Scientific literature, Distribution records
- 3. Clearing-House Mechanisms:** A Clearing-House Mechanism (CHM) is an information-sharing system that connects data providers, researchers, institutions, governments and other users. Under the Convention on Biological Diversity (CBD), the Clearing-House Mechanism helps countries exchange biodiversity-related information, technologies and knowledge and improves coordination among organisations.

Principles and Policies of Biodiversity Information Management

- 1. Public Policy:** Governments develop policies and regulations to promote the collection, management and responsible sharing of biodiversity information while protecting sensitive information.
- 2. Private and Institutional Policies:** Institutions may establish guidelines concerning: Ownership of data, Access to databases, Confidential information, Sensitive locations of threatened species, Intellectual property rights
- 3. Culture of Information Sharing:** Effective biodiversity conservation requires a culture of **cooperation and responsible information sharing** among universities, research institutions, government departments, conservation organisations and local communities.

Importance of Communication in Biodiversity Conservation

Information becomes useful for conservation only when it is communicated effectively to the people who need it.

- 1. Creating Awareness:** Clear and simple communication helps people understand the importance of biodiversity, threats to ecosystems, and the importance of endangered species, and the need for conservation
- 2. Supporting Behavioural Change:** Communication can encourage people to adopt sustainable practices, reduce waste, protect habitats and use natural resources responsibly.

3. Policy Support: Scientific information communicated effectively helps policymakers and administrators develop appropriate environmental laws, programmes and conservation strategies.

4. Stakeholder Participation: Communication encourages the participation of local communities, Indigenous and traditional knowledge holders, Farmers, scientists, Government agencies, non-governmental organisations, and conservation groups

5. Local Biodiversity Registers: People's Biodiversity Registers (PBRs) document local biological resources and associated traditional knowledge. They provide an important link between **local communities, biodiversity information and conservation planning.**

Revision Question

Essay Questions

1. Explain the major types of biodiversity loss and the projected scenario of biodiversity decline.
2. Describe the roles of IUCN, UNEP, UNESCO, WWF, and NBPGR in biodiversity conservation.
3. Explain the role of IUCN in biodiversity conservation and management.
4. Discuss the importance of biodiversity legislation in India and its role in conservation.
5. Describe the major methods of plant biodiversity conservation, including in-situ and ex-situ conservation.
6. Explain biodiversity information management, documentation, databases, and communication in conservation.

B. Short-Answer Questions

1. What is genetic diversity?
2. What is agro-biodiversity?
3. Write a short note on IUCN.
4. What is the role of NBPGR in plant biodiversity conservation?
5. What is the importance of biodiversity legislation?
6. What is biodiversity information management?

UNIT-3

3.1 Conservation of Biodiversity

Conservation of biodiversity is one of the most pressing environmental concerns facing the world today. Conservation may be defined as the management of the biosphere to obtain sustainable benefits for present generations while maintaining its potential to meet the needs and aspirations of future generations.

The maintenance of ecological processes and genetic diversity is essential for the sustainable growth and development of all living organisms on Earth. However, several factors, such as changes in environmental conditions, temperature, rainfall and humidity, are causing significant changes in natural habitats. In addition, changes in human lifestyles, increasing population, urbanisation, industrialisation, and overexploitation of natural resources are contributing to large-scale environmental changes.

As a result, biodiversity is declining rapidly, leading to the destruction of many plant and animal species and causing disturbances in ecosystems. The loss of biodiversity also affects food chains and food webs, thereby disturbing the ecological balance and reducing the stability of ecosystems. Therefore, it is essential to protect biodiversity by preventing the destruction of natural habitats and conserving biological resources at local, national and global levels. Conservation requires the active participation of governments, non-governmental organisations, scientific institutions, local communities and social organisations. All nations and communities must work together with commitment and dedication to conserve biodiversity and ensure a healthy and sustainable environment for present and future generations.

Different Types of Conservation

Even though sustainable land, animal, and resource management practices have existed for generations, there's still much work to be done. With endangered plants and animals, a growing threat of invasive species, and devastating wildfires destroying our forests and impacting our ecosystems, conservation is more important than ever.

According to Aldo Leopold, the father of conservation and author of *A Sand County Almanack*, conservation is a "state of harmony between man and land." He believed humans are part of a larger community that includes water, vegetation, and animals. His beliefs laid the groundwork for modern-day conservation.

Environmental Conservation: This type of conservation focuses on the protection, preservation, and restoration of natural habitats and the many species that inhabit them. It involves protecting and managing natural environments like forests, grasslands, and reefs to preserve biodiversity and ecosystems and support ecosystem functions.

Soil conservation, a key part of environmental conservation, focuses on protecting and maintaining soil health. According to Dr Agan, “Soil is the foundation from which we get our subsistence. Fertile soil provides healthy plants, the base of the food chain. When soils are degraded, we face lower crop yields, leading to food shortages and increased prices.”

Environmental conservationists work closely with non-profits and government organizations to establish policies and regulations to benefit protected areas, such as national parks and biosphere reserves. Additionally, environmental conservation plays a role in preventing and reversing the destruction of our ecosystems due to climate change and carbon dioxide emissions.

Human Conservation: Our health is directly connected to our food, water, air, and interactions with nature and land. Human conservation refers to the unique relationship between people, human health, and the environment. From sustainable agriculture to responsible water and soil management, the impact living beings have on the environment harms natural species, biodiversity, and other humans. Air pollution, increasing temperatures, and drought can contribute to health issues, along with harmful viruses and diseases that come from fish and animal hosts. Climate change is also causing disease-carrying organisms to spread into new areas. As a result, there is an increased risk of disease exposure that in turn can impact human health.

Wildlife Conservation: Human activities such as hunting, pollution, and fishing put stress on our natural resources and ecosystem functions, pushing many species toward extinction. Wildlife conservation (also known as animal conservation) refers to the protection and preservation of plant and animal species and their habitats.

Wildlife conservationist duties may include: Protecting and restoring habitats, preventing wildfires, testing water and soil for contamination, educating the public on sustainable living, and preserving biodiversity. Working with government agencies to pass policies and regulations “Wolves and other wildlife are not only important for their role in ecosystems,

but they also have cultural significance for many different indigenous communities,” explains Dr. Agan. “For the Lakota in the Great Plains, wolves are associated with the warrior spirit. There are many others, but the goal is to understand that conservation of wildlife is important to maintain not only the health of our ecosystems but also the well-being and integrity of our cultural heritage.” Through wildlife and animal conservation efforts, we can preserve ecosystems and natural habitats and protect the diversity of life.

Marine Conservation: As Earth’s most prominent life support system, the ocean is critical to human health and well-being. However, our waterways face severe threats from fishing, pollution, and climate change, which endanger coastal communities, coral reefs, and our sea population.

Marine conservation involves the protection, management, and preservation of marine ecosystems and all aspects of the environment. By promoting the benefits of sustainable fishing and reducing plastic waste, humans can help conserve marine life, maintain biodiversity, and keep beaches clean. Through research and public advocacy, humans can restore ocean habitats, safeguard marine species populations, and conserve the ocean to benefit future generations.

Our oceans absorb a lot of carbon dioxide. Although this absorption is good for the atmosphere, it is not good for the oceans because it leads to acidification, a major factor in the decline of marine organisms. This problem will take a considerable amount of time and effort to overcome.

Causes a Species to Become Endangered

There are many species on the endangered list, according to Dr Agan. “Since the creation of the Endangered Species Act in 1972, more than 2,375 species have been listed worldwide as endangered or threatened, of which at least 1,678 occurred in the U.S.,” warns Dr. Agan.

“Listing is the first step toward conservation as it gives endangered species some protection until they can recover. For species such as bald eagles, grey wolves, humpback whales, and peregrine falcons, these measures have proven to be life-saving as they have been restored and subsequently delisted from the ESA.” So, what is an endangered species? A single species (whether a bird, tree, insect, or fungus) is considered endangered when there’s a

threat that it may become extinct due to various reasons. For instance, a loss of habitat or a lack of genetic variation could eventually lead to a species becoming endangered or extinct.

Experts will assess each species and categorise it based on answers to a list of questions created by the International Union for Conservation of Nature (IUCN), including.

Over time, the IUCN will reassess its categorisation and the species' performance. If a species' population has grown, it will be downlisted. Otherwise, it'll be uplisted if the species population has decreased.

In-situ means "in the original place." In-situ conservation is when a species is protected in its natural surroundings. This conservation approach can help maintain genetic diversity, support natural behaviours and adaptations, and evolution.

Examples of in-situ conservation include biosphere reserves, national parks, and nature preserves. "By establishing our national parks, we provided the necessary space for bison to once again thrive where they had been abolished," says Dr. Agan. "The California condor is once again thriving in the Grand Canyon, and black-footed ferrets were reintroduced into Badlands National Park."

Ex-situ means "away from the natural location." Ex-situ conservation is when an endangered species is removed from its natural ecosystem and placed in a protected area and under human care. This type of conservation method is sometimes used to protect a species that may be having problems surviving due to external changes in its traditional habitat or internal changes. Examples of ex-situ conservation include botanical gardens, aquariums, zoos, and sanctuaries. Habitat loss is one of the greatest threats to biodiversity and has huge consequences for the species' survival. In fact, it's the reason why 85% of current species have been placed on the IUCN's Red List as threatened or endangered. From forests to wetlands, nature's homes are being destroyed to create farms, shopping centers, and housing developments. The environments of endangered species require increased protection and resource management to achieve effective conservation efforts. Without them, more animals and plants may see population declines or extinction.

Technological advancements happen every second, leading to emerging trends that make conservation easier. "Technological tools allow us to monitor species and places in remote

areas,” states Dr Agan. “While we have long used telemetry and satellite tracking, GPS collars and other ways of tagging wildlife are becoming better every year.”

Automated radio telemetry helps facilitate global conservation and creates partnerships that can follow wildlife without borders. According to Dr Agan, “We can check the vitals of an animal swimming through the Atlantic and use a QR code to follow sharks.”

Global monitors deliver real-time environmental data such as air or water temperature, salinity, or air quality. Apps can also help scientists and researchers view data, plan out research projects, or even develop a conservation plan for someone’s property based on high-quality scientific data.

“One of the latest, greatest, and maybe controversial trends is de-extinction,” explains Dr. Agan. “With our modern knowledge of DNA, we have the capacity to bring back species that have gone extinct.”

From the woolly mammoth to the carrier pigeon, there are questions about whether an extinct species would thrive today and what would happen. Habitats have changed drastically or disappeared since certain species last roamed the earth. If a species could somehow be brought back, they would most likely live in zoos or other enclosed facilities.

Every small step we take today can lead to big outcomes tomorrow. To reduce our environmental impact at home and save endangered species and their habitats, we can.

- Plant native grasses, trees, and shrubs
- Remove invasive vegetation and weeds
- Create a pollinator garden to attract bees and birds
- Limit the use of fertilizers and pesticides
- Reduce, reuse, and recycle products whenever possible
- Purchase upcycled or recycled products
- Replace light bulbs and electronics with energy-efficient products
- Turn off electronics when they are not being used
- Conserve water
- Volunteer with local conservation groups
- Create a backyard wildlife habitat
- Slow down while driving

- Avoid littering

3.1.1 Conservation of genetic diversity

Genetic diversity refers to the variation in genes and alleles present within and among populations of organisms. The conservation of genetic diversity is essential for maintaining the survival, adaptability and evolutionary potential of species.

Activities such as selective harvesting, habitat destruction, overexploitation, environmental changes and replacement of traditional varieties by a few modern varieties can cause the loss of genetic diversity. The loss of particular genes or alleles may be irreversible, and some of them may possess valuable traits useful for agriculture, medicine and human welfare. Therefore, conserving genetic diversity is important for preventing species extinction and ensuring human well-being.

Plant Genetic Resources: Plant genetic resources include the total hereditary material present in cultivated plants and their wild relatives. They include all the genes and alleles that occur within crop species and related wild species. These resources are important for improving crop productivity, adaptability and resistance to environmental stresses. Important plant genetic resources include: Landraces, Wild relatives of crops, Wild species, Genetic stocks, Advanced breeding materials, Modern crop varieties.

These resources provide valuable genetic variation for the development of improved crop varieties with desirable characteristics such as disease resistance, pest resistance, drought tolerance, salinity tolerance, improved nutritional quality and higher yield.

Role of Biotechnology in Genetic Conservation: Biotechnological techniques are increasingly used for the characterisation, conservation and utilisation of plant genetic resources. Important techniques include: DNA sequencing, Molecular markers, *in vitro* culture, Cryopreservation, Gene banks, Genomic analysis, Marker-assisted selection (MAS), and marker-assisted backcrossing (MABC). Genomic tools help identify quantitative trait loci (QTLs) and useful genes associated with important characteristics. These genes can then be incorporated into cultivated varieties through suitable breeding programmes.

International Treaty on Plant Genetic Resources: The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) came into force in 2004. Its major objectives are to promote the conservation and sustainable use of plant genetic resources for

food and agriculture and to ensure the fair and equitable sharing of benefits arising from their use.

Conservation and sustainable utilisation of plant genetic resources are essential for sustainable agriculture and crop improvement. They also help crops adapt to changing environmental conditions and future human needs.

Nagoya Protocol: The Nagoya Protocol, which came into force in 2014, deals with access to genetic resources and the fair and equitable sharing of benefits arising from their utilization. It encourages responsible use of genetic resources and provides incentives for their conservation and sustainable utilisation.

Cartagena Protocol on Biosafety: The Cartagena Protocol on Biosafety aims to ensure the safe handling, transport and use of living modified organisms (LMOs) produced through modern biotechnology. It is particularly concerned with protecting biodiversity and human health from potential risks associated with the use and movement of genetically modified organisms.

Importance of Genetic Diversity in Crop Improvement: The utilisation of crop genetic diversity is essential for developing new and improved crop varieties adapted to changing environmental conditions. Genetic diversity provides breeders with useful genes for disease resistance, climate tolerance, nutritional improvement and increased productivity, thereby contributing to global food security. Regular monitoring of genetic erosion and genetic vulnerability is necessary to identify and protect rare, endangered and genetically threatened plant species. Biotechnology and modern genomic tools can support the characterisation, conservation and effective utilisation of plant genetic resources in crop improvement programmes.

Landraces: Landraces are traditional crop varieties that have developed through local cultivation and natural selection and are well adapted to specific local environments. They are valuable sources of genetic diversity and useful traits for crop improvement.

3.1.2 Species diversity

Species diversity refers to the variety of different species present in a particular habitat, ecosystem or region. Conservation of species diversity involves the protection and proper

management of species, their habitats and ecosystems to ensure their continued survival and ecological functioning.

The conservation of species is essential because once a species becomes extinct, it cannot be brought back. The survival of most species depends directly on the protection and maintenance of their natural habitats. Conserving diverse plant communities also helps protect associated animals, fungi and microorganisms and maintains important ecological processes.

Biodiversity has enormous genetic, commercial, medicinal, ecological, aesthetic and educational value. These values emphasise the need for effective conservation of species diversity. Therefore, several measures are being implemented throughout the world to protect plant and animal species.

Major Activities for Conservation of Species Diversity

- 1. Habitat Maintenance:** Protection and restoration of natural habitats are essential for species survival. Maintaining diverse plant communities provides food, shelter and breeding sites for many other organisms and helps maintain ecological processes.
- 2. Establishment of Protected Areas:** Protected areas are an important component of species conservation. **National parks, wildlife sanctuaries, biosphere reserves and other conservation areas** provide safe habitats where species can survive and reproduce with minimum human disturbance.
- 3. Development of Conservation Strategies:** Science-based conservation strategies, management plans and policies should be developed to identify threats and determine appropriate measures for protecting species and their habitats.
- 4. Conservation Actions:** Practical conservation measures should be taken to improve the status of threatened species. These include species recovery programmes, habitat restoration, population monitoring, captive breeding and capacity building.
- 5. Protection of Migratory Flyways:** Migratory routes, or **flyways**, used by birds and other migratory organisms should be protected. Conservation of habitats along these routes is essential for feeding, breeding and seasonal movement.

Importance of Species Conservation: Species are fundamental components of biodiversity, and their survival is essential for maintaining healthy ecosystems. The present biodiversity crisis has increased the need for effective conservation programmes. Both **in-situ** and **ex-situ**

conservation, together with protected areas and species recovery programmes, are important for preventing species extinction.

The **International Union for Conservation of Nature (IUCN)** works with scientists, governments, conservation organizations and local communities to promote effective species conservation throughout the world.

IUCN Approach to Species Conservation

The **IUCN Species Survival Commission (SSC)** follows a three-stage approach to species conservation.

