PLANT ECOLOGY AND BIODIVERSITY

M.Sc. BOTANY

FIRST YEAR, SEMESTER-II, PAPER-I

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M.Sc. BOTANY: Plant Ecology and Biodiversity

First Edition : 2025

No. of Copies :

Published by:

Prof. V. VENKATESWARLU
Director, I/c
Centre for Distance Education,
Acharya Nagarjuna University

Printed at:

FOREWORD

Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining 'A+' grade from the NAAC in the year 2024, Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from over 221 affiliated colleges spread over the two districts of Guntur and Prakasam.

The University has also started the Centre for Distance Education in 2003-04 with the aim of taking higher education to the door step of all the sectors of the society. The centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even to housewives desirous of pursuing higher studies. Acharya Nagarjuna University has started offering B.Sc., B.A., B.B.A., and B.Com courses at the Degree level and M.A., M.Com., M.Sc., M.B.A., and L.L.M., courses at the PG level from the academic year 2003-2004 onwards.

To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise in the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.

It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn be part of country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will go from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic Coordinators, Editors and Lesson-writers of the Centre who have helped in these endeavors.

Prof. K. Gangadhara Rao
M.Tech., Ph.D.,
Vice-Chancellor I/c
Acharya Nagarjuna University.

M.Sc. BOTANY

FIRST YEAR, Semester-II, Paper-I

201BO24- PLANT ECOLOGY AND BIODIVERSITY

SYLLABUS

UNIT-I

Levels of Ecological Organization; Population characteristics and dynamics; Communities characteristics and their analysis; Structure and function of ecosystem; Energy flow in ecosystem; Homeostasis of ecosystem; Biomes and their types.

UNIT-II

Soils: Soil properties and types of soils; Global biogeochemical cycles of Carbon and Sulfur; Dynamic Phytogeography: Basic principles, Age and area theory; Centre of origin; Endemism, Migration and Continental drift.

UNIT-III

Biodiversity: Current concepts, Levels of Biodiversity like Species, Ecosystem and Genetic diversities, IUCN categories of threat; Causes of biodiversity loss; Keystone species; Biodiversity hotspots of India and world; Organizations involved in biodiversity conservation: IUCN, WWF, UNEP and UNESCO.

UNIT-IV

Strategies for *in situ* conservation: Protected areas: Sanctuaries, National Parks, Biosphere Reserves and Mangroves; Strategies for *ex situ* conservation: Botanical Gardens, Seed Banks, Field Banks, Gene Banks, *in vitro* preservation.

UNIT-V

Air pollution and climate change; Sustainable development; Phytoremediation; Application of Remote sensing and Geographical Information System (GIS) in biodiversity studies.

TEXT BOOKS:

1. **Marchese, C.** 2014. *Biodiversity hot spots: A shortcut for more complicated concept.* Global Ecology and conservation. http://dx.doi.org/10.1016/j.gecco.2014.12.008.

2. **Odum, E.P. and Gary W. Barrett.** 2011. *Fundamentals of Ecology* (5th Edition), Saunders ISBN.

3. **Russel, P.J., Wolfe, S. L., Hertz, P. E., Starr, C. and Mc Million B.**, 2008. *Ecology*, Cengage Learning India Pvt. Ltd., New Delhi.

4. **Wilkinson, D.A.** 2007. *Fundamental Processes in Ecology: An Earth system Approach*. Oxford.

5. **Chapman, J.L. and Reiss, M.J.**, 2003. *Ecology: Principles and Applications*, (2nd Edition) Cambridge University Press, UK.

6. **Ambasht, R.S. and Ambasht, N.K.**, 1999. *A Text Book of Ecology*, CBS Publishers and Distributers, New Delhi.

7. **IUCN Red List of threatened species Version 2019.1**.

8. **Chauhan, S.S.** 2014. *Status of Biodiversity in India: Issues and Challenges*. Indian Journal of Plant Sciences 3(1): 35-42.

9. **Wood, A., Pamela, S.E. and Johanna, M.** 2000. *The root causes of biodiversity loss*. United Kingdom: Early-Scan Publications.

10. **Richard B. Primack**, 1993. *Essentials of Conservation Biology* (6th Edition) Oxford University Press.

11. **Heywood, V.M. and Watson, R.T.** 1985. *Global Biodiversity Assessment*, Cambridge University Press, Cambridge.

12. **Swaminathan M.N. & Jam R.S.**, 1982. *Biodiversity: Implications for Global Security*, Macmillan.

Paper Code: 201BO24

CENTRE FOR DISTANCE EDUCATION
ACHARYA NAGARJUNA UNIVERSITY
NAGARJUNA NAGAR , A.P INDIA
M.Sc. DEGREE EXAMINATIONS (2025)
Second Semester

BOTANY

PAPER 2.1: **Plant Ecology & Biodiversity**

Time 3 Hours Max Marks: 70

Answer All Questions
Each Question carries equal marks (5X14=70)

UNIT –I

1. (a) Give a detailed note on Different types of Biomes.

Or

(b) Give a detailed note on Energy flow in ecosystems.

UNIT –II

2. (a) Give a detailed note on different types of soil and their properties.

Or

(b) Give a detailed note on the global biogeochemical cycle of carbon.

UNIT –III

3. (a) Give a detailed note on different levels of biodiversity.

Or

(b) Give a detailed note on different biodiversity hotspots in India

UNIT –IV

4. (a) Give a detailed note on strategies of in situ conservation

Or

(b) Give a detailed note on strategies of ex-situ conservation

UNIT –V

5. (a) Give a detailed note on Air pollution and climate change

Or

(b) Give a detailed note on applications of GIS in biodiversity studies

CONTENTS

LESSON -1

LEVELS OF ORGANIZATION AND POPULATION CHARACTERISTICS AND DYNAMICS

1.0. Objectives:

To understand the interactions between living organisms (biotic factors) and their physical environment (abiotic factors), explaining the distribution

STRUCTURE OF THE LESSON:

1.0 OBJECTIVE

The main objective of ecology is to understand the interactions between living organisms (biotic factors) and their physical environment (abiotic factors), explaining the distribution and abundance of life on Earth, from microbes to ecosystems. Ecologists aim to discover how organisms adapt, how energy flows, and how ecosystems function, providing knowledge for managing resources, conserving biodiversity, and addressing environmental issues like pollution and climate change for sustainable living.

1.1. INTRODUCTION

Ecology constitutes the rigorous scientific examination of the interrelations among living organisms (including flora, fauna, and microorganisms) and their abiotic surroundings (such as atmosphere, hydrosphere, lithosphere, and photonic energy), investigating the manner in which these associations influence the spatial distribution and numerical abundance of biological entities on Earth, ranging from individual adaptations to comprehensive ecosystems such as forests or marine environments. The term was first articulated by Ernst Haeckel, derived from Greek lexemes signifying "habitat" and "inquiry," with ecology endeavoring to elucidate the structural attributes, functional dynamics, and operational processes of the natural world, while addressing pivotal concerns such as resource stewardship, biodiversity conservation, and anthropogenic effects on our planet.

Core Concepts
Interactions: Concentrates on the reciprocal influences among organisms (including predation, competition, and cooperation) and their abiotic milieu (comprising non-biological factors). Levels of Study: Encompasses a spectrum extending from the adaptive behaviors of individual organisms (autecology) to the dynamics of populations, communities, ecosystems, and the overarching biosphere. Biotic & Abiotic Factors: Investigates living (biotic) constituents, such as flora and fauna, alongside non-living (abiotic) elements, including temperature, hydric availability, and edaphic characteristics.

Resource Management: Provides insight into the sustainable utilization of natural resources and ecosystemic services. Human Health: Facilitates the understanding of environmental determinants influencing human health and well-being. Conservation: Supplies empirical data essential for the management of endangered species and the safeguarding of critical habitats. Ernst Haeckel: Originated the concept of "ecology" in 1869, characterizing it as the comprehensive study of organism-environment interactions. Eugene Odum: Recognized as the progenitor of contemporary ecology, he defined the discipline as the analysis of the structural and functional aspects of nature and ecosystems.

1.2. LEVELS OF ECOLOGICAL ORGANIZATION

Ecology is basically concerned with various levels of organization. There are 6 main levels in ecology. All these *levels* help in sustaining and regulating the environment. Levels of organization include an individual (a species/ organism), population, community, ecosystem, biome and biosphere from the smallest to the largest ones.