- 1. Assess:** The conservation status, population size, distribution and major threats to a species are assessed. This helps determine whether a species is secure, threatened or at risk of extinction.
- 2. Plan:** Based on the assessment, appropriate conservation strategies and action plans are developed. These plans identify the major threats and suggest suitable measures for protecting and recovering species.
- 3. Act:** The planned conservation measures are implemented on the ground. These actions may include habitat protection, species recovery programmes, population management, community participation and other measures designed to reduce the risk of extinction.

Effective species conservation requires cooperation among **government agencies, scientists, non-governmental organizations, local communities and other stakeholders**. Collaborative efforts can produce positive and measurable results in the protection of threatened species and wildlife.

3.1.3 Ecosystem Diversity

Ecosystem diversity refers to the variety of ecosystems, habitats, ecological communities and ecological processes present in a particular region or across the biosphere. It includes forests, grasslands, wetlands, deserts, freshwater ecosystems, marine ecosystems and agricultural ecosystems. Conservation of ecosystem diversity is essential for maintaining ecological balance and supporting the survival of plants, animals and microorganisms.

Major Methods of Ecosystem Conservation

- 1. Establishment of Protected Areas:** National parks, wildlife sanctuaries, biosphere reserves, nature reserves and other protected areas should be established and effectively managed to conserve natural ecosystems and their biodiversity.
- 2. Prevention of Deforestation:** Deforestation is a major threat to ecosystem diversity. Forest destruction should be controlled through forest protection, afforestation, reforestation and sustainable forest management.
- 1. Reduction of Pollution:** Soil, water and air pollution should be reduced by proper waste management, pollution control measures and the safe use of chemicals. This helps maintain healthy ecosystems.
- 2. Promotion of Sustainable Agriculture:** Sustainable agricultural practices should be encouraged by reducing excessive use of pesticides, chemical fertilizers and other harmful substances. Organic farming, crop rotation and integrated pest management can help maintain soil biodiversity.
- 3. Support for Native Species:** Native plants should be encouraged in gardens, farms and local landscapes. Planting indigenous fruits, vegetables, flowers and trees helps provide food and shelter for local wildlife and supports native biodiversity.
- 4. Control of Invasive Species:** Invasive alien species can compete with native organisms for food, space and other resources. They may reduce native populations and sometimes cause local extinction. Therefore, invasive species should be identified, monitored and controlled.
- 5. Conservation of Biological Resources:** The diversity of food crops, traditional crop varieties, timber plants, livestock breeds, microorganisms and agricultural animals should be conserved. These resources provide valuable genetic material for future use.
- 6. Identification and Conservation of Economically Important Organisms:** Species that are important for food, medicine, agriculture, forestry, industry and other economic activities should be identified and conserved for sustainable utilization.
- 9. Prevention of Poaching and Hunting:** Illegal hunting, poaching and wildlife trade should be strictly controlled through effective laws, regular monitoring and public participation.

Major Activities in Ecosystem Conservation

Ecosystem conservation mainly involves three important activities.

- a. Monitoring of Ecosystems:** Regular monitoring helps assess changes in ecosystem health, biodiversity, population size, habitat conditions and environmental factors.
- b. Maintenance of Ecosystems:** Natural ecosystems should be protected from habitat destruction, pollution, overexploitation, invasive species and other harmful activities.
- c. Restoration of Damaged Ecosystems:** Degraded ecosystems should be restored through activities such as reforestation, wetland restoration, soil conservation, removal of invasive species and rehabilitation of damaged habitats.

Importance of Ecosystem Conservation

Ecosystem conservation is essential for human well-being because ecosystems provide clean air, fresh water, food, medicines, raw materials and other ecosystem services. Healthy ecosystems also help control floods, prevent soil erosion, support pollination, store carbon and reduce the impacts of climate change. Therefore, conservation of ecosystem diversity is fundamental to sustainable development and the well-being of present and future generations.

Specific Objectives of Conservation of Natural Resources

The conservation of natural resources has the following three major objectives:

1. Preservation of Biological Diversity

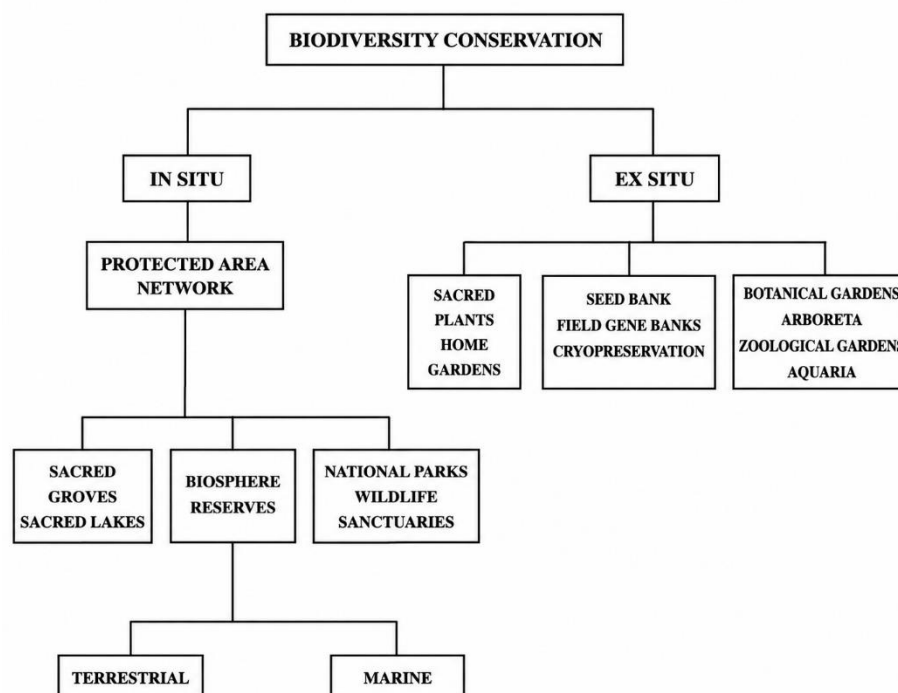
To conserve the diversity of species and maintain the genetic variability present among all living organisms on Earth.

2. Maintenance of Ecological Processes

To maintain essential ecological processes and life-supporting systems, such as nutrient cycling, water cycles, energy flow and ecosystem stability.

3. Sustainable Utilisation of Natural Resources

To ensure the sustainable use of species, habitats and ecosystems so that they continue to support millions of rural communities and major industries throughout the world.



Methods of Conservation

There are two basic approaches for the conservation of biodiversity and living organisms. These methods help protect species, their genetic diversity, and their natural habitats.

1. In-situ Conservation

In-situ conservation means the **conservation of species in their natural habitats**. It protects organisms within the ecosystems where they naturally occur. Examples include **national parks, wildlife sanctuaries, biosphere reserves and sacred groves**.

2. Ex-situ Conservation

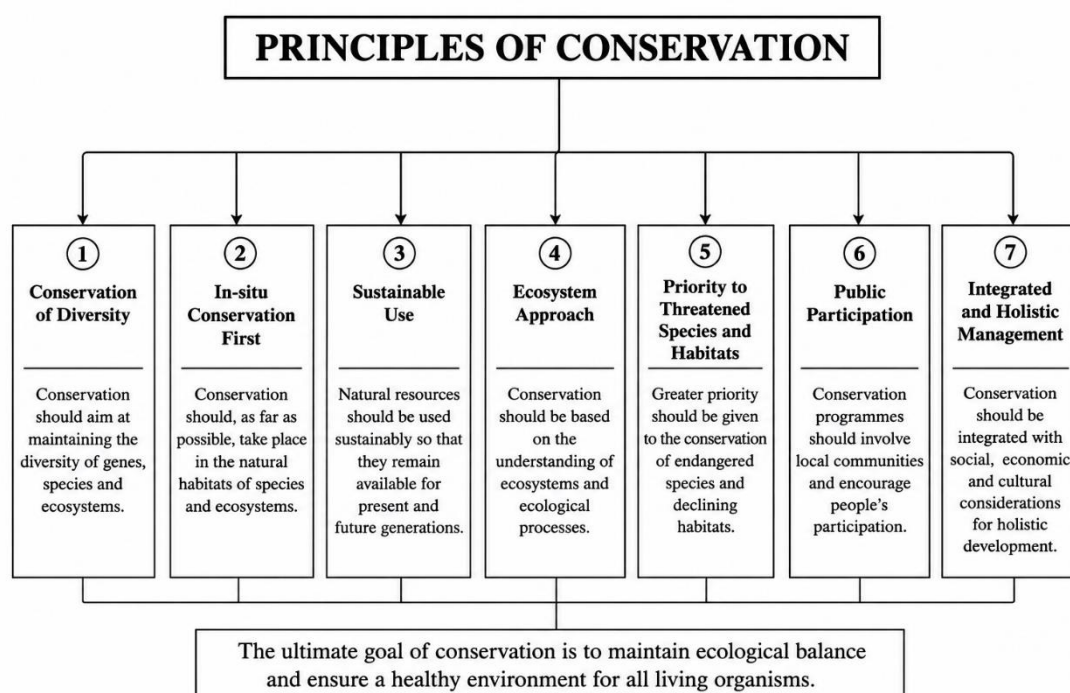
Ex-situ conservation means the **conservation of species outside their natural habitats**. It is used when species are threatened in their natural environment. Examples include **botanical gardens, zoological parks, seed banks, gene banks, tissue culture and cryopreservation**.

3.2 Principles of conservation

The main principles of biodiversity conservation are.

1. **Conservation of Biological Diversity** – Protect the diversity of genes, species and ecosystems.
2. **In-situ Conservation** – Give priority to conserving species in their natural habitats and ecosystems.

3. **Sustainable Utilisation** – Use natural resources carefully and sustainably so that they remain available for future generations.
4. **Ecosystem Approach** – Conservation should consider the structure, functions and ecological processes of entire ecosystems.
5. **Protection of Threatened Species and Habitats** – Special attention should be given to endangered, vulnerable and rare species and their habitats.
6. **Public Participation** – Local communities and the public should actively participate in conservation programmes.



7. **Integrated Management** – Conservation should be integrated with social, economic and cultural needs to achieve sustainable development.

In simple terms, the ultimate goal of conservation is to maintain ecological balance and ensure the continued survival of all living organisms.

3.2.1 In situ conservation

In-situ conservation is the conservation of genetic resources in their **natural habitats**, where plant or animal species occur naturally. It preserves not only the organisms but also their natural ecological and evolutionary processes.

In India, biosphere reserves, national parks, wildlife sanctuaries, reserved forests, protected forests, and nature reserves provide legal protection to biodiversity-rich areas.

An important advantage of in-situ conservation is that species remain in their original environment, allowing natural reproduction, adaptation, and evolution to continue. Turkey is considered one of the first countries to develop a national strategy for conserving genetic diversity in natural habitats.

Purpose and Uses of In-situ Conservation

In-situ conservation can follow two major approaches.

1. **Species-centred approach** – focuses on the conservation of particular species or populations.
2. **Ecosystem-based approach** – focuses on conserving entire ecosystems and their ecological processes.

The main objectives are to

- Maintain viable populations in their natural habitats.
- Allow natural reproduction and continued evolution.
- Protect ecological and evolutionary processes.
- Conserve populations, species, communities, and their physical environment.
- Protect the habitats where species developed their unique characteristics.
- Maintain biodiversity within natural ecosystems.

In-situ conservation is also important for **agricultural biodiversity**. Some crop varieties and domestic species develop unique characteristics through long-term cultivation and traditional farming practices. Therefore, conserving **traditional agricultural systems and agro-ecosystems** is essential for maintaining genetic diversity.

In-situ Conservation

In-situ conservation means protecting plants, animals, and other organisms **in their natural habitats**. It allows natural processes such as reproduction, adaptation, and evolution to continue while protecting the entire ecosystem.

Protected Areas

3.2.1.1 Sacred grove

Sacred groves are small or large patches of natural vegetation that are protected by local communities because of religious, cultural, and traditional beliefs. They are often dedicated

to local deities, ancestral spirits, or sacred trees. Sacred groves represent an important traditional form of in-situ conservation.

Background of Sacred Groves in India: In India, traditional beliefs and indigenous practices have historically promoted respect for nature and natural resources. Many tribal and rural communities depend on forests for food, fibre, fuel, medicine, and other necessities. Their traditional practices have helped conserve numerous plant and animal species.

However, urbanisation, industrialisation, infrastructure development, changing social values, and overexploitation of forest resources have resulted in the degradation and fragmentation of many natural forests. Despite these pressures, some forest patches have remained relatively undisturbed because local communities have traditionally protected them. Such community-protected patches are known as **sacred groves**.

Characteristics of Sacred Groves

1. Sacred groves are traditionally protected patches of natural vegetation.
2. Their size may range from a few trees or square metres to several hectares.
3. They are commonly associated with local deities, spirits, ancestors, or sacred trees.
4. Traditional beliefs discourage or prohibit activities such as tree cutting, hunting, and collection of forest products.
5. The degree of protection varies between communities and regions.
6. Some groves preserve relatively undisturbed vegetation and provide refuge for rare and endemic species.
7. Sacred groves may occur near **ponds, streams, springs, or other water sources**.

Threats to Sacred Groves

Sacred groves face several threats, including.

- Decline of traditional beliefs and cultural practices
- Rapid urbanization and infrastructure development
- Construction of roads, railways, dams, and other projects
- Encroachment and fragmentation
- Commercial forestry and other land-use changes
- Replacement of traditional nature worship by other forms of worship
- Invasion by exotic and invasive plant species
- Increasing livestock pressure

- Excessive collection of fuelwood and other forest resources
- Changing attitudes towards traditional conservation practices

Significance of Sacred Groves

- 1. Conservation of Biodiversity:** Sacred groves provide refuge for **rare, threatened, endemic, and locally important species** of plants and animals.
- 2. Genetic Resource Conservation:** They preserve valuable **genetic diversity** of wild plants, including species that may have medicinal, nutritional, or ecological importance.
- 3. Traditional Ecological Knowledge:** Sacred groves represent the **traditional ecological knowledge** of local and indigenous communities and demonstrate how cultural practices can contribute to conservation.
- 4. Soil Conservation:** Dense vegetation protects the soil from **erosion**, improves soil stability, and contributes organic matter to the ecosystem.
- 5. Water Conservation:** Many sacred groves occur around **springs, streams, and ponds**. Their vegetation helps maintain water quality, reduce runoff, and support **groundwater recharge**.
- 6. Climate and Microenvironment Regulation:** Trees and vegetation within sacred groves help regulate the **local microclimate**, store carbon, and maintain humidity.
- 7. Cultural and Religious Importance:** Sacred groves preserve the cultural heritage, religious traditions, customs, and spiritual values of local communities.

Sacred Groves and In-situ Conservation: Sacred groves are an excellent example of **community-based in-situ conservation**. Biodiversity is conserved **within its natural habitat**, while local communities play a central role in protecting the ecosystem.

In simple terms: Sacred grove = Traditional belief + Community protection + Natural vegetation + Biodiversity conservation. Thus, sacred groves demonstrate that cultural traditions and biodiversity conservation can work together to protect natural ecosystems and their genetic resources.

3.2.1.2 Botanical Garden

A botanical garden is a controlled and scientifically managed institution dedicated to the collection, cultivation, maintenance, study and display of a wide variety of living plants. Plants are grown under suitable conditions and are usually labelled with their correct botanical names to facilitate identification and study. Botanical gardens may contain general

plant collections as well as specialized collections such as cacti and succulents, medicinal plants, herb gardens, orchids, aquatic plants and plants from different geographical regions.

Many botanical gardens have greenhouses and shade houses for maintaining plants that require special environmental conditions, such as tropical and subtropical species. They may also include test grounds, an arboretum, herbarium, laboratories, libraries and museums, depending on their objectives and available resources.

Botanical gardens provide important facilities for education, research, plant conservation and public awareness. Visitor facilities may include guided tours, educational displays, exhibitions, libraries or book rooms, and cultural and educational programmes. Their activities help students; researchers and the general public develop knowledge and appreciation of plant diversity.

A botanical garden is often established and managed by a university, college, government department or scientific research organization. When associated with an educational institution, it may support teaching programmes in botany, taxonomy, ecology, horticulture and plant conservation. Many botanical gardens also have associated herbaria and research programmes.

History of Botanical Gardens

The history of botanical gardens is closely linked with the development of botany. The concept of botanical gardens has changed considerably over time, from small gardens established mainly for medicinal purposes to modern scientific institutions involved in plant research, education, conservation and horticulture.

Early History: The earliest botanical gardens developed from physic gardens, which were established mainly for the cultivation of plants used in medicine. These gardens provided physicians, students and botanists with living plants for identification, study, medicinal use and experimentation.

In Europe, the tradition of physic gardens has a long history. Aristotle is traditionally associated with a garden at the Lyceum in Athens, where plants were studied for educational and scientific purposes. His pupil Theophrastus, often regarded as the “Father of Botany,” also made important contributions to the systematic study of plants.