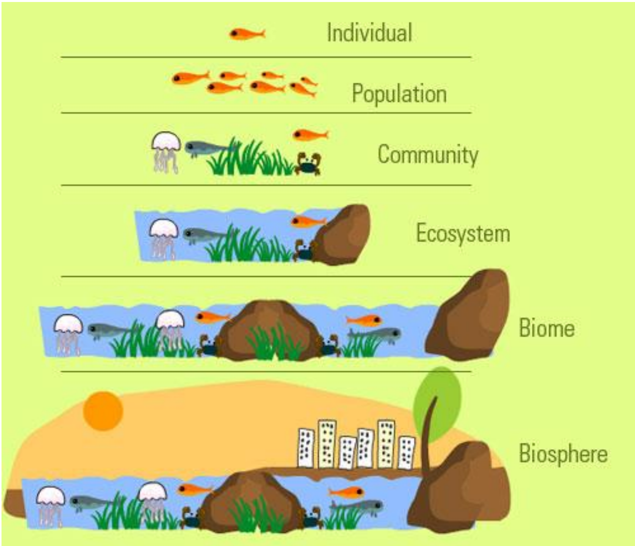


Fig : 1.1 Level 1 - Individual (Species, Organism)

An individual is any living thing or organism. Individuals do not breed with individuals from other groups. Animals, unlike plants, tend to be very definite with this term because some plants can cross-breed with other fertile plants.

Level 2: Population
A group of individuals of a given species that live in a specific geographic area at a given time. The populations include individuals of the same species, but may have different genetic makeup such as colour and size between themselves and other populations.

Level 3: Community
This includes all the populations of in a specific area at a given time. A community includes populations of organisms of different species. These different species coexist in a defined location. A great community usually includes biodiversity.

Level 4: Ecosystem
An ecosystem includes more than a community of living organisms (biotic) interacting with the environment (abiotic). At this level, the biotic factors depend on other abiotic factors such as rocks, water, air and temperature.

Level 5: Biome
A biome is a set of ecosystems sharing similar characteristics with their abiotic factors adapted to their environments. They are very large ecological areas on the earth's surface, with fauna and flora (animals and plants) adapting to their environment. Biomes are often defined by abiotic factors such as climate, relief, geology, soils and vegetation.

Level 6: Biosphere
The biosphere is the sum of all the ecosystems established on planet Earth. It is the living (and decaying) component to the earth system. When we consider all the different biomes, each blending into the other, with all humans living in many different geographic areas, we form a huge community of humans, animals and plants, and micro-organisms in their defined habitats.

1.3. POPULATION CHARACTERISTICS

(Latin Populus = people/ nation/ citizens*)* "A population is a group of individuals of a particular species occupying a particular area at specific time. The seed population of different species present in the soil is referred to as seed bank/ seed pool. All the seeds do not germinate, or all the seedlings do not establish. Some die due to environmental stresses and is called "environmental sieve". It allows only stronger individuals to survive.

POPULATION CHARACTERISTICS

The populations are showing many important properties of groups.
1. Density
2. Dispersion
3. Age structure
4. Natality
5. Mortality
6. Species interaction and competition

An individual cannot have a density; it cannot have birth rate and death rate. The science that deals with group attributes/ population characteristics with respect to rates of birth, death, reproduction etc. is known as **demography.** When ecologically studied in relation to environmental conditions, it is called '**Population ecology/ Democology'**.

1. Size and Density
a. Size: Total size is generally expressed as the number of individuals in a population. The population size (**N**) is determined by the process of birth (**B**), death (**D**), new arrivals from outside due to immigration (**I**) and going out due to emigration (**E)**

Birth (+)

Immigration (+) → Size → Immigration (-)

Death (-)

b. Density: Density refers to the number of individuals / unit area of space.
e.g. estimates of density (no./ unit area) as Trees /ha^{-1} and Phytoplankton million cells / m^3
It is important to distinguish between crude density and specific (ecological) density.

Crude density: The density per unit total space.

Specific (ecological) density: The density per unit of habitat space can be colonized by the population. e.g. In nature, the plants grow clumped into groups. e.g. *Cassia tora* are crowded in shady patches.