Botanical Gardens during the 16th and 17th Centuries

During the 16th and 17th centuries, many European botanical gardens were established primarily as medicinal or physic gardens. They were associated with universities and medical schools and were used for teaching students about medicinal plants and their properties.

As European exploration expanded, plants from distant regions and European colonies were introduced into these gardens. This greatly increased the diversity of plants cultivated in Europe.

Change in Purpose: With the arrival of plants from different parts of the world, the purpose of botanical gardens gradually changed. Gardens began to display plants not only for their medicinal properties but also because they were beautiful, unusual, scientifically interesting or economically valuable. These newly introduced plants became important materials for botanical study and classification. Botanical gardens therefore became important centres for the development of plant taxonomy and systematic botany.

Development during the 18th Century: During the 18th century, botanical gardens became increasingly important as centres of botanical education and scientific research. Botanists associated with herbaria and botanical gardens developed and demonstrated new systems of plant classification.

Living plants in botanical gardens provided opportunities to compare different species and understand their morphology, relationships and classification. Thus, botanical gardens played an important role in the development of modern systematic botany.

Development during the 19th and 20th Centuries: During the 19th and 20th centuries, botanical gardens expanded their activities and developed both specialised and diverse plant collections. They increasingly combined horticulture with scientific research.

Their functions expanded to include: Plant taxonomy and systematics, Plant introduction and cultivation, Horticultural research, Plant geography and ecology, Education and public awareness, Conservation of rare and endangered plants, Seed and germplasm conservation and Plant propagation and exchange. Botanical gardens consequently developed into important institutions for both scientific research and plant conservation.

Modern Botanical Gardens: Modern botanical gardens are multifunctional institutions that combine research, education, horticulture, conservation and public awareness. Many maintain living collections, herbaria, seed banks, laboratories, libraries and specialized research facilities. They also play an important role in ex-situ conservation by maintaining threatened plant species outside their natural habitats and supporting their propagation and, where appropriate, reintroduction.

Definition: A botanical garden may be defined as a controlled and staffed institution that maintains living collections of plants under scientific management for purposes of education, research, conservation and dissemination of botanical knowledge. Supporting facilities such as libraries, herbaria, laboratories and museums may be maintained according to the particular objectives of the institution.

Organisation and Specialisation: Each botanical garden develops its own special areas of interest according to its geographical location, available land, scientific staff, financial resources and institutional objectives. It may specialise in particular groups of plants, such as ferns, orchids, medicinal plants, cacti, succulents or plants of a particular geographical region.

A botanical garden generally maintains both scientific staff and horticultural or plant-growing staff. Scientific publications are an important means of communicating the knowledge and research generated by the institution.

Major Components: A botanical garden may include.

1. **Living plant collections** – plants maintained for study, education and conservation.
2. **Greenhouses** – controlled environments for special plant collections.
3. **Shade houses** – facilities for plants requiring reduced light intensity.
4. **Herbarium** – a collection of preserved and scientifically documented plant specimens.
5. **Arboretum** – a specialized collection of living trees and woody plants.
6. **Test grounds** – areas used for cultivation, observation and research.
7. **Laboratories** – facilities for scientific investigation.
8. **Libraries** – sources of botanical literature and reference materials.
9. **Museums and educational displays** – facilities for public education and awareness.

Institutional Status: A botanical garden may function as an independent institution, a governmental organization, or an institution affiliated with a college or university. When it is part of an educational institution, it may be closely associated with teaching and research programmes. The primary purpose of a botanical garden is the acquisition, maintenance, study and dissemination of botanical knowledge. Therefore, it is more than an ornamental or landscaped garden.

Botanical Garden and Other Gardens: A botanical garden should not be regarded simply as an ornamental garden, public park or experimental station. Although it may be aesthetically attractive and provide recreational facilities, its essential characteristic is its scientific purpose. Plants are maintained, documented, labelled and studied systematically for education, research, conservation and the advancement of botanical knowledge.

Importance of Botanical gardens

1. Scientific Research: Botanical gardens are important centres for scientific research in plant science. They are often managed by universities, government institutions or scientific organisations and may have associated herbaria, laboratories and research programmes. They support research in plant taxonomy, systematics, morphology, ecology, physiology, horticulture, conservation biology and other areas of botanical science.

2. Conservation of Plant Diversity: One of the major functions of botanical gardens is the ex-situ conservation of plant biodiversity. They maintain living collections of rare, threatened and endangered plants outside their natural habitats. Seeds, cuttings, tissue cultures and other plant materials may also be conserved for long-term protection and future use.

3. Maintenance of Documented Living Collections: Botanical gardens maintain well-documented collections of living plants. Each plant is properly identified, labelled and recorded. Such collections provide valuable material for scientific research, teaching, plant identification and conservation programmes.

4. Role in Ecological Restoration: Botanical gardens are well positioned to support ecosystem restoration because they possess expertise in plant taxonomy, horticulture, biodiversity assessment, conservation biology, restoration ecology and ethnobotany. This knowledge helps in selecting appropriate native plant species and designing restoration programmes that are ecologically suitable.

5. Conservation of Genetic Diversity: Botanical gardens help conserve not only species but also their genetic diversity. Seed banks, living collections and other germplasm collections

preserve genetic material that may be useful for research, plant breeding, restoration and adaptation to environmental changes. Maintaining appropriate genetic provenance is important for successful ecological restoration.

6. Plant Propagation and Reintroduction: Botanical gardens provide facilities for the propagation of rare and endangered plants. Plants can be multiplied through seeds, cuttings, grafting, tissue culture and other techniques. When suitable habitats are available and conservation guidelines permit, propagated plants may be used in reintroduction or population-recovery programmes.

7. Education and Training: Botanical gardens are important centres for botanical education. Students, researchers and visitors can observe living plants and learn about plant identification, diversity, ecology, conservation and economic importance. They also provide opportunities for practical training in horticulture, taxonomy and plant conservation.

8. Public Awareness: Botanical gardens help create public awareness about biodiversity conservation. Exhibitions, guided tours, educational displays, lectures and other programmes help people understand the importance of plants and the need to protect threatened species and ecosystems.

9. Global Exchange of Plant Resources: Botanical gardens collectively function as a global repository of documented plant material. Through seed banks, living collections, herbaria, libraries and scientific networks, they can exchange information and, where legally and ethically appropriate, plant material for research and conservation.

10. Support for Taxonomy and Plant Identification: Botanical gardens provide essential resources for plant taxonomy and identification. Living collections can be compared with herbarium specimens and botanical literature to verify plant identity and relationships. Accurate taxonomy is fundamental to biodiversity inventories, conservation planning and ecological restoration.

11. Support for Ethnobotanical Studies: Botanical gardens also contribute to ethnobotanical research, which examines the relationships between people and plants. Traditional knowledge about medicinal, food, fibre and culturally important plants can be documented and studied, helping to conserve both biological resources and associated traditional knowledge.

12. Recreation and Appreciation of Nature: In addition to their scientific functions, botanical gardens provide attractive spaces where people can enjoy plants and natural landscapes. Beautiful plant displays, gardens, streams, ponds and other landscape features provide opportunities for relaxation, recreation and appreciation of nature.

13. Role in Climate and Environmental Education: Botanical gardens can demonstrate the effects of climate change, habitat loss, invasive species and other environmental problems. Through plant collections and educational programmes, they help visitors understand the importance of sustainable environmental management.

14. Contribution to Ecologically Resilient Ecosystems: Botanical gardens can contribute to the restoration of diverse and ecologically resilient ecosystems by selecting appropriate species and, where necessary, suitable genetic sources. This reduces the risk of establishing inappropriate plants in unsuitable environments and improves the long-term success of restoration projects.

3.2.1.3 Biosphere reserve

A biosphere reserve is a large area of terrestrial, coastal, or marine ecosystems recognized under UNESCO's Man and the Biosphere (MAB) Programme, launched in 1971. Biosphere reserves serve as living laboratories for conservation and sustainable development, where biodiversity protection is combined with the sustainable use of natural resources.

Unlike strictly protected areas, biosphere reserves recognise that people and nature are interconnected. Local communities, Indigenous Peoples, researchers, government agencies, civil society, and other stakeholders can participate in conservation and sustainable livelihood activities.

Objectives of Biosphere Reserves

The major objectives are to.

- Conserve **biodiversity, ecosystems, and genetic resources.**
- Protect important habitats and threatened species.
- Promote **sustainable development** while maintaining ecological integrity.
- Support scientific research, monitoring, and environmental education.
- Encourage local communities to participate in conservation.
- Promote sustainable livelihoods and responsible use of natural resources.

Zonation of a Biosphere Reserve

A biosphere reserve is generally organized into **three interconnected zones.**

1. Core Zone: A strictly protected area with minimal human interference.

Conserves ecosystems, habitats, species, and genetic resources.

Research and monitoring may be permitted under appropriate regulations.

2. Buffer Zone: Surrounds or adjoins the core zone.

Allows activities compatible with conservation, such as **research, education, ecological monitoring, and regulated tourism**. Acts as a protective zone around the core area.

3. Transition Zone: The outermost zone where people commonly **live and work**.

Supports sustainable agriculture, forestry, fisheries, settlements, and other livelihood activities.

Emphasises the sustainable use of natural resources.

Example: Nilgiri Biosphere Reserve

The **Nilgiri Biosphere Reserve** extends across parts of **Tamil Nadu, Kerala, and Karnataka**. It is one of India's important biodiversity-rich landscapes and contains a variety of forests, grasslands, wetlands, and montane ecosystems.

It supports important species such as the **Asian elephant, Bengal tiger**, Leopard, Nilgiri tahr and Several endemic plants and animals.

Importance in In-situ Conservation: Biosphere reserves are important for **in-situ conservation** because they protect biodiversity within natural ecosystems while also recognising the needs of human communities. They demonstrate that **conservation and sustainable development can be achieved together** through scientific research, community participation, ecological management, and responsible resource use.

In simple terms

Biosphere reserve = Conservation + Sustainable development + Community participation + Scientific research.

3.2.1.4 Sanctuaries.

Protected areas established mainly for the conservation of wild animals and birds. Certain regulated human activities may be permitted, provided they do not adversely affect wildlife.

A wildlife sanctuary is a protected area established for the conservation of wild animals, plants, and their natural habitats. The main objective is to protect wildlife from activities such as hunting, capturing, killing, and poaching and to provide suitable conditions for animals to survive and reproduce in their natural environment.

Unlike national parks, certain regulated human activities may be permitted in wildlife sanctuaries, provided they do not adversely affect wildlife or the conservation objectives (Table 3.1).

Table 3.1: Examples of Wildlife Sanctuaries in India.

S. No.	Wildlife Sanctuary	State	Major Conservation Importance
1	Bharatpur Bird Sanctuary (Keoladeo)	Rajasthan	Migratory and resident birds
2	Chilika Lake Bird Sanctuary	Odisha	Waterbirds and wetland biodiversity
3	Chinnar Wildlife Sanctuary	Kerala	Dry forest and diverse wildlife
4	Gir Wildlife Sanctuary	Gujarat	Asiatic lion and associated wildlife
5	Govind Wildlife Sanctuary	Uttarakhand	Himalayan flora and fauna
6	Mudumalai Wildlife Sanctuary	Tamil Nadu	Elephants, tigers and other wildlife
7	Periyar Wildlife Sanctuary	Kerala	Elephants, tigers and forest biodiversity

Importance of Wildlife Sanctuaries

1. Protection of Endangered Species

Sanctuaries provide safe habitats for **threatened and endangered species** and help prevent their decline and extinction.

2. Conservation in Natural Habitats: Animals are protected **within their natural habitats**, allowing them to feed, reproduce, and interact with other organisms under relatively natural conditions.

3. Protection from Hunting and Poaching: Strict regulations help prevent **hunting, capturing, killing, and illegal wildlife trade**.

4. Scientific Research: Wildlife sanctuaries provide opportunities for **biological, ecological, behavioural, and conservation research**. Scientists can study species and their interactions with the environment.

5. Breeding and Population Recovery: Protection allows threatened populations to **increase naturally**. Where necessary, carefully planned conservation-breeding programmes may also support species recovery.

6. Rescue and Rehabilitation: Some protected areas and associated facilities support the **rescue, treatment, and rehabilitation of injured or displaced wild animals**, followed by their return to suitable habitats whenever possible.

7. Conservation of Biodiversity: Sanctuaries protect not only individual animals but also **plants, microorganisms, habitats, food chains, and ecological processes**.

8. Ecotourism and Environmental Education: Where permitted and properly regulated, sanctuaries can support **nature tourism, guided visits, interpretation programmes, and**

environmental education. Such activities should be managed so that they do not disturb wildlife.

3.2.1.5 National parks (In situ)

A **National Park** is a protected natural area established to conserve wild plants, animals, habitats, ecosystems, and landscapes. National parks are important components of in-situ conservation, because species are protected within their natural habitats. Human activities such as hunting, grazing, collection of forest products, and other activities that may damage wildlife are generally prohibited or strictly regulated.

India is one of the world's biodiversity-rich countries and has numerous national parks representing a wide range of ecosystems, including forests, grasslands, wetlands, mountains, deserts, and coastal regions.

Important National Parks

1. Jim Corbett National Park

Jim Corbett National Park is located in Uttarakhand and is India's oldest national park, established in 1936 as Hailey National Park. It was renamed Jim Corbett National Park in 1957, in honour of the famous naturalist and conservationist Edward James Corbett.

The park covers approximately 520 km² and contains a variety of habitats, including sal forests, grasslands, riverine areas, hills, streams, and wetlands.

Table 3.2 Famous National Parks and Protected Areas in India.

National Park / Protected Area	State/Union Territory	Major Conservation Importance
Bandipur National Park	Karnataka	Tiger, Asian elephant and other wildlife
Bandhavgarh National Park	Madhya Pradesh	Tiger
Jim Corbett National Park	Uttarakhand	Bengal tiger and diverse wildlife
Dudhwa National Park	Uttar Pradesh	Tiger, swamp deer and rhinoceros
Gir National Park	Gujarat	Asiatic lion
Hemis National Park	Ladakh	Snow leopard and high-altitude wildlife
Kaziranga National Park	Assam	Greater one-horned rhinoceros, elephant and tiger
Keoladeo National Park	Rajasthan	Migratory and resident waterbirds
Manas National Park	Assam	Tiger, rhinoceros, elephant and other wildlife
Nagarhole National Park	Karnataka	Tiger, elephant and other forest wildlife
Panna National Park	Madhya Pradesh	Tiger and gharial-associated riverine

		ecosystem
Periyar National Park	Kerala	Asian elephant, tiger and evergreen forests
Pench National Park	Madhya Pradesh	Tiger and diverse forest fauna
Ranthambore National Park	Rajasthan	Bengal tiger
Tadoba–Andhari Tiger Reserve	Maharashtra	Tiger and dry deciduous forest biodiversity

Major features

- Famous for the Bengal tiger.
- Supports elephants, leopards, deer, crocodiles and many species of birds.
- Forms an important part of the Corbett Tiger Reserve.
- It was among the first areas included in Project Tiger in 1973.

2. Gir National Park

Gir National Park and Wildlife Sanctuary, commonly known as Sasan Gir, is located in Gujarat. It is the most important natural habitat of the Asiatic lion (*Panthera leo persica*). The protected Gir landscape includes the national park, wildlife sanctuary and surrounding forests.

Major features

- The principal conservation area for the **Asiatic lion**.
- Contains dry deciduous forests, grasslands and seasonal rivers.
- Supports leopards, chital, sambar, nilgai, wild boar and numerous bird species.
- The **Gir Wildlife Sanctuary was established in 1965**, while the national park was subsequently established within the protected landscape.

3. Kaziranga National Park

Kaziranga National Park is located in **Assam**, mainly along the floodplains of the **Brahmaputra River**. It is internationally renowned for conserving the **greater one-horned rhinoceros** (*Rhinoceros unicornis*).

Major features

- One of the world's most important habitats for the **greater one-horned rhinoceros**.
- Supports large populations of elephants, wild water buffalo, swamp deer and tigers.
- Contains tall grasslands, wetlands, forests and riverine habitats.
- Declared a national park in 1974.

- Recognised as a UNESCO World Heritage Site because of its exceptional biodiversity and conservation importance.

4. Ranthambore National Park

Ranthambore National Park is located in Rajasthan and is one of India's best-known tiger conservation areas. The landscape combines dry deciduous forests, grasslands, lakes, rocky terrain and historic ruins.

Major features

- Famous for the Bengal tiger.
- Supports leopard, sloth bear, sambar, chital, nilgai and many bird species.
- The area was initially established as the Sawai Madhopur Game Sanctuary in 1955.
- It became part of Project Tiger in 1973.
- It was declared a national park in 1980.
- The wider tiger reserve landscape is associated with the Banas and Chambal river systems.