The population density varies from place to place with varying time population may remain constant or they may fluctuate. Natality and immigration lead to increase in density and size. Mortality and emigration lead to decrease in density and size. A **rate** is generally obtained by dividing the change by the period. The growth rate of a population is the number of organisms added to the population per time.

Δ (delta) = The change in some thing
N= number of organisms
t = the time
ΔN = Change in number of organisms

$\frac{\Delta N}{\Delta t}$ = The average rate of change in number of organisms.

This is **Growth rate**.

$\frac{\Delta N}{N \Delta t}$ = The average rate of change in number per time per organism.

This is **Specific growth rate.**

2. DISPERSION

It is the spatial pattern of individuals in a population.
There are 3 basic patterns.

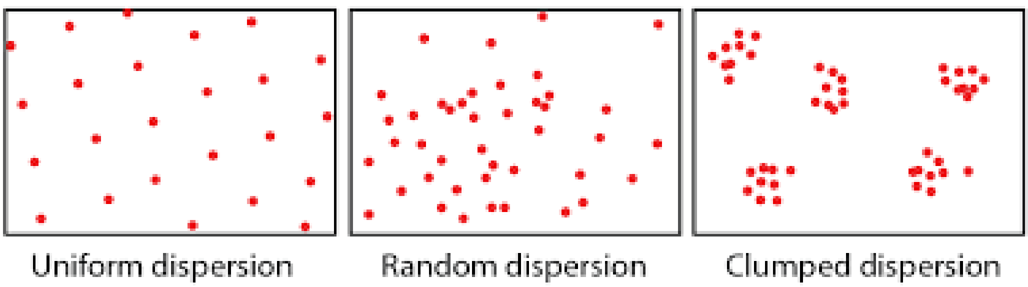


Fig: 1.2 Pattern of individuals in population

a. Regular dispersion (Uniform dispersion): The individuals are spaced at equal distance from one another. This is rare in nature. e.g. Managed Cropland system.

b. Random dispersion: The position of one individual is unrelated to the positions of its neighbor. They are relatively rare.

c. Clumped dispersion: The individuals are aggregated into patches. e.g. families.

3. AGE STRUCTURE

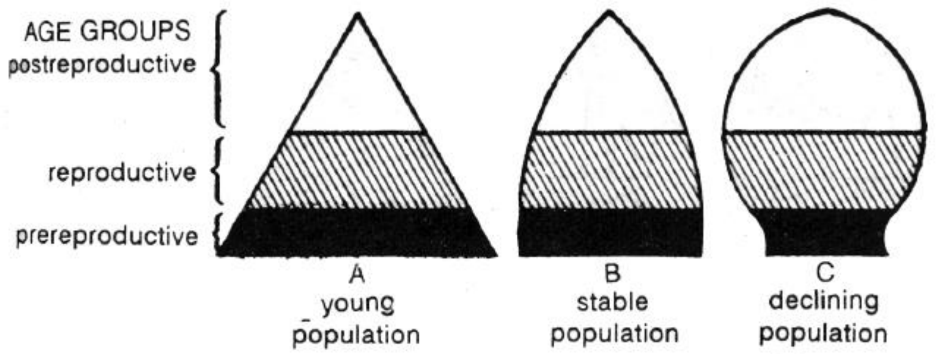
In populations, individuals are of different ages. The proportions of individuals in each group is called "Age structure". e.g. An understory palm tree population has 50% individuals as seedlings (less than 2 years), 19% as saplings (8-year-old), 5% as adults (30 year old) and less than 2% as old. From an ecological viewpoint, there are 3 major ecological age groups.

a. Pre-reproductive age (Juvenile)
b. Reproductive age (Adult)
c. Post-reproductive age (Old age)

Many plants have extremely long pre-reproductive periods.

Age pyramids: The graphic representations of the proportions of different age groups in the population is called "Age pyramid".

There are 3 hypothetical pyramid types.



Hypothetical diagram showing different types of age pyramids.

Fig: 1.3 Age pyramids

A. Pyramid with broad base: High percentages of young individuals.

In rapidly growing young populations, birth rate is high and population growth may be exponential. eg: Yeast.

Each successive generation is more numerous than preceeding one. Hence the pyramid is with broad base.

B. A bell shaped polygon: Moderate proportion of young to old.

Rate of growth becomes slow and stable, i.e. pre-reproductive and reproductive age groups become equal in size and post-reproductive remains the smallest, hence a bell shaped curve.

C. An urn shaped curve: Low percentage of young individuals.

If birth rate is drastically reduced, the pre-reproductive group dwindles in proportion to other groups, and it results in an urn-shaped figure.

4. NATALITY (Birth rate)
This term deals with the production of new individuals of any organism. The new individuals can be formed through birth, hatching (eggs), germination / cell division. Natality rate is the number of offspring produced per female per unit time.
It is of 2 types.

a. **Maximum (Absolute/ Potential/ Physiological) natality:** It is the theoretical maximum production of new individuals under ideal conditions. It is a constant for a given population.
b. **Ecological (realized) natality:** It refers to population increase under actual existing specific conditions.

Three population characteristics determine the rate of natality.
(i) Clutch size: The number of young produced on each occasion.
(ii) The time between one event and the next.
(iii)The age of first reproduction.

Natality rate usually increases during the period of maturity and then falls again as the organism gets older. Natality patterns differ in tropical and temperate populations. Breeding time and clutch size are 2 important criteria. In tropical population, breeding is seasonal. In tropical humid areas, breeding may occur throughout the year. The natality rate is always positive.

5. MORTALITY (Death rate)
It refers to death of individuals in population. The mortality may be:
a. **Minimum (Specific/ Potential) mortality:** Least loss under ideal conditions. All organisms have a physiological longevity representing the age up to which the organism can live under ideal conditions and death occurs purely due to ageing.

b. **Ecological (Realised) mortality:** It is the actual loss of individuals in each ecological condition. Mortality age differs for individuals of different age groups. many seedlings die at the stage of their establishment. But all organisms must die by the process of ageing.
The other way of expressing mortality is “Vital Index”. It is expressed as

$$\text{Vital Index} = \frac{\text{Number of births x 100}}{\text{Number of deaths}}$$

SURVIVAL:
We find 3 main types of **Survivorship curves** based on death and number of survivors at 3 phases.
1. Juvenile/ Dependent phase (Type I)
2. Reproductive / Adult phase (Type II)
3. Post-reproductive/ Old phase (Type III)

I. **Highly convex curve**: In many large size plants of perennial habit, the plants die after reaching post- reproductive phase within a narrow period of old age. Not much mortality at young and adult stage.

II. **Diagonal curve**: Some species show a more even death rate among all individuals of all stages.
III. **Highly concave curve**: In many short-lived weedy annuals, there is a heavy mortality at the young seedling stage.

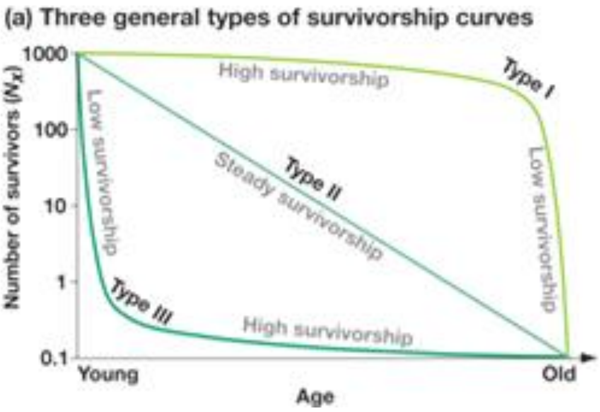


Fig 1.4 survivorship curves

BIOTIC POTENTIAL:
Each population has the inherent power to grow. When the environment is unlimited, the specific growth rate becomes constant and maximum for the existing conditions.
Biotic potential (r) = b – d (b= birth rate: d= death rate), Chapman proposed and defined the term "Biotic Potential" as the inherent property of an organism to reproduce survive.

6. SPECIES INTERACTION AND COMPETITION
The populations have been developed because of their own biotic potentials, carrying capacity and interactions among members of population symbiosis (symbiosis= living together).