Conservation Significance

National parks play a major role in in-situ conservation by protecting species within their natural ecosystems. They help to.

- conserve threatened and endangered species;
- protect natural habitats and ecosystems;
- maintain genetic diversity;
- preserve food chains and ecological interactions;
- support scientific research and environmental education;
- promote regulated nature-based tourism; and
- maintain important ecological processes for future generations.

Role in In-situ Conservation

Wildlife sanctuaries are an important component of in-situ conservation because organisms are conserved in their natural or historically occupied habitats. They therefore help maintain genetic diversity, natural ecological interactions, viable populations, and ecosystem functions. Marine Protected Areas.

Marine Protected Areas (MPAs) are specific areas of marine, coastal, estuarine, or intertidal ecosystems where human activities and the exploitation of natural resources are regulated or restricted to conserve marine biodiversity. They are an important component of in-situ conservation.

India has a long coastline of about 7,500 km, including its mainland and islands, and a large Exclusive Economic Zone (EEZ). Its marine ecosystems include coral reefs, mangroves, estuaries, lagoons, seagrass beds, mudflats, beaches, and coastal wetlands. These ecosystems support a wide variety of marine organisms and provide important ecological and economic services.

Objectives of Marine Protected Areas

The major objectives of MPAs are to.

- Conserve marine and coastal biodiversity.
- Protect threatened and endangered marine species.
- Preserve coral reefs, mangroves, seagrass beds, estuaries, and wetlands.
- Control destructive human activities and overexploitation of marine resources.
- Provide safe breeding and nursery grounds for marine organisms.
- Maintain ecological processes and food webs.
- Support scientific research, monitoring, education, and regulated ecotourism.
- Promote sustainable use of marine resources where permitted.

Table 3.3 Important Marine Protected Areas in India.

State/UT	Marine Protected Area / Important Coastal Protected Area
Gujarat	Gulf of Kachchh Marine National Park
Tamil Nadu	Gulf of Mannar Marine Biosphere Reserve / Marine National Park
Odisha	Bhitarkanika National Park
Odisha	Gahirmatha Marine Sanctuary
West Bengal	Sundarbans National Park / Biosphere Reserve
Maharashtra	Malvan Marine Wildlife Sanctuary
Maharashtra	Thane Creek Flamingo Sanctuary
Odisha	Chilika Lake – Nalabana Bird Sanctuary
Andhra Pradesh	Coringa Wildlife Sanctuary
Andhra Pradesh	Krishna Wildlife Sanctuary
Andhra Pradesh–Tamil Nadu	Pulicat Lake
Tamil Nadu	Point Calimere Wildlife and Bird Sanctuary

Goa	Chorao Island / Dr. Salim Ali Bird Sanctuary
Kerala	Kadalundi–Vallikkunnu Community Reserve
Gujarat	Khijadiya Wildlife Sanctuary
West Bengal	Sajnekhali Wildlife Sanctuary

Major Examples

1. Gulf of Kachchh Marine National Park – Gujarat

It protects important **coral reefs, mangroves, mudflats, seagrass and marine fauna**. It is particularly important for conserving diverse coastal and marine ecosystems.

2. Gulf of Mannar – Tamil Nadu

The Gulf of Mannar contains coral reefs, seagrass beds, mangroves and numerous marine species. It is particularly important for marine biodiversity and supports species such as dugongs, sea turtles, dolphins and numerous reef-associated organisms.

3. Gahirmatha Marine Sanctuary – Odisha

Gahirmatha is an important nesting and conservation area for olive ridley sea turtles (*Lepidochelys olivacea*). Large-scale seasonal nesting, known as arribada, makes the region especially significant for sea turtle conservation.

4. Sundarbans – West Bengal

The Sundarbans is a vast mangrove ecosystem associated with the Ganges–Brahmaputra–Meghna delta. It provides habitat for the Royal Bengal tiger, estuarine crocodile, numerous fish, birds, and other organisms.

5. Coringa Wildlife Sanctuary – Andhra Pradesh

Coringa protects one of India's important **mangrove ecosystems** near the Godavari delta. Its mangrove forests provide breeding and nursery habitats for many aquatic organisms and help protect the coastline from erosion and storms.

Importance of Marine Protected Areas

Marine Protected Areas are essential for conserving India's marine biodiversity because they.

Protect habitats → conserve species → maintain ecological processes → support sustainable fisheries → protect coastal communities.

They also help ecosystems become more resilient to pressures such as overfishing, habitat destruction, pollution, climate change, and coastal development.

Community and Cultural Conservation Areas

6. Community Reserves

A **community reserve** is a protected area established on private or community-owned land for the conservation of wildlife, habitats, and biodiversity, with the active participation of local communities. It is an important example of community-based in-situ conservation.

Legal Basis: Community reserves were introduced in India through the Wildlife (Protection) Amendment Act, 2002, which amended the Wildlife (Protection) Act, 1972. The provision encourages local communities and private landowners to participate voluntarily in biodiversity conservation.

Community Reserves and In-situ Conservation

Community reserves demonstrate that biodiversity conservation does not always require complete separation of people from nature. By involving local communities in the protection and sustainable management of their surroundings, they provide an effective approach to community-based in-situ conservation. In simple terms: Community Reserve = Community participation + Legal protection + Biodiversity conservation + Sustainable resource use.

Importance of In-situ Conservation

- Conserves species in their natural habitats.
- Maintains genetic diversity.
- Allows natural reproduction and evolution.
- Protects entire ecosystems and ecological processes.
- Provides long-term protection for threatened and endangered species.
- Involves local communities in sustainable conservation practices.

3.2.2 Ex-situ conservation.

Ex-situ conservation is an important method of biodiversity conservation in which species, genetic material or biological resources are conserved outside their natural habitats. It provides a safety net for species that are threatened or endangered in the wild. Ex-situ conservation is complementary to in-situ conservation, which protects species within their natural habitats. When wild populations become critically small, ex-situ methods can help maintain their genetic diversity, support breeding and, where appropriate, facilitate their eventual reintroduction into suitable natural habitats.

Definition: Ex-situ conservation means the conservation of plants, animals and their genetic resources outside their natural habitats under controlled or managed conditions. It involves specialised facilities and scientific techniques to maintain biological material for long-term conservation, research, education, breeding and possible restoration.

Importance of Ex-situ Conservation: Ex-situ conservation is particularly valuable when a species is critically threatened in its natural habitat. It helps preserve genetic diversity, provides opportunities for scientific research and controlled breeding, and supports education and public awareness. Conserved organisms or genetic material can also provide a source for population recovery and reintroduction when suitable habitats and conditions are restored. Important ex-situ approaches include botanical gardens, seed banks, gene banks and cryopreservation.

3.2.3 Seed banks

A seed bank is a specialised facility where seeds of different plant species and varieties are collected, dried, stored and preserved under controlled conditions for long-term conservation. Seed banks are an important method of ex-situ conservation because they conserve plant genetic resources outside their natural habitats.

Seed banks play a major role in conserving plant biodiversity and agricultural genetic diversity. Modern agriculture often depends on a limited number of high-yielding crop varieties. As a result, many traditional crop varieties and wild plant species may become neglected or threatened with extinction. Seed banks help prevent the permanent loss of these valuable genetic resources.

Importance of Seed Banks: Seed banks act as a genetic backup system for plants. They preserve seeds that may contain valuable characteristics such as drought resistance, disease resistance, pest resistance, high nutritional value and adaptability to different environmental conditions. These genetic resources can be used in future plant breeding and crop improvement programmes.

Seed banks also provide protection against unexpected threats such as climate change, natural disasters, habitat destruction, pests, diseases, wars and other environmental or human-induced disturbances. If a plant population is lost from its natural habitat, stored seeds may provide genetic material for research, propagation and, where appropriate, restoration.

Types of Seed Banks: Seed banks may range from small community-based collections to large national and international facilities. Community seed banks generally conserve locally important and traditional crop varieties, while national and international seed banks maintain large collections of agricultural and wild plant genetic resources.

Svalbard Global Seed Vault: The Svalbard Global Seed Vault in Norway is one of the world's best-known seed conservation facilities. It provides long-term backup storage for seed samples held in other gene banks around the world. The facility was designed to provide additional protection against natural disasters, climate-related threats and other emergencies that could result in the loss of important crop genetic resources.

Role in Food Security: Seed banks are closely associated with global food security. The genetic diversity preserved in seed banks provides plant breeders and researchers with material needed to develop crops that can tolerate changing environmental conditions. Such genetic resources are particularly important for developing varieties with improved yield, nutritional quality, drought tolerance, salinity tolerance and resistance to pests and diseases.

Role in Biodiversity Conservation

Seed banks contribute to the conservation of agricultural biodiversity and wild plant diversity. They help preserve traditional crop varieties and plant genetic resources that may no longer be widely cultivated. In this way, seed banks reduce the risk of genetic erosion and maintain resources for future generations.

Seed banks are essential centres of ex-situ conservation that safeguard plant genetic resources for the future. By preserving seeds under controlled conditions, they help protect biodiversity, support crop improvement, strengthen food security and provide a genetic reserve against environmental and human-induced threats. Thus, seed banks are an important component of modern biodiversity conservation and sustainable agriculture.

3.2.5 Gene banks

GenBank is a comprehensive, open-access database of nucleotide sequences and their associated biological annotations. It is maintained by the National Centre for Biotechnology Information (NCBI) and forms part of the International Nucleotide Sequence Database Collaboration (INSDC) along with the European Nucleotide Archive (ENA) and the DNA

Data Bank of Japan (DDBJ). The database contains sequence information from a very large number of organisms and is continuously updated as new sequence data are submitted.

GenBank is widely used by researchers, students and scientists in molecular biology, genetics, genomics, biotechnology, microbiology and bioinformatics. It provides sequence information that can be used for gene identification, sequence comparison, evolutionary studies and many other biological investigations.

Main Components of a GenBank Record

1. Header: The **header** provides general information about a sequence record. It may include the **locus name, sequence length, molecule type, database division, accession number, definition, organism name, taxonomy and references** to scientific publications. The header helps users understand the basic identity and origin of the sequence.

2. Features: The **Features** section contains detailed biological information and annotations associated with different regions of the sequence. It may identify **genes, coding sequences (CDS), promoters, regulatory regions and other important sequence features**. For coding sequences, the corresponding amino-acid translation may also be provided. This section helps researchers understand the biological function and organization of the sequence.

3. Sequence: The **Sequence** section contains the actual nucleotide sequence, usually represented by the bases **A, T, G and C** for DNA or **A, U, G and C** for RNA. It provides the primary sequence data that can be analysed using bioinformatics tools and compared with sequences from other organisms.

Database Organization

4. Divisions: GenBank organizes sequence records into different database divisions according to organism groups and specific projects. Examples include PRI (primate), BCT (bacterial), VRL (viral) and ENV (environmental sampling). This organization facilitates efficient storage, retrieval and analysis of sequence information.

5. International Data Exchange: GenBank works together with the European Nucleotide Archive (ENA) and the DNA Data Bank of Japan (DDBJ) as members of the International Nucleotide Sequence Database Collaboration. The partner databases exchange sequence data regularly, helping maintain a globally coordinated and consistent collection of nucleotide sequence information.

Importance of GenBank: GenBank is an important resource for modern biological research and bioinformatics. It helps scientists identify genes, compare DNA sequences, study genetic variation, determine evolutionary relationships and investigate the genomes of organisms. It is also widely used in molecular identification, genome annotation, phylogenetic analysis, biotechnology and medical research.

3.2.6 Pollen Bank

A pollen bank is a specialised facility used for the collection, preservation and long-term storage of viable pollen grains from different plant species. It is an important method of ex-situ conservation because it preserves male genetic material outside the natural habitat of the plant. Pollen banks are particularly useful in plant breeding, conservation of rare species and genetic-resource management.

1. Collection and Preparation of Pollen

Mature pollen is collected from freshly opened flowers or other pollen-bearing structures at the appropriate stage of development. The collected material is carefully dried under controlled conditions, and pollen grains are separated from unwanted floral parts. The pollen is then packed in suitable, labelled containers before storage.

2. Cryopreservation

For long-term storage, pollen may be preserved at **very low temperatures**, commonly around **–196°C in liquid nitrogen**. At such temperatures, metabolic activity is greatly reduced or stopped, allowing viable pollen to remain preserved for extended periods. The exact storage conditions depend on the plant species and the characteristics of its pollen.

3. Role in Crop Improvement

Pollen banks provide valuable material for **plant breeding and crop improvement**. Stored pollen can be used for controlled pollination and hybridization to develop varieties with desirable characteristics such as **high yield, disease resistance, drought tolerance and improved quality**.

4. Conservation of Genetic Diversity

Pollen banks help conserve the **genetic diversity of rare, threatened and economically important plant species**. By preserving pollen from different plants or populations, valuable male genetic resources can be safeguarded against genetic erosion and loss.

5. Hybridization between Plants with Different Flowering Periods

Stored pollen makes it possible to carry out **cross-pollination between plants that flower at different times**. Pollen collected during one flowering season can be stored and used when the compatible female plant becomes available. This is particularly useful in controlled breeding programmes.

6. Conservation of Distant or Geographically Separated Genetic Resources

Pollen storage can facilitate the use of genetic material from plants growing in **different geographical regions**. When direct transfer of living plants is difficult, properly preserved pollen may provide an alternative source of genetic material for breeding and research, subject to applicable regulations.

7. Scientific Research

Pollen banks provide useful material for research on **plant reproduction, pollen viability, genetics, breeding, pollination biology and evolutionary relationships**. Stored pollen can be studied to understand reproductive characteristics and genetic variation among plant populations.

Importance in Ex-situ Conservation

Pollen banking is an important **ex-situ conservation technique** because it preserves male reproductive material while requiring much less space than maintaining complete living plants. It is especially valuable for species in which conventional seed storage is difficult or unsuitable.

3.2.7 Tissue culture

Tissue culture is a technique in which small pieces of plant tissue, cells or organs are grown **in vitro under sterile and controlled laboratory conditions** on a suitable nutrient medium. The plant material used for culture is called an **explant**. The technique is widely used for plant propagation, conservation, crop improvement and production of disease-free planting material.

Plant tissue culture is commonly associated with **micropropagation**, in which a large number of plants are produced from a small amount of plant material. The technique is based on the **totipotency of plant cells**, which means that a living plant cell or tissue has the potential to regenerate into a complete plant under suitable conditions.

Tissue culture requires a sterile laboratory environment, suitable nutrient media, controlled temperature and light, trained personnel and facilities for acclimatizing regenerated plants. It has been successfully applied to crops such as banana, pineapple, potato, sweet potato, tomato, eggplant, oil palm and rubber.

Types of Tissue culture

1. Seed Culture: Seed culture involves the germination and growth of seeds under sterile in-vitro conditions. Seeds are surface-sterilised and placed on a suitable nutrient medium. This method is useful for obtaining healthy seedlings and for studying seed germination and plant development.

2. Embryo Culture: Embryo culture involves the isolation and growth of a mature or immature embryo on a suitable nutrient medium under in-vitro conditions. It is useful for rescuing embryos that may not develop normally in the seed and for overcoming certain problems associated with seed dormancy or hybridization.

3. Callus Culture: A **callus** is an unorganised mass of actively dividing plant cells. When suitable explants are cultured on an appropriate nutrient medium containing plant growth regulators, callus formation may occur. The callus can subsequently differentiate into shoots and roots and may regenerate into a complete plant.

4. Organ Culture: In **organ culture**, a plant organ or part of an organ, such as a **leaf, root or shoot**, is cultured under controlled conditions. This technique is useful for studying organ development, regeneration and maintaining specific plant tissues.

5. Protoplast Culture: A **protoplast** is a plant cell from which the cell wall has been removed, usually using suitable enzymes. Under appropriate culture conditions, the protoplast can regenerate a cell wall, undergo cell division and eventually develop into a complete plant. Protoplast culture is particularly important in **plant breeding, somatic hybridization and genetic manipulation**.

6. Pollen Culture: Pollen culture involves the cultivation of immature pollen grains or microspores on a suitable nutrient medium to produce haploid plants. It is useful in **plant breeding and the production of homozygous lines**.

7. Anther Culture: In **anther culture**, the entire anther containing developing pollen grains is cultured in vitro. Under suitable conditions, the pollen grains may develop into haploid plantlets. This technique is useful for producing **haploid and doubled-haploid plants** in plant breeding programmes.

8. Single-Cell Culture: **Single-cell culture** involves the growth of individual plant cells under suitable nutritional and environmental conditions. It is useful for studying cell growth, metabolism, genetic variation and plant regeneration.

9. Suspension Culture: In **suspension culture**, individual cells or small groups of cells are grown in a liquid nutrient medium. Continuous or periodic agitation keeps the cells suspended. It is useful for **rapid cell multiplication and production of valuable plant metabolites**.

10. Somatic Embryogenesis: **Somatic embryogenesis** is the formation of embryo-like structures from somatic, or non-reproductive, cells. These embryos can develop into complete plants. It is useful for **rapid multiplication, conservation and large-scale propagation** of plants.

Steps of Tissue culture

1. Selection and Initiation: A healthy and suitable plant part is selected as the **explant**. The explant is collected and surface-sterilized to remove microorganisms. It is then transferred aseptically onto a suitable sterile culture medium.

2. Multiplication: The explant is cultured on a nutrient medium containing appropriate **plant growth regulators, vitamins, minerals, sugars and other nutrients**. Cells divide actively and produce shoots or, in some cases, an undifferentiated mass called **callus**. Repeated subculturing can produce a large number of plantlets.

3. Shoot Formation: Under suitable hormonal conditions, **shoots develop from the cultured tissue**. Cytokinins and other growth regulators are commonly used to promote shoot multiplication and development.

4. Root Formation: The regenerated shoots are transferred to a suitable rooting medium. Appropriate concentrations of **auxins** help stimulate root development. Well-developed roots produce complete plantlets.

5. Acclimatisation: Plantlets produced in vitro are delicate and must be gradually adapted to conditions outside the culture vessel. They are transferred first to a **greenhouse or controlled environment**, where humidity, temperature and light are carefully regulated. After successful acclimatisation, the plants are transferred to a nursery and eventually grown under natural environmental conditions.

Flow of Tissue Culture

Selection of Explant → Surface Sterilization → Culture Initiation → Multiplication → Shoot Formation → Root Formation → Acclimatization → Nursery → Field Plant

Advantages of tissue culture

1. A **large number of plants** can be produced from a small amount of plant material.
2. Plants can be propagated **rapidly** within a relatively short period.
3. Production can be carried out **throughout the year**, independent of the normal growing season.
4. It requires comparatively **less space** than conventional propagation.
5. Properly managed tissue-culture systems can produce **healthy and disease-free planting material**, particularly when suitable meristem-based methods are used.
6. Rare and economically important plants can be **rapidly multiplied**.
7. Plants that are difficult to propagate through seeds can be propagated vegetatively.
8. It is useful for the rapid multiplication of **ornamental plants** such as orchids, chrysanthemums and other horticultural species.
9. It can support the production of genetically uniform plants, or **clones**, when appropriate propagation methods are used.
10. It provides valuable material for **plant breeding and genetic improvement**.

Importance of tissue culture

1. **Ex-situ Conservation:** Tissue culture is an important technique for **ex-situ conservation of plant biodiversity**. Rare, threatened and endangered plants can be multiplied and maintained under controlled laboratory conditions. This provides an additional safeguard against the loss of plant species.
2. **Rapid Multiplication:** Micropropagation allows thousands of plants to be produced from a small piece of plant tissue. This is especially useful for plants that are **slow-growing, difficult to propagate or produce few viable seeds**.
3. **Production of Disease-Free Plants:** Meristem and shoot-tip culture can be used to produce **pathogen-free planting material**, particularly in vegetatively propagated crops. This is valuable for maintaining healthy agricultural and horticultural stocks.
4. **Crop Improvement:** Tissue culture can be combined with **plant breeding and biotechnology** to produce plants with desirable characteristics. It also provides techniques for selecting, multiplying and maintaining useful genetic variants.

5. Conservation of Difficult-to-Store Plants: Some plants cannot be conserved effectively as conventional seeds. Their **shoot tips, embryos, cells or tissues** can be maintained through tissue culture and, when appropriate, transferred to long-term storage systems such as cryopreservation.

6. Production of Valuable Plant Products: Plant cell and tissue cultures can be used to produce **secondary metabolites and other valuable compounds**, including substances used in medicines, cosmetics, food products and industries.

3.2.8 Cryopreservation (Ex-situ).

Cryopreservation is a technique used for the long-term preservation of living cells, tissues and other biological materials at extremely low temperatures. It is an important method of ex-situ conservation, particularly for preserving valuable genetic resources that cannot be maintained easily under normal conditions. The biological materials are commonly stored at about -196°C using liquid nitrogen.

At such extremely low temperatures, cellular metabolism and biochemical reactions are greatly reduced or effectively suspended. This allows biological materials to remain viable for long periods. However, freezing can cause the formation of **ice crystals**, which may damage cell membranes and cellular structures. Therefore, suitable cryoprotective agents and controlled freezing or vitrification techniques are used to reduce cellular injury.

Principle of Cryopreservation: The basic principle of cryopreservation is to **slow or prevent cellular damage during freezing and thawing**. Water present inside cells can form ice crystals during freezing, which may rupture membranes and damage organelles. Cryoprotective agents and appropriate cooling procedures reduce this risk and help maintain cell viability.

Materials Preserved by Cryopreservation

A wide range of biological materials can be cryopreserved, including: Seeds and plant germplasm, Pollen grains, Plant cells and tissues, Embryos, Sperm and oocytes, Cell cultures, microorganisms, and Rare genetic materials.

Steps in Cryopreservation

1. Selection and Collection of Material: The biological material is carefully selected and collected in a healthy and viable condition. Factors such as **age, developmental stage, size,**

moisture content and physiological condition are considered. Damaged or diseased material is generally avoided.

2. Addition of Cryoprotective Agents: Cryoprotective agents (CPAs) are used to protect cells from freezing injury. Examples include **glycerol, dimethyl sulfoxide (DMSO), ethylene glycol, propylene glycol and certain sugars**. These substances help reduce ice-crystal formation and protect cellular membranes during freezing and thawing.

3. Freezing or Vitrification: The prepared material is subjected to a suitable freezing procedure. In **controlled-rate freezing**, the temperature is lowered gradually at a controlled rate. In **vitrification**, the material is rapidly cooled after treatment with suitable cryoprotectants, reducing the formation of damaging ice crystals.

4. Storage in Liquid Nitrogen: After freezing, the biological material is transferred to **liquid-nitrogen storage systems at approximately -196°C** . Under these conditions, metabolic activity is effectively suspended, allowing long-term preservation with minimal biological change.

5. Thawing and Recovery: When the material is required, it is carefully **thawed using an appropriate warming procedure**. Controlled thawing helps minimize damage caused by ice-crystal formation and allows the preserved cells or tissues to regain normal biological activity.

Cryopreservation in Biodiversity Conservation

1. Conservation of Plant Germplasm: Cryopreservation is useful for conserving **valuable plant genetic resources**, particularly species that are difficult to conserve through conventional seed storage. Plant embryos, shoot tips, meristems, pollen and other tissues can be preserved for long periods.

2. Conservation of Vegetatively Propagated Plants: Many plants are propagated vegetatively and may not produce suitable seeds for conventional seed-bank storage. Cryopreservation provides an alternative method for conserving their **genetic resources**, including important fruit, tuber and horticultural crops.

3. Conservation of Rare and Endangered Species: Cryopreservation can help safeguard genetic material from **rare and endangered plant species**. Preserved material can serve as a genetic resource for future propagation, research and, where appropriate, restoration programmes.

4. Pollen Conservation: Pollen can be cryopreserved to maintain **male genetic material** for future breeding and conservation. Stored pollen may be useful when plants have different flowering periods or when fresh pollen is not readily available.

5. Animal Genetic Resources: In animals, cryopreservation is widely used for storing **sperm, oocytes and embryos**. These materials can support breeding programmes and the conservation of genetic diversity in domestic and threatened animal populations.

Advantages of cryopreservation

1. **Long-term preservation** of biological materials.
2. Requires relatively **little space** compared with maintaining living collections.
3. Helps maintain valuable **genetic resources**.
4. Reduces genetic changes associated with prolonged cultivation.
5. Useful for conserving **rare and endangered species**.
6. Protects valuable germplasm for future research and breeding.
7. Provides material for **plant propagation and restoration**.
8. Can preserve material that is difficult to maintain by conventional methods.

Applications of Cryopreservation

Cryopreservation has applications in **biodiversity conservation, plant breeding, agriculture, biotechnology, microbiology, animal breeding and medicine**. Important applications include: Conservation of seed and plant germplasm, Gene-bank collections, Pollen banks, Conservation of endangered plants, Preservation of cell and tissue cultures, Storage of embryos and gametes, Artificial insemination and assisted reproduction, Preservation of valuable microorganisms, Research in genetics and biotechnology, and long-term conservation of biological resources.

Revision Questions

Easy Questions

1. Explain the conservation of genetic, species, and ecosystem diversity.
2. Discuss the principles and importance of in-situ and ex-situ conservation of biodiversity.
3. Describe in-situ conservation methods with special reference to sacred groves, botanical gardens, biosphere reserves, wildlife sanctuaries, and national parks.
4. Explain ex-situ conservation methods, including tissue culture, gene banks, seed banks, pollen banks, and cryopreservation.

5. Discuss the importance of biosphere reserves, wildlife sanctuaries, and national parks in biodiversity conservation.
6. Explain the role of tissue culture, seed banks, gene banks, pollen banks, and cryopreservation in the conservation of plant genetic resources.

Short-Answer Questions

1. What is genetic diversity conservation?
2. What is species diversity conservation?
3. Define ecosystem diversity conservation.
4. What is in-situ conservation?
5. What is ex-situ conservation?
6. What is a sacred grove?
7. What is a biosphere reserve?
8. What is a botanical garden?

UNIT-4

4.1 Role of plants in relation to Human Welfare

Critical to Human Survival, Welfare and a Sustainable Future

Plants are the basis of life on earth and are essential for the survival and welfare of mankind, and the development of a sustainable future. They provide the oxygen we breathe, the food we eat and many of the materials used for clothing, shelter, medicine, fuel and industry. Plants also help in maintaining ecological balance, regulating climate, conserving soil and water, supporting biodiversity and livelihood of millions of people. Actually, life on Earth could not go on without plants. Hence, the slogan “No Plants... No Life” underlines the essential part played by plants in sustaining all life.

1. Basic Needs & Survival

Plants are essential for meeting the basic needs of human beings. Plants take in carbon dioxide and give off oxygen into the air through a process called photosynthesis. This helps keep the right balance of gases in the air for life to exist. Plants are also the primary producers at the bottom of the food chain and provide grains, pulses, fruits, vegetables, nuts, spices and edible oils. These foods provide important nutrients, vitamins, minerals, fibre and bioactive compounds for human health and nutrition. Plants are a source of materials essential to shelter and construction. Plant materials such as timber, bamboo, thatch and cork are often used to make houses, furniture, paper and construction materials. Textiles, clothes, ropes and bags are made from natural fibres such as cotton, flax, jute, hemp and bamboo. Plants also serve as an important source of renewable energy resources. Firewood, charcoal, biofuels, ethanol, biodiesel, and other biomass-based energy resources originate from plants.

2. Health, medicine and well-being

Plants are very important for human health and in the cure of diseases and for the improvement of physical and mental well-being. Plants are the source of many medicines and traditional remedies. Neem, tulsi, turmeric, aloe vera and willow are important medicinal plants that have been used traditionally and scientifically for many health applications. Plants also play a large part in recreation and mental health. Green spaces, gardens, forests, parks and indoor plants can help reduce stress, improve mood, promote relaxation, encourage physical activity and improve overall quality of life. Plants also have important cultural, religious and spiritual value. Flowers, trees, leaves and other plant products are intricately

linked to festivals, rituals, ceremonies, traditions and cultural practices in societies around the world.

3. Environmental and ecological significance

Plants play an important role in maintaining ecological stability and balance. They help moderate the climate by taking carbon into their biomass and soils, and absorbing carbon dioxide from the atmosphere, helping to reduce global warming. Roots of plants hold soil particles, reduces erosion and helps to maintain soil fertility and structure. Plants also drive the water cycle through transpiration, infiltration and water retention and, through vegetation, contribute to groundwater recharge. They help to cycle nutrients, taking them up from the soil and returning them during decomposition, thus helping to maintain soil fertility. Plants are vital for animals, birds, insects, fungi and microorganisms, offering habitat, food, shelter and breeding sites to sustain biodiversity. They also provide nectar and pollen for bees, butterflies and other pollinators, which are crucial to crop production. Plants also clean air and water by filtering pollutants, trapping dust, absorbing harmful gases, and removing excess nutrients and pollutants from aquatic environments.

4. Food Security and Agriculture

“Plants are the basis of agriculture and global food security. The diversity of crops and the genetic resources of wild plants play a major role in the development of improved varieties of crops that can resist changing environmental conditions and the appearance of new agricultural challenges. Plant genetic diversity underpins the development of crops with enhanced pest and disease resistance, drought and heat tolerance, nutritional quality, greater yield and productivity, and increased climate resilience. Hence, conservation and sustainable utilisation of plant genetic resources is necessary for providing adequate food production for present and future generations. Maintaining a diversity of plant resources will allow agriculture to adapt to climate change, environmental stresses, emerging diseases and changing nutritional needs.

5. Economic and Industrial Significance

Plants provide a huge variety of raw materials for industries and make a great contribution to the national and world economies. Paper and pulp, rubber, vegetable oils, resins and gums, dyes and pigments, essential oils, perfumes and cosmetics, beverages, processed foods, timber and furniture, natural fibres, bioplastics and other biodegradable materials are produced from plant resources. Plant-derived resources support the pharmaceutical, textile,

food, cosmetic, construction, biotechnology and manufacturing industries among others. So the sustainable exploitation of plant resources can create economic opportunities, decrease dependency on non-renewable resources and allow for environmentally sound industrial development.

6. Rural Development and Livelihoods

Plants are the direct or indirect source of livelihood and economic security for millions of people around the world. Rural communities have employment and income in agriculture, forestry, horticulture, floriculture, medicinal-plant cultivation, agroforestry, beekeeping and forest-based enterprises. Sustainable management and use of plant resources can create jobs, increase incomes, reduce poverty and encourage rural development. Plant-based businesses can also stimulate entrepreneurship and create opportunities for local communities to add value to agricultural and forest products and strengthen rural economies.

7. Ecosystem Services

Plants provide a range of essential ecosystem services that support nature and human society. Their provisioning services are food, medicine, timber, fibre and fuel. Their regulating services are climate regulation, carbon sequestration, erosion control, air purification and water regulation. Plants also provide supporting services such as nutrient cycling, soil formation, primary production and maintenance of ecological processes. They also offer cultural services that support recreation, education, aesthetic enjoyment, cultural traditions and spiritual values. These ecosystem services provide evidence that plants are biological resources as well as components of healthy and functioning ecosystems.

8. Scientific and Educational Importance

Plants play an essential role in scientific research and education, including botany, genetics, ecology, physiology, biotechnology, agriculture, pharmacology, environmental science, and evolutionary biology. The study of plants has greatly increased our knowledge of basic biological processes such as photosynthesis, respiration, genetics, reproduction, metabolism, adaptation, evolution and plant-environment interactions. Modern plant models, such as *Arabidopsis thaliana*, have been crucial in advancing research in genetics, molecular biology, developmental biology and plant biotechnology. Thus, plant science contributes to the academic knowledge base and to innovations in agriculture, medicine, environmental management, biotechnology and sustainable development.

Plants form the basis of terrestrial ecosystems and human civilisation. They provide food, medicine, clothing, shelter, fuel, industrial raw materials and livelihood opportunities and at the same time they balance the climate, conserve soil and water, support biodiversity and sustain vital ecological processes. The continued survival and good health of humans is directly related to the health and diversity of plant life. So to protect the plants is to protect the ecosystems, human society and future generations.

4.1.1 Importance of forestry

1. Healthy Forests, Healthy Planet, Healthy Tomorrow

Forestry is the science and art of managing, conserving, protecting and regenerating forests and their resources for the benefit of present and future generations. Forests are one of the most important natural ecosystems on the globe. They provide important environmental, economic, social, cultural and health benefits and underpin biodiversity, livelihoods and ecological stability. The saying 'Forests are the lungs of our Earth' stresses the importance of forests for the health of our planet. Forests should therefore be protected, nurtured and sustainably managed for the benefit of current and future generations.

2. Forestry's Environmental Significance

Forestry plays a major role in the protection and preservation of the environment and ecological balance. Forests support biodiversity by providing food, shelter, breeding and living space for a huge variety of plants, animals, birds, insects, fungi and microorganisms. At the same time, forest vegetation removes carbon dioxide from the atmosphere and stores carbon in trees, vegetation and soils to help mitigate climate change. Forests also help maintain soil fertility and prevent soil erosion, because the roots of trees bind soil particles and reduce the loss of topsoil. They control the water cycle through increased infiltration, reduced surface runoff and improved groundwater recharge. "Forest ecosystems can buffer against floods, landslides, and droughts by stabilising soils, controlling water flow, and maintaining vegetation cover. Forests also play a role in regulating local and regional climate conditions by influencing temperature, humidity, rainfall and atmospheric moisture. Therefore, sustainable forestry is essential for environmental protection and ecological resilience.