Odum divided symbiotic interactions into 2 major groups.
1. Positive (Useful/Helpful/Beneficial)
2. Negative (Harmful)

I. Positive interactions
The populations help one another and either one or both are benefited.
a. Mutualism: Both organisms derive benefit (physiological exchange) e.g. Pollination by animals (bees, moths derive food from the nectar) dispersal of fruits, lichens, N2 fixers, Mycorrhizae
b. b. Commensalism: Only one is benefited and neither is harmless (No physiological exchange). e. g . Lianes- *Bauhinia, Tinospora* Epiphytes- orchids
c. Protocooperation: Both populations are benefited but the association is not obligatory, (not essential for the survival of either population).

II. Negative interactions
One or both the species are harmed. Some prefer to call antagonism.
a. Exploitation: One species harms the other by making its use for support, shelter or food.
i. Shelter: One species of ant uses another species as slave labour.
ii. Food: Parasitism: A parasite is the organism living on or in the body.

Predation: A predator is free living which kills another. e.g. Grazing, food carnivorous plants.

b. Antibiosis: It refers to the complete/ partial inhibition or death of one organism by another through the production of some substance. e.g. bacteria, actinomycetes and fungi produce several antimicrobial substances.
c. Competition: The organisms compete for light, nutrients, water, space etc. This competition may be intraspecific or interspecific.

1.4 POPULATION DYNAMICS

Population dynamics deals with the study of the size and age composition of populations as dynamic systems driven by biological and environmental processes. Populations are never static and they are changing with time and space. These changes in their size over time show varied trends. When environment is unlimited (adequate food and space is available), the growth rate is maximum and constant under a set of environmental conditions. If the environment is limited, the growth rate is typically sigmoid (S- shaped).
To explain these growth patterns, there are two types of growth models.

a. J- shaped / Exponential / Geometric Growth Model
b. S- shaped / Sigmoid/ Logistic Growth Model

a. J- shaped / Exponential / Geometric Growth Model/ J- curve
Population increases geometrically or exponentially (becoming more) until there is resource limitation. Then, growth declines rapidly until favourable period is restored. Mathematically, this growth model can be expressed as rate of population increase with time.

$$dN/dt = rN$$

Where,
N = population size
t =time
r= intrinsic rate of natural increase
The value of **r** is the maximum when resources are unlimited. since, the curve drawn between population size (Y-axis) and time (X-axis) is J- shaped.

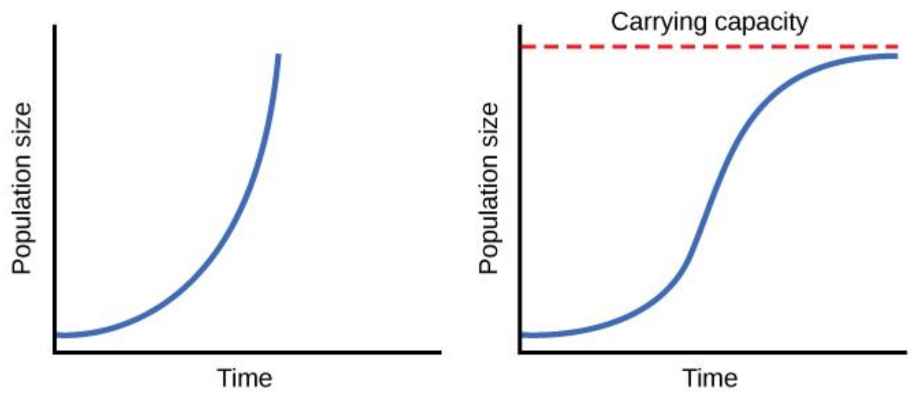


Fig 1.5 J- shaped curve & S- shaped curve

b. S- shaped / Sigmoid/ Logistic Growth Model
When the resources are limited, the growth attains a sigmoid/ S- shaped curve showing minimum death during early stages. the population increases in size until it reaches an upper limit. This upper limit is called Carrying capacity (K). This may be defined as capacity of an

ecosystem to support maximum number of individuals of a species. So, sigmoid growth is density dependent and can be expressed by the following equation.

$$dN/dt = rN\,(K-N/K)$$

Where,

N = population size

t =time

r= intrinsic rate of natural increase and

K= carrying capacity

When **N** equals **K**, the growth rate becomes **0** and the population reaches equilibrium.