3. The Financial Significance of Forestry

Forests provide a wide range of products and services, which contribute significantly to economic development. Timber and fuelwood are important forest products for construction,

furniture, energy and many other purposes. Forests are also sources of pulp and paper, bamboo and cane, gums, resins, latex, oils, fruits, nuts, seeds and medicinal plants. Forests are also important sources of honey, fibres and other nontimber forest products. Resources serve a number of industries including paper, furniture, construction, pharmaceutical, food, cosmetic, handicraft and biotechnology. Forestry activities also generate jobs and income, especially for rural and forest dependent communities. Therefore, the sustainable use of forest resources can improve the economy and ensure that forest ecosystems remain productive for future generations.

4. Social and Cultural Values of Forests

Forests are of great social and cultural importance to human societies. They provide vital resources such as food, fuel, timber, bamboo, fibres, medicinal and building resources, especially for rural and forest-dependent communities. Forests and forest-based industries provide livelihoods and employment to millions of people. Forest ecosystems also serve as repositories of traditional knowledge, indigenous practices, cultural heritage and community based resource management systems. Many forests and individual trees are of religious, spiritual and cultural importance and are associated with sacred traditions, festivals, rituals and ceremonies. Forests also offer opportunities for recreation, nature education, ecotourism, trekking, wildlife observation and other nature-related activities. Thus, forests provide more than material well-being they provide cultural identity and social well-being.

5. Forestry: Its Relevance to Health

Forests are important for human health and well-being. Forests make the air cleaner by removing carbon dioxide and some pollutants and other harmful gases from the atmosphere. Forests are important sources of medicinal plants and natural products used in traditional medicine and modern pharmaceutical research. Spending time in forests and other natural environments can promote relaxation, reduce stress, enhance mental health and strengthen people's connection to nature. The vegetation also provides shade which helps cool the local environment and affects humidity which also helps regulate local temperatures and environmental conditions. Healthy forest ecosystems therefore contribute to physical and mental well-being.

Advantages of natural forests

Natural forests are of particular value, as they contain complex ecosystems with a high degree of biological diversity and natural ecological processes. They are home to many

species and are important reservoirs of genetic resources. Natural forests are important in storing carbon and regulating the climate, and in water regulation and soil conservation. Their plants help control floods and mitigate the risks of erosion, landslides and other environmental disasters. The cultural, recreational, aesthetic and spiritual values of natural forests are also enormous. They offer opportunities for learning, research, recreation, tourism and nature enjoyment. At the same time, they support traditional livelihoods of forest dependent communities. Thus, conservation of natural forests is of critical importance for the maintenance of biodiversity, stability of ecosystems and human well-being.

Silviculture industrial

Commercial forestry is the planned growing, tending and cutting of trees for the principal purpose of producing wood and other forest products of economic value. This involves choosing the appropriate species of trees, planting, promoting healthy tree growth, managing pests and diseases, safeguarding forests from fire and other hazards, and harvesting trees in line with planned management practices. Commercial forestry supplies raw materials for construction, furniture, paper, packaging, energy and other industries. If properly planned and regulated, commercial forestry can generate jobs and income and relieve pressure on natural forests. But it should be done responsibly with sufficient regard for biodiversity conservation, soil and water protection, regeneration and long-term forest productivity.

Major uses of wood: Timber is one of the most important products obtained from the forest and it has many uses in human society. It is widely used in the construction of houses, buildings, doors, windows, roofing and structural members. Timber is also widely used for furniture such as tables, chairs, cupboards, beds and other household products. Wood fibres are converted into paper and pulp for books, newspapers, packaging, educational materials, and many industrial uses. Energy can also be obtained from wood and wood waste. Wood is also used for packaging such as crates, boxes, pallets and containers. It has important uses in art and decoration like sculptures, carvings, ornaments, interior designs, etc. Engineered wood products are produced using modern wood-processing technologies. They are used in construction and furniture manufacturing. Forests are sources of many valuable non-timber products apart from timber. These include medicinal plants, bamboo, fruits, honey, gums, resins, fibres and other natural resources.

Ecological forestry: Sustainable forestry is how we manage forest resources in a way that meets the needs of the present without compromising the ability of future generations to own and benefit from forests. It includes afforestation and reforestation to increase and restore forest cover and natural and assisted regeneration of forests. Harvesting should be selective and controlled so as to avoid overexploitation and to maintain the productivity of the forest. Sustainable forestry also means protection of biodiversity and wildlife habitats, prevention of illegal logging and conservation of soil and water resources. Suitable management strategies need to be carefully implemented to control forest fires, pests, invasive species and other threats. Local and indigenous communities are important stakeholders because their knowledge, cooperation and livelihoods are closely linked with forest resources. Forest health, biodiversity, regeneration and resource availability need to be monitored regularly to be able to manage effectively. Using forest products responsibly means that economic benefits can be obtained without causing long-run ecological damage.

Sustainable development and forestry

Forestry provides a link between environmental protection, economic development and social well-being. Healthy forests provide ecosystem services that protect the environment, forest products that support industries and livelihoods, and natural spaces that contribute to human health and cultural well-being. Sustainable management of forests is a balance between conservation and responsible use. It can increase jobs, rural development, climate change mitigation, biodiversity conservation, water security and long-term economic stability. Thus, forestry is an important link between ecological sustainability and human development.

Final thoughts: Forestry is much more than simply growing and harvesting trees. It is a comprehensive strategy to the conservation, management, restoration and sustainable use of one of the most precious natural resources on earth. Forests protect biodiversity, regulate climate and water, conserve soil, provide timber and non-timber products, support industries and livelihoods, improve human health and preserve cultural and spiritual values. Natural forests are important for their biodiversity, ecological complexity and irreplaceable ecosystem services. Well-managed commercial forestry can provide renewable resources and economic benefits.

The future of mankind is bound up with the future of the forests. Hence, afforestation, reforestation, conservation of natural forests, sustainable harvesting, prevention of illegal

logging, community participation and responsible consumption of forest products are important for a resilient and sustainable future.

4.1.2 Utilisation and commercial aspects

Use and trade in forestry: Cutting and felling

Cutting and gathering are important operations in the use of forest resources. Felling is the process of cutting down mature or selected trees with the help of suitable tools and equipment such as axes, saws, and power chain-saws. The time of felling is an important element of forest management. In many areas trees are preferably felled in the dry season, usually after the rainy season, when soil and weather conditions are more favourable for forest operations. Timely, proper treatment can reduce damage to the forest floor, minimise soil compaction and erosion, and make timber easier to handle and transport. Felling must always be undertaken in accordance with scientific forest-management practices, to avoid unnecessary damage to surrounding vegetation and wildlife habitats.

Conversion is the change of felled trees in shape and size to commercially useful forms. After a tree has been felled, branches and undesirable parts are trimmed off and the main stem is cut into logs depending on size, quality, species and end use. The logs produced can be transformed into sawlogs, poles, beams, planks, boards, veneer, pulpwood, or other raw timber. Correct conversion is important to make sure that different portions of the tree are directed toward appropriate end uses and thus the maximisation of the economic value of harvested trees. “This means less waste and better overall use of forest resources.”

Transport: Transportation is the movement of harvested logs and other forest products from the felling site to temporary storage depots, timber yards, sawmills, processing industries or other specified places. Transportation needs to be efficient, because harvesting sites in the forest are often remote and in difficult terrain. Depending on the location and accessibility, timber may be moved by tractors, trucks, trailers, cable systems or other appropriate methods. Proper planning of forest roads and transportation routes can reduce the damage to the remaining vegetation and soil and reduce transportation costs. Prompt transportation also speeds up the processing and storing of timber and other forest products.

Commercial Aspects and Forest Products Principal Forest Products

Timber and wood are some of the most important commercial products from forests. Timber is an extremely common raw material and is used in construction, housing, furniture, doors,

windows, flooring, packaging and other wood-based products. Different species and grades of timber have different physical and mechanical properties which suit them for particular purposes. Wood as fuelwood can also contribute to energy production through the use of biomass and wood residues. Efficient harvesting and processing are important to ensure that timber resources are available for future generations.

Non-Wood Forest Products (NWFPs)

Apart from timber, forests yield many valuable products, which are collectively known as Non-Timber Forest Products (NTFPs). These are bamboo, cane, medicinal plants, fruits, nuts, seeds, flowers, leaves, gums, resins, latex, fibres, dyes, essential oils, edible oils, honey and other natural products. Non-timber forest products (NTFPs) are especially important to rural and forest-dependent communities, providing food, medicine, household materials, supplementary income and employment. The sustainable harvesting and management of NTFPs can provide economic benefits and contribute to the conservation of forest biodiversity and maintenance of ecosystem functions.

Industries Dependent on Forests: Forests are a source of important raw materials to many industries. Wood and other plant fibres are widely used in the paper and pulp industry to make paper. Timber and wood are also made into plywood, veneer, boards, furniture and engineered wood products. Materials from forests such as natural rubber, latex are important raw materials for rubber-based industries. Medicinal plants and compounds obtained from plants are important raw materials for pharmaceutical and herbal-products industries. Other forest resources are used by industries such as food processing, cosmetics, essential oils, paints, adhesives, handicrafts, textiles and biotechnology. Hence, forestry is closely related to manufacturing, processing and value-added industries.

Forestry's Economic Impact: Forestry has an important role to play in economic development at local, regional, national and international levels. Activities based on forests create jobs and income, especially in rural areas and communities that depend on forests. Plantation development, forest management, harvesting, transportation, timber processing, furniture production, paper manufacturing, NTFP collection and forest-based enterprises generate employment. Forest products also contribute to domestic markets and international trade, providing opportunities for export earnings and industrial development. Sustainable forestry can thus be used to contribute to rural development, to the strengthening of local

economies and entrepreneurship, and to the growth of the economy as a whole, without threatening the ecological functions of forests.

4.1.3 Avenue trees

Avenue Trees: Avenue trees are trees planted or naturally occurring along roadsides, streets, highways, avenues and other transit corridors in urban and rural locations. They are significant elements of urban and roadside vegetation, providing shade, improving the visual aspect of highways, reducing air pollution, conserving soil and water, and supporting biodiversity.

Street trees play a vital role in maintaining ecological equilibrium. They provide a range of environmental, social, physiological and economic services. Their leaves trap dust and other particle pollution, while their foliage absorbs carbon dioxide and releases oxygen. Trees cool metropolitan environments, both by giving shade and by transpiration.

The globe is confronting major environmental concerns like global warming, climate change, floods, droughts, air pollution and deterioration of ecosystems. These challenges are largely due to rapid urbanisation, industrialisation, construction activity and rising motor traffic. Urban regions are particularly sensitive to growing amounts of carbon dioxide and other contaminants.

Thus, planting and conservation of suitable avenue trees is an important aspect of urban environmental management and biodiversity conservation. Well-designed avenue planting can improve air quality, reduce heat, offer food and habitat for birds and insects and increase the attractiveness and liveability of towns and highways.

Values of Avenue Trees

1. Leaves can also absorb some gaseous pollutants and collect dust and particulate matter, reducing air pollution.
2. Carbon sequestration is the process of trees pulling carbon dioxide from the atmosphere and storing it in their tree biomass.
3. Photosynthesis produces and releases oxygen into the atmosphere.
4. Tree canopies also provide shade and help reduce the urban heat island effect, which plays a role in temperature regulation.
5. Noise reduction – Dense vegetation can be used to assist in reducing the noise of autos.

6. Roots hold the soil together and reduce soil erosion, therefore conserving the soil.
7. Trees are beneficial to many organisms, as they supply food, shelter, nesting places and habitats, thereby contributing to the conservation of biodiversity.
8. Value from an aesthetic standpoint: blooming and lovely trees add to the visual appeal of highways and public locations.
9. Water conservation: the roots of trees improve the soil structure and water penetration.
10. Green spaces have been related to social and psychological advantages. Green spaces are important for human well-being and provide leisure amenities.

Table 4.1 List of 20 Important Avenue Plants

No.	Scientific Name	Common Name	Important Feature
1	<i>Pongamia pinnata</i>	Indian Beech, Karanja, Honge	Shade, nitrogen fixation, drought tolerance
2	<i>Azadirachta indica</i>	Neem	Pollution tolerance and medicinal value
3	<i>Ficus benghalensis</i>	Banyan	Huge canopy and aerial roots
4	<i>Ficus religiosa</i>	Peepal, Sacred Fig	Large canopy and ecological importance
5	<i>Butea monosperma</i>	Flame of the Forest, Palash	Attractive orange-red flowers
6	<i>Cassia fistula</i>	Golden Shower Tree	Long clusters of yellow flowers
7	<i>Lagerstroemia speciosa</i>	Pride of India, Jarul	Attractive flowers and ornamental value
8	<i>Delonix regia</i>	Gulmohar, Royal Poinciana	Brilliant red-orange flowers
9	<i>Polyalthia longifolia</i>	False Ashoka	Tall, narrow crown; suitable for avenues
10	<i>Samanea saman</i>	Rain Tree	Broad canopy and excellent shade
11	<i>Tamarindus indica</i>	Tamarind	Long-lived tree with dense canopy
12	<i>Albizia lebbek</i>	Siris	Shade and soil-improvement value
13	<i>Millingtonia hortensis</i>	Indian Cork Tree	Fragrant flowers and tall growth
14	<i>Peltophorum pterocarpum</i>	Copperpod	Yellow flowers and attractive foliage
15	<i>Tabebuia rosea</i>	Pink Trumpet Tree	Attractive pink flowers
16	<i>Saraca asoca</i>	Ashoka Tree	Ornamental and cultural importance
17	<i>Terminalia catappa</i>	Indian Almond	Broad leaves and attractive branching
18	<i>Mimusops elengi</i>	Spanish Cherry, Bakul	Fragrant flowers and evergreen foliage
19	<i>Syzygium cumini</i>	Jamun, Java Plum	Evergreen canopy and edible fruits
20	<i>Azadirachta indica</i>	Neem	Hardy, evergreen and pollution-tolerant

1. *Pongamia pinnata* L. Indian Beech / Karanja / Honge

Description: *Pongamia pinnata* is a medium to big, spreading, deciduous to semi-evergreen tree 15–25 m in height. It forms a wide and dense canopy providing great shade. The leaves are glossy green, compound. Young leaves can be reddish or bronze; The tree yields clusters of white, pink, or purple blooms, succeeded by brown, leathery seed pods. It has a robust tap root and well-developed lateral roots and is hence relatively tolerant of drought and harsh growing circumstances. The species is a nitrogen fixing leguminous tree and adds to soil fertility. Also ideal for roadside plantations due to its shade, hardiness and environmental value.

Common/local names: Pongam, Indian Beech, Karanja, Honge

Flowers and Fruit: Flowering mostly in spring with following fruit development.

2. *Azadirachta indica* (Neem Tree)

Description: The fast-growing neem tree is evergreen to semi-evergreen and usually grows to 15–20 m in height. The trunk is short and straight and the head large and spreading. The bark is rough, fissured and greyish brown in colour. The roots comprise a strong taproot and well-developed laterals.

Leaves complex, pinnate, hairy. The blooms are tiny, white and fragrant, borne in branching clusters. The fruit is a smooth oval to elongated drupe, normally yellow when ripe.

Neem is recognized for its medicinal, insecticidal, environmental and cultural significance. It is a resilient tree and can stand quite dry circumstances and is therefore useful as an avenue tree. Local names Neem Vepa Bevu, Flowers and Fruit: Mostly winter to summer.

3. *Ficus benghalensis* Banyan tree

Description: The Banyan is a huge, long-lived tree with a very extensive spreading crown. The most distinctive trait is the formation of aerial roots on the branches. The roots extend downwards, reach the soil and develop into more supporting trunks.

Leaves are big, leathery and widely ovate. The tree produces figs, borne in pairs, that redden as they ripen. The blossoms are in the fig.

The Banyan with its vast canopy and many supporting trunks shelters and feeds many birds, insects and other species. It thus has important biodiversity and ecological values.

Local names: Aladamara, Bargad, Banyan, Nyagrodha, Flowers and fruits: For most of the year.

4. *Ficus religiosa* L. Sacred Fig / Peepal

Ficus religiosa is a huge tree, attaining a height of around 30 m. Its crown is large and its trunk is sturdy. The leaves are unusual, heart-shaped with a long, narrow point that tapers to a point. The figs are small, 1–1.5 cm in diameter, green when young, becoming purple when mature. The Peepal is of cultural and theological significance to Hindu, Buddhist and Jain traditions. Ecologically, it is also essential since its fruits are eaten by birds and other animals.

Local Names: Peepal, Pipal, Bodhi, Ashvattha, Flowers and fruits. Mainly Dec–Mar.

5. *Butea monosperma* (flame of the forest)

Flame of the Forest / Palash

Description: *Butea monosperma* is a medium-sized, dry-season deciduous tree, growing to around 15 m in height. The leaves are trifoliolate compound leaves with 3 large leaflets. This tree is quite lovely in its season of blossoming, when it produces many bright orange-red blossoms, making it look like a tree on fire. The fruit is a flat pod with a solitary seed.

It is an important native tree with great aesthetic, ecological and cultural importance.

Local names: Palash, Dhak, Kinshuk, Moduga/Modugu. Flowers and fruits: Jan–May mainly.

6. Golden Shower Tree (*Cassia fistula*)

Description: The Golden Shower Tree is a medium-sized tree that grows to a height of about 10–20 m. It has pinnate leaves with a number of pairs of leaflets. The most appealing thing about it is its long, drooping clusters of bright yellow blooms, so profuse that the entire tree can look golden when in bloom. The fruit is a large, cylindrical pod, dark brown to black, with many seeds.

Local names: Kakke, Amaltas, Aragvatha, Golden Shower Tree. Flowers and fruits: Mostly Spring to summer.

7. *Lagerstroemia speciosa*: Jarul / Queen's Crape Myrtle / Pride of India

Description: *Lagerstroemia speciosa* is a nice-looking medium-sized deciduous tree. Its leaves are huge, simple, elliptic and may turn crimson before falling. The tree has lovely pink to purple crinkled flowers in big clusters at branch ends. The fruit is a woody capsule that splits open when ripe. It is often grown as an ornamental avenue tree for its lovely flowers and foliage.

Local Names: Jarul, Pride of India, Queen's Crape Myrtle, Flowers and fruit. Mostly Mar–Jun.

8. Royal Poinciana, Gulmohar / Royal Poinciana

Description: Gulmohar is a medium to large ornamental tree with a broad, spreading crown. The leaves are big and bipinnate, giving the tree a delicate, fluffy appearance. It is known for its beautiful, brilliant red to orange-red blossoms. The fruit develops as long, rigid, dark brown pods. It is one of the most popular blooming trees for avenues due of its lovely canopy and bright blossoms.

Flowering: Primarily summer.

9. *Polyalthia longifolia*. Fake Ashoka tree / Mast tree

Description: *Polyalthia longifolia* has a tall, thin pyramidal crown. The leaves are long and slender with wavy borders. Its columnar growth makes it especially ideal for roadsides, institutional campuses, gardens and narrow avenues where horizontal space is limited. Notable characteristics: Evergreens, slender crown, decorative aspect.

10. *Samanea saman* (Rain Tree): Tree of Rain

Description: Rain Tree is a huge, fast-growing tree with a very broad umbrella-shaped crown. In overcast weather and at night, the bipinnate leaves are partially closed. It casts dense shade and hence is often planted in public areas and along roadways. The flowers are tiny, pinkish white and appear in groups. Key features: Large canopy, great shade, carbon sequestration and wildlife habitat.

11. *Tamarindus indica* Tamarindo

Description: The tamarind is a long-lived tree with a large, heavy canopy. The leaves are tiny, pinnately compound. The tree has lovely yellow flowers with red streaks. The fruit is a typical brown curved or straight pod with an appetising acidic pulp. It is extensively grown for the value of its food, and is valuable also as a shade and avenue tree.

12. *Albizia, Lebbeck* Siris / East Indian Walnut

Description: *Albizia lebbeck* is a huge spreading tree with a wide, spreading crown. It bears bipinnate leaves. The flowers are fragrant, pale greenish-white, and are borne in circular clusters. It also provides good shade and helps in improving the fertility of the soil because of its interaction with nitrogen-fixing microbes.

13. Indian Cork Tree *Millingtonia hortensis*

Description: The Indian cork tree is a tall, thin evergreen tree that can grow to enormous heights. It has a narrow crown and is consequently valuable in avenue plantations. Large clusters of white, tubular, fragrant blooms are produced, especially lovely at night.

14. *Peltophorum pterocarpum* D.C. Copperpod / Yellow Flame Tree

Description: None. Copperpod is a medium to large ornamental tree with a spreading crown. It produces yellow flowers in branching clusters and bipinnate leaves. Young leaves and

developing pods may be attractively coppery or scarlet. It is a common roadside and urban landscape plant.

15. Pink Trumpet Tree *Tabebuia rosea*

Description: This decorative tree has an open habit and produces lovely pink trumpet-shaped blooms. In bloom, the tree may be almost totally covered with blossoms. It is particularly prized for ornamental use on avenues, in parks, and in institutional grounds.

16. *Saraca asoca* Ashoka Tree

Description: *Saraca asoca* is a small to medium-sized evergreen tree with dense leaves. The leaves are pinnate. The juvenile leaves may be reddish or copper-coloured. The blooms are borne in dense clusters and mature from yellow-orange to orange-red or reddish. It is treasured for its ornamental, cultural and traditional value.

17. Indian Almond *Terminalia catappa*

Indian Almond is a medium to large tree with a unique tiered branching style. Its broad, big leaves grow in bunches at the tips of branches. The leaves are often coloured before falling, and it makes an attractive avenue tree. The fruit is an edible drupe with a seed similar to an almond.

18. *Mimusops elengi* Bakul / Spanish Cherry

Mimusops elengi is a medium-sized evergreen tree with dense leaves. The little, white, star-shaped, intensely scented blossoms are a key feature. The fruits are tiny, fleshy, yellowish to orange-red when mature. It is good for avenues on account of its dense evergreen canopy and lovely aroma.

19. Jamun / Java Plum (*Syzygium cumini*)

Description: Jamun is a huge evergreen tree with a dense crown. Leaves are tough and lustrous. The flowers are small and light; the fruits are initially green and turn deep purple to black when ripe. Edible fruits are of great importance for wildlife and humans. The tree offers shade and helps sustain urban biodiversity.

20. *Cassia siamea* - Siamese Cassia / Kassod Tree

Description: *Cassia siamea* is a rounded-crowned medium-sized evergreen or semi-evergreen tree. The leaves are pinnate with a number of pairs of leaflets. It bears lovely brilliant yellow

flowers in groups. The tree grows swiftly and is often used as an ornamental and shade tree in tropical and subtropical areas.

4.1.4 Ornamental plants of India.

All plants in the shape of herbs, vines, shrubs or trees that people actively plant as components of gardens, home gardens, room decorations, rituals, components of make up or clothing and as components of flower garlands are called ornamental plants.

There are different sorts of ornamental plants such trees, shrubs, annuals, perennials, ground coverings, grasses and bulbs. These are mentioned briefly below.

A. Trees.

Ornamental Trees are types that have lovely foliage and blossoms solely. Landscapers select Ornamental trees like Amaltas (Xanaru), Gulmohar etc. These plants beautified the landscape with their floral display and, despite their ornamental attributes, generally provide shelter to wildlife.

1. *Lagerstroemia speciosa*: This is a medium sized tree and the blossoms bloom only once in the year at the peak of the summer known as pride of India.
2. *Cassia fistula*: The golden shower flowering tree of Fabaceae is native to the Indian subcontinent and is the state flower of Kerala. Golden shower tree is the most popular ornamental plant in India.
3. *Delonix regia* (Gulmohar): It is most common flowering tree in India were grown as ornamental tree.
4. *Mimosifolia Jacaranda*: It is flowering plant with blue to purple-blue blossom which is grown as ornamental plant in India.
5. *Plumeria alba* Most common evergreen white flowering ornamental tree of Apocynaceae.

B. Shrubs

Shrubbery usually consists of the bushes which are employed as low border plants to all evergreen shrubs Shrubs may be deciduous or evergreen, and flowering or non-flowering. Gardeners select the shrubs for a range of ornamental attributes. Many shrubs have exceptionally attractive leaves, which provides long-lasting beauty to the landscape even after blooms expire.

Some ornamental common shrubs are

(1) *Euphorbia tithymaloides*: This plant loves hot regions and flowers given good sunlight. They are often pink or crimson in hue.

(ii) *Hydrangea macrophylla* Hydrangeas are known for its huge flower group that blooms in blue, purple, pink and white colours. You can use them to designate your garden walks, or lay them as a flower bed, or sometimes use them as a fence.

(iii) *Syringa vulgaris* (Common Lilac) Lilac is an easy plant to grow and resistant to most pests. Flowers tubular and aromatic are pink, purple and white colours

(iv) *Yucca glauca*: A drought tolerant evergreen perennial shrub with unusual sword like blue green leaves that helps to give diversity at any garden. It is a great choice for landscape design.

C. Annual Flowers: Flowering plants that survive for only one growing season and are used as purely ornamental plants in the landscape

(i) *Petunias, marigolds, zinnias, calendulas* and geraniums are bedding plants that provide immediate beauty to the garden, for the duration of a single growing season ornamental annual plants are chosen both as flowering plant varieties and some plants prized for their unique foliage.

Common ornamental annual blooms and beautiful foliage include.

(ii) *Petunia xatkinsiana* The common garden petunia (*Petunia xatkinsiana*) is an ornamental plant often used in summer flower gardens and window boxes for its beautiful trumpet-shaped flowers. Geranium sp. They are one of the most popular of bedding and greenhouse plants.

(iii) *Coleus scutellarioides*: It has lovely foliage, succulent stems and numerous hues, making for year-round interest.

Caladium: Sp. several. Caladium are planted as ornamental plants for its big arrowhead-shaped leaves patterned with different patterns in white pink and scarlet.

D. Perennial flowers: Perennials are plants that grow year after year unless they are killed. Some other go dormant, but their roots continue alive and new plants come in the next season. Perennials: Lilies, Daylilies, Peonies, Hostas and Ferns. The same common ornamental perennial flowers are Lavender, Salvia, Artemisia, Chrysanthemum, Poppy, Daylily etc."

E. Ornamental Grasses – Ornamental grasses are gorgeous display of greenery and easy upkeep. They belong to the Poaceae family. Some common ornamental grasses are

(1) Indian grass (*Sorghastrum nutans*)

(II) Desho grass *Pennisetum pedicellatum*

F. Bulbs. Bulb plants are beautiful in the landscape for a comparatively short time. Spring flowering ornamental bulbs are different to summer flowering bulbs such as Dahlia, lilies or Gladiolas.

4.2 Alcoholic beverages through the ages.

Alcohol, especially ethyl alcohol or ethanol, has been produced for thousands of years by fermenting grain, fruit juice and honey. Alcoholic beverages have been a significant part of human life throughout history and have been related with food, social customs, religious events, medicinal practices, and cultural traditions.

There is evidence of an early alcoholic drink in China dating back to about 7000 BC, and early Egyptian civilisation had fermented liquids. These first drinks were made by watching and taking use of the natural process of fermentation, in which microbes turned the sugars in plants into alcohol.

Alcoholic beverages were also present in the Indus Valley Civilisation, particularly in the Chalcolithic period. Sura was an alcoholic beverage made from fermented or processed rice and other grains that was consumed in ancient India between (about) 3000 and 2000 BC. Different strata of society devoured it, including the Kshatriya warriors, the agricultural populations. Ancient Hindu Ayurvedic literature spoke of both the probable beneficial usage of alcoholic concoctions and the detrimental effects of intoxication and excess alcohol consumption.

The Babylonians had a long history of wine and are said to have worshipped a 'wine goddess' as early as 2700 BC. I also learned about mead, a fermented honey and water drink that was among the first alcohols to become popular in ancient Greece. There are many references to drinking in Greek literature, including several warnings against the dangers of excessive drinking and drunkenness.

Before European contact, several Native American cultures produced alcoholic drinks. In the Andes region of South America, vegetables and fruits such as maize, grapes and apples were

fermented into several types of drinks. Chicha, usually made by fermenting corn and other agricultural products, was an important traditional beverage.

In the sixteenth century, alcohol, frequently referred to as a “spirit,” was increasingly employed for medicinal and other uses. In Britain, gin drinking became particularly popular, and the rapid increase in consumption was accompanied by major societal problems including alcoholism. The period showed that alcohol was not only useful, but that when misused it had serious social implications.

By the eighteenth century, attitudes around alcohol began to change. The temperance movement arose, advocating moderation or abstinence from alcohol. Many groups campaigned against excessive drinking over concerns about drunkenness, health problems, family problems and societal chaos.

Prohibition, banning the manufacture, sale and transportation of intoxicating alcoholic beverages under federal law, was passed by the United States in 1920. The ban helped to fuel a black market for alcohol. Finally, prohibition ended in 1933, and the countrywide prohibition regime was replaced by the legal regulation of alcoholic beverages.

The history of alcoholic drinks shows that fermented beverages have been a part of human society from ancient times. Humans watched the natural fermentation process and eventually devised techniques for making alcoholic beverages for dietary, social, religious, ceremonial, medical, and recreational uses. Alcohol is sometimes described as refreshing or exciting but excessive use can create major adverse effects on the human body and can lead to dependence and alcohol-related disorders. Industrial alcohol and beverage alcohol are often created by microbial fermentation, primarily by yeast, where carbohydrates are converted to ethanol.

Classification of drinks

Alcoholic beverages are generally divided into three major types: fermented beverages, distilled beverages, and compound beverages. Fermented drinks are generated when micro-organisms, mainly yeasts, transform sugar into alcohol. Spirits are made by distilling an alcoholic liquid. Distillation concentrates the ethanol and separates the volatile components. A compound beverage means a beverage made by mixing or combining alcoholic spirits with

additional ingredients, such as herbs, fruits, nuts, spices, sweeteners, or other flavouring materials.

A. Fermented drinks

Alcohol is produced primarily by the fermentation of carbohydrates by microbes such as yeast. In fermented beverages, the two main traditional alcoholic fermented beverages are beer and wine however, additional fermented beverages including cider, palm wine, root beer and mead are also made.

Beer: Beer is an alcoholic beverage prepared from fermented grain, typically barley. Since cereals contain starch and not readily fermentable sugar, extra methods are necessary to transform the starch into sugars. This is mostly done by malting and brewing. Cereal grains are germinated during malting under regulated conditions. This activates enzymes that can break down starch. During brewing, the soluble sugars are dissolved and create a liquid called wort. The yeast then ferments the sugars in the wort into ethanol and carbon dioxide. The beer is subsequently matured, filtered or conditioned and packaged.

Wine: Wine is an alcoholic drink prepared by the fermentation of grapes or other plant ingredients. Most often it is made from grape juice. Grapes have natural sugars that yeast may ferment to produce ethanol and carbon dioxide. The qualities and alcohol content of wine depend on grape variety and production process. During the fermentation process, the sugars contained in the grape juice are converted into alcohol and carbon dioxide. Traditionally, wine with around 6–12% alcohol is made by the fermentation of grape juice containing 12–18% sugar, depending on the conditions of fermentation and other factors.

Other Fermented Drinks

Hard cider is an alcoholic drink made by fermenting fresh apple juice. The natural sugar in the apple juice is turned into alcohol and carbon dioxide by yeasts. The time and conditions of fermentation determine the properties of the final beverage. Palm wine is a traditional fermented beverage made from the sap or juice of young inflorescence or other suitable sections of different kinds of palm. The sap collected contains carbohydrates that can be fermented by microorganisms existing in the environment.

Root beer is traditionally a beverage made by fermentation of an infusion or extract of roots, barks, herbs or other plant material. In classical terms, fermentation may involve the

inclusion of yeast or other microbes. But today, many commercial root beers are made as nonalcoholic carbonated beverages. Mead is an alcoholic beverage made mostly from honey and water. Honey contains sugars which break down into ethanol and carbon dioxide by yeast. Depending on how it is made and fermented, mead can vary a lot in sweetness, flavour and alcohol concentration.

B. Spirits: Distillation is a method of separating the constituents of a liquid mixture based on differences in volatility or boiling properties. In the manufacturing of alcoholic beverages, the fermented alcoholic liquid is heated to transfer the volatile components, including ethanol, into the vapour phase. The vapour is then cooled and condensed to liquid again. This technique can improve the strength of the alcohol and permits the manufacturing of many kinds of distilled alcoholic beverages, generally called spirits.

The important distilled liquors are brandy, whisky, rum, gin and fenny. Whisky is usually made by fermenting cereal grains, followed by distillation and ageing. Rum is made from by-products of sugar cane, like molasses or sugar cane juice. Gin is a distilled alcohol with the flavor of juniper and other botanicals. Brandy is distilled from fermented fruit juice, usually grape wine. Feni is a traditional distilled alcoholic beverage of Goa and may be made from the juice of the cashew apple or coconut palm sap.

C. Mixed drinks: Compound beverages are produced by mixing or blending alcoholic spirits with additional ingredients such as herbs, fruits, nuts, spices, sugars, syrups and flavouring materials. They're designed to provide distinctive flavours and aromas.

A cocktail is a mixed drink that is made by blending one or more alcoholic spirits with additional ingredients, such as fruit juices, syrups, herbs, spices, carbonated beverages, or other mixers. And a great many cocktails are prepared by varying the combination and quantities.

Liqueurs are sweetened and flavoured alcoholic drinks, usually made from a distilled spirit that has had fruits, herbs, spices, nuts, flowers, or other flavourings added to it. They are often known for their unique tastes. They are quite sweet.

1. Alcoholic fermentation.

Alcoholic fermentation is a metabolic process in which yeast transforms fermentable carbohydrates into ethanol and carbon dioxide. This is usually done in the absence of oxygen.

The procedure is notably significant in the production of beer, wine, cider, mead and a number of other fermented alcoholic drinks. The basic reaction of alcoholic fermentation can be expressed as.



More precisely: $C_6H_{12}O_6 \rightarrow 2 C_2H_5OH + 2 CO + \text{heat}$

One of the most significant microorganisms in alcoholic fermentation is the yeast *Saccharomyces cerevisiae*. It is commonly utilised for the manufacturing of beer, wine and other fermented goods. Another major yeast related to beer production is *Saccharomyces Pastorious*, which is specifically connected with lager-type beer fermentation.

4.2.1 Fruits and nuts

Fruit

A fruit is the mature ovary of a flowering plant that typically contains one or more seeds. The fruit is the result of the ovary after flowering, when it is fertilized. Their principal roles are to shield the developing seeds and to aid in their dispersal. Fruits come in a wide variety of shapes, including juicy fruits like apples and berries and dry fruits like beans and grains. They are significant components of the human diet as they often include carbohydrates, dietary fibre, vitamins, minerals, water and other phytochemicals.

1

Dried fruit

A nut is botanically a sort of fruit. It has a hard outer shell (usually not edible) that surrounds one seed. True botanical nuts like acorns and chestnuts don't usually split apart when mature to release their seeds. However, in the culinary world, there are a number of seeds and fruits, such as peanuts, almonds and cashews, that are popularly referred to as nuts due to their similar look, flavour, nutritional value and culinary applications.

Types of Fruit

Fruits can be categorised into numerous groups depending on their botanical structure, origin and mode of development. The main types include **simple fruits, aggregate fruits, numerous fruits and accessory fruits.

1. Simple Fruit

Simple fruits grow from the single ovary of a single flower. They may be fleshy or dried-up. Fleshy fruits have a pericarp that is mushy or juicy at maturity.

A berry has a generally soft and often juicy pericarp, like in tomato and grape. A drupe has a hard stone or pit enclosing the seed, such as peach, cherry, and olive. A pome is a fruit with a core of seeds and an edible fleshy part, as in apple and pear. A pepo is characterized by a thick rind and is typical of fruits such as cucumber and watermelon. A hesperidium is a fruit like an orange or lemon with a leathery exterior and juicy segments.

Dry fruits are those with a dry pericarp at maturity. Dry fruits can be dehiscent or indehiscent. Dehiscent fruit: Fruit that opens at maturity to release seeds. A legume bursts along two seams, as in beans and peas; a capsule opens in several ways, as in poppy. Fruits that are indehiscent do not open at maturity. An achene has one seed adhering loosely to the fruit wall, as in sunflower, while a nut has a hard shell around the seed, as in acorn and chestnut.

2. Fruit Aggregates

Several ovaries of one flower form aggregate fruits. Examples include strawberry, blackberry and raspberry.

3. Fruits - Various.

The fruits formed by the fusion of fruits or ovaries of more than one flower of an inflorescence are said to be multiple fruits. Important examples are pineapple, mulberry, and fig.

4. Supplementary Fruits

Accessory fruits develop with the help of other floral organs than the ovary, especially the receptacle. Examples are apple and strawberry. The fruits are extremely diverse in their texture, taste, structure and culinary usage.

Under-utilized and neglected fruits

Wild edible fruits were a major source of nourishment for humanity before the advent of organised agriculture and civilisation. Today, nonetheless, many tribal and forest-reliant populations get nourishment from wild fruits. Knowledge of identification, collection, preparation and applications of these fruits is traditionally transmitted from one generation to the next.

There are about 30,000 edible plant species known. However, about 7,000 species have been documented to have been used as food over human history. Approximately 150 plant species are economically cultivated, and about 103 plant species provide more than 90% of the

calories for the world. Therefore, hundreds of fruit and plant species are ignored, underutilised or used to a minimal extent, yet they are potentially important from nutritional and economic perspectives.

Small fruit and nut wealth: The earth abounds in tiny fruits and nuts of great diversity. The source material lists around 3,000 tropical species and 1,200 temperate species, for a total of about 4,200 species. For families, genera and species too, a great diversity is documented in the Asia-Pacific area and India.

Fruit nutrition: Fruits usually contain rather minor amounts of protein and fat, except for some fruits such as avocado and olive, which are significant sources of fat. Most fruits contain carbohydrates predominantly as sucrose, glucose and fructose. Unripe fruits often contain starch, which is converted to sugars as the fruit ripens. Pectin is found in the cell walls of fruit, and cellulose is an important part of dietary fibre. Fruits such as pears, apples, oranges and melons are good sources of fibre.

Fruits are good providers of vitamins, especially vitamin C. Good sources include blackcurrants, strawberries, citrus and kiwifruit. Yellow, orange and red fruits are high in beta-carotene, a precursor of vitamin A. Fruits also include nutrients such as iron and calcium, in lesser amounts and bananas are especially known as a source of potassium. Most fruit contains a lot of water.

Nutritional value of fruits

Fruits add to the diversity of the human diet in terms of colour, taste, scent and texture. They are generally low in calories and rich in fibre and can be included in low-calorie, high-fibre diets since they contain a lot of water and fibre and very little fat. Fruits also include antioxidant substances like vitamin C and beta-carotene, which are good for a healthy diet.

Fruits can be eaten raw or cooked and can be added to a wide range of sweet and savoury meals. They are also a handy and nutritious snack that requires minimal preparation beyond washing and, when required, peeling.

Fruit ripening

Fruit ripening begins in the later stages of growth and in many fruits can continue after harvest. Unripe fruits are usually less tasty than ripe fruits. This is due of the significant biochemical and physiological changes that occur during ripening.

During ripening, enzymes change the starch into sugars, sweetening and making the fruit more pleasant. Pectins are converted to soluble pectins leading to softening of the fruit. Ethylene has a significant part in regulating the ripening process in some fruits as bananas. Ripening also brings about changes in the colour, texture, fragrance, flavour and overall quality of the fruit.

Kinds of nuts and examples

Nuts are typically categorised into true botanical nuts and culinary nuts. Botanically, a nut is a special kind of dried indehiscent fruit, although in the culinary sense various seeds and drupes are considered “nuts.”

1. True Nut (botanical): True botanical nuts are hard, indehiscent fruits, meaning that they do not naturally break apart at maturity to release the seed. They typically have one seed in a hard shell.

An acorn is the fruit of the oak tree. It has a hard shell and a cap that looks like a cup. Chestnut grows inside a prickly outer shell known as a burr, which opens when the nut is ripe. Hazelnut is covered by a hard shell and leafy husk. Beechnut A little triangular nut in a burr with soft spines.

2. Culinary Nuts: These comprise seeds and drupes that are treasured for their unique texture, flavour, nutritional characteristics and culinary purposes.

An almond is the edible seed of a peach-related drupe. Walnut is a drupe seed contained in a hard, woody shell. Pecan is a cousin of Walnut. Cashew is a seed from a drupe that grows outside the fleshy cashew apple. Brazil nuts are the seeds of a big capsule fruit. Pine nuts are edible seeds of several pine tree species. Macadamia nuts are the seeds of the macadamia tree; they are hard-shelled and often considered culinary nuts.

3. Nuts considered as legumes: Legume seeds are often thought of as nuts due to their culinary usage. For example, a peanut is technically a legume, yet we often think of it as a nut when cooking. Soy nuts are roasted soybean seeds that are a good nut alternative.

4. Drupaceous Nuts: Some seeds of drupes are also generally regarded as nuts. Coconut: a huge fibrous drupe. The edible seed is generally handled as a nut. Pistachio is a seed of a drupe that has a hard shell that splits open naturally when ripe.

Each nut type has a characteristic nutritional composition and offers vital nutrients namely healthy fats, protein, vitamins and minerals. Compared to the various things we call nuts in culinary usage; true botanical nuts are comparatively rare.

Nutritional value of nuts: Nuts are nutrient-dense foods and good sources of plant protein. They are often rich in fat, including polyunsaturated fatty acids, and hence a good source of energy. They also contain carbs and dietary fibre. They also supply tiny amounts of B-group vitamins and vital minerals like iron and calcium. Their water content is usually very low, about 5%.

Composition of Peanuts (100 g): According to this data, 28.1% of the composition of peanuts by weight is protein, 49% is fat, and 8.6% is carbohydrates/fibre in 100 g of peanuts. B₁, B₂ and niacin vitamin content. Peanuts include nutrients like calcium and iron. Water content is roughly 5%, and energy value is about 586 kilocalories per 100 g.

Nuts – dietetic value: Nuts are a great source of protein, particularly for vegetarians and vegans. They offer texture, flavour and variety to meals and may be used in both sweet and savoury dishes. Nuts are easy to keep, and they are available in a variety of forms: whole, flaked, chopped, and crushed. Nuts are energy-dense and relatively high in calories; thus, their intake may need to be limited in low-calorie diets. Also, some people have nut allergies and must avoid certain nuts that cause allergic responses.

Fruit Crops: Economic Importance: Fruit crops are of high economic and commercial importance as they are consumed fresh and also processed into goods like juices, jams, jellies, dried fruits, drinks, oils and other value-added products. Major fruit crops such as apple, banana, citrus, grapes, pineapple, mango, strawberry, avocado, coconut, olive, papaya, date palm, blueberry and pomegranate assist agricultural output and international trade.

Apple is in high demand as a fresh fruit and in processed products such as juice and cider. Its longish shelf-life makes it amenable to large-scale trading. Major producing countries are China, the United States and India: Banana is an important staple and commercial fruit in tropical and subtropical countries. It is eaten fresh and also processed into value-enhanced and dried items. India, Ecuador, Brazil and the Philippines are among the major producers.

Citrus fruits are high in vitamin C and are consumed fresh or as juice. Citrus oils are widely utilised in cleaning products, fragrances and cosmetics. The main producers are the United

States, Brazil, Spain and China. Grapes are significant for fresh consumption and are processed into wine, juice and raisins. Grapes are of great economic importance in the wine business. Major producing countries are France, Italy, Spain and the United States. Pineapple There is a huge global demand for pineapple, notably for canned and juice products. Major producers include Costa Rica, Thailand and the Philippines.

Mango is one of the most popular fruits in the world, sometimes known as the “king of fruits” and consumed in fresh, dried and processed forms throughout the world. It is also utilised in the preparation of juices, chutneys and other items. Major manufacturing countries are India, Mexico, Thailand and Brazil.

Strawberry is consumed fresh and is used extensively in jams, jellies, desserts and other processed foods. Cultivation also encourages agritourism activities, such as pick-your-own farms. The major producers are the United States, Spain and Mexico.

Avocado is commercially important due to its healthful fats and increasing global demand. It is eaten fresh, as well as in processed items. Major producers are Mexico, the United States, and Peru.

Coconut is a versatile crop of great importance, used for food, coconut oil, coconut water and many other by-products. Coconut products are also utilised in cosmetics, biofuels and construction. The main producing countries are the Philippines, Indonesia and India.

Olive is very essential in the agriculture of the Mediterranean. Olive oil is an agricultural product of high value and great worldwide demand. Spain, Italy and Greece are the main manufacturers.

Papaya is a popular fresh fruit, and it is prized for its vitamins, especially vitamins A and C. It also has traditional medicinal uses. The largest producers are India, Brazil and Mexico.

Date palm - Significant commercially and culturally in dry areas, especially in the Middle East Saudi Arabia, Egypt and Iran are big producers. Blueberry is in significant demand for its nutritional and health reputation and is marketed fresh and frozen. Major producers include the United States, Canada and Poland. ****Pomegranate**** is prized for its antioxidant content and is sold as fresh fruit, juice, and extracts. Major producers are India, Iran, and the United States.

Overall Significance: Fruits and nuts are essential to human nutrition, agriculture, biodiversity and the world economy. Fruits supply water, carbohydrates, fibre, vitamins, minerals and bioactive substances, while nuts are particularly significant sources of protein, healthy fats, minerals and energy. Fruit and nut crops are of nutritional value, but they also give employment, income, processing opportunities and international trade. The conservation and commercial utilisation of neglected and underutilised fruit species can further contribute in food security, nutritional diversity, rural livelihoods and sustainable agriculture.

4.2.3 Wood and its uses

Wood is obtained from trees and is widely used for **construction, furniture, crafts and other useful products**. Different tree species produce different types of wood with specific properties and uses.

Main Types of Wood: Wood is broadly classified into **three main types**.

1. Softwood

- Softwoods are obtained mainly from **coniferous trees (Gymnosperms)**.
- These trees generally have **needle-like leaves and produce cones**.
- Examples: **Pine, Cedar, Fir, Spruce and Redwood**.
- Softwoods are commonly used for **construction, framing, utility structures, decking and outdoor furniture**.
- Cedar and Redwood have good resistance to **rot and insects**.

2. Hardwood

- Hardwoods are mainly obtained from **angiosperms**.
- They generally produce **leaves and seeds**.
- Examples: **Oak, Maple, Cherry, Mahogany and Walnut**.
- They are widely used for **furniture, flooring, cabinets and decorative products**.
- Hardwood does not necessarily mean that the wood is always harder or stronger than softwood.

3. Engineered Wood

- Engineered wood is **manufactured from wood materials** rather than occurring naturally as a solid wood type.
- It may be produced from **wood fibres, particles or veneers**.
- Examples: **Plywood, MDF, OSB and Hardboard**.

- It is widely used in **construction, furniture and interior applications**.
- Engineered wood can be manufactured in specific sizes and forms.

Table-4.1 Important Properties and Major Uses of Different Types of Wood.

Wood	Important Property	Major Uses
Alder	Smooth and easy to work	Furniture, cabinets, frames
Ash	Strong and durable	Furniture and general woodworking
Aspen	Light and moisture-tolerant	Saunas, matchsticks, utensils
Balsa	Very light and buoyant	Models, crafts, rafts
Bamboo	Strong and dense	Furniture, fences, flooring
Basswood	Light and easy to carve	Carving, models, crafts
Beech	Strong and easily steam-bent	Furniture, piano parts
Birch	Strong and economical	Furniture and construction
Redwood	Weather and decay resistant	Decks, outdoor structures
Cedar	Aromatic and rot resistant	Chests, fences, decks
Cherry	Attractive reddish colour	Furniture and decorative work
Douglas Fir	Strong and economical	Construction and utility work
Ebony	Very dense and black	Musical instruments, carving
Mahogany	Premium and attractive	Furniture, guitars, pianos
Maple	Hard and durable	Flooring and furniture
Oak	Strong with attractive grain	Furniture, flooring
Pine	Economical and versatile	Construction and furniture
Plywood	Made from layers of veneer	Construction and furniture
Poplar	Light and easy to work	Furniture parts, models
Rosewood	Exotic and decorative	Musical instruments
Spruce	Light with straight grain	Construction, instruments
Teak	Durable and naturally oily	Boats, outdoor furniture
Walnut	Strong with rich brown colour	Furniture, flooring, instruments
Zebrawood	Distinctive striped grain	Premium furniture, veneers

Special Examples

Bamboo: Bamboo is technically a grass, but its strong and dense stems are widely used like wood. It is used for furniture, fences, decorations, cabinets and flooring.

Balsa: Balsa is a very lightweight hardwood. Because of its low density and buoyancy, it is commonly used for models, crafts, rafts, life-saving devices and surfboards.

Teak: Teak is an exotic hardwood known for its durability and natural oily character. It is widely used for boat building, outdoor furniture and decking.

Oak: Oak is a popular hardwood with an attractive grain. The two major types are **Red Oak** and **White Oak**. It is widely used for **furniture and flooring** and can also be used outdoors after suitable treatment.

Plywood: Plywood is an **engineered wood product** made by joining several layers of wood veneer. It is available in different thicknesses and is widely used in **construction and furniture**.

Revision Questions

Essay Questions

1. Explain the role of plants in human welfare and discuss their importance in daily life.
2. Describe the importance, utilisation, and commercial aspects of forestry.
3. Explain the importance of avenue trees and discuss the major ornamental plants cultivated in India.
4. Trace the history of alcoholic beverages through the ages and describe their major plant sources.
5. Describe the important fruit and nut crops of India and discuss their commercial importance.
6. Explain the properties, types, and major uses of wood in human life and industry.

Short-Answer Questions

1. What is the role of plants in human welfare?
2. Mention two important uses of forest products.
3. What are avenue trees?
4. Give two examples of ornamental plants of India.
5. What are alcoholic beverages?
6. Mention two important fruit crops of India.

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