ALLEE`S PRINCIPLE

W. C. Allee (**Warder Clyde Allee**) gave a concept called Allee`s Principle. It is a relationship between population density and survival. This principle states that overcrowding (very high density) and undercrowding (very low density) are detrimental (harmful) to the population survival, growth and development. An intermediate optimal population density flourishes the population / individuals well. Several plant species occur in groups, which may be in response to habitat preference or suitable climatic or environmental conditions or due to reproductive strategies. Within a group, the survival rates of species increase in response to the adverse environmental conditions.

For example, *Polygonum pleibium* prefers to grow in clayey soil and often groups or patches. Some species form groups or patches due to vegetative reproduction or due to lack of effective seed dispersal mechanism. Survival chances and fitness of such species is best at moderate populations.

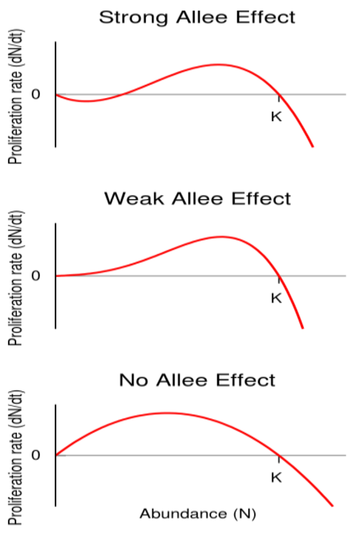


Fig: 1.6 Allee effect

1.5 SUMMARY

Population characteristics, encompassing aspects such as size, density, age structure, sex ratio, and distribution, serve to delineate a specific assemblage, whereas population dynamics examines the temporal transformations of these characteristics due to births, deaths, immigration, and emigration, with these changes being modulated by various factors such as resource availability, resulting in growth trajectories characterized by either exponential or logistic growth, constrained by the carrying capacity (K) of the environment.

Key Characteristics
Population Size: The aggregate number of individuals within a defined area. Density: The quantification of individuals per unit area or volume (e.g., per hectare). Age Structure: The distribution of individuals across pre-reproductive, reproductive, and post-reproductive cohorts, which significantly influences growth potential. Sex Ratio: The relative proportion of males to females, which has a consequential effect on reproductive output. Dispersion/Distribution: The spatial arrangement of individuals, which can be classified as clumped, uniform, or random.

Key Dynamics (Factors Affecting Change)
Natality (Birth Rate): The rate at which new individuals are added to the population. Mortality (Death Rate): The rate at which individuals are removed from the population. Immigration: The influx of individuals into a population, resulting in an increase in size. Emigration: The outflow of individuals from a population, leading to a decrease in size.
Growth Patterns & Concepts

Exponential Growth (J-curve): A phase of rapid population increase occurring under conditions of unlimited resources, which is seldom sustainable over the long term. Logistic Growth (S-curve): A phase where growth decelerates as the population nears the environmental carrying capacity. Carrying Capacity (K): The maximum sustainable population size that an environment can support. Limiting Factors: Elements such as resource availability, disease prevalence, predation pressure, and spatial constraints that impose limits on population growth.

1.6 SELF ASSESSMENT

A self-assessment would require the user to define the terms, explain the relationships between them, and potentially apply them to hypothetical scenarios or real-world case studies.

1.7. SUGGESTED READING

- Fundamentals of Ecology by Eugene P. Odum and Gary W. Barrett (Fifth Edition, 2012, Cengage Learning).
- Elements of Ecology by Thomas M. Smith and Robert L. Smith (Eighth Edition, 2012)..
- Ecology, Environmental Science and Conservation by J.S. Singh, S.P. Singh, and S.R. Gupta (2015, S. Chand Publishing).
- Fundamentals of Ecosystem Science by Kathleen C. Weathers and a group of experts (Second Edition, 2021, Elsevier).

Dr C.V.S.Bhaskar

LESSON- 2

COMMUNITY CHARACTERISTICS AND ANALYSIS OF COMMUNITIES

2.0 OBJECTIVES

The primary objective of studying community characteristics and analysis in living systems (ecology) is to understand the interactions, structure, diversity, and dynamics of species assemblages to better manage and conserve the health of ecosystems.

STRUCTURE OF THE LESSON:

2.1 INTRODUCTION

A community is a complex assemblage of populations (ecological) or people (social) in a particular area, sharing characteristics and interactions, forming a unique, interdependent system that can be studied through its defining features and quantitative/qualitative measures to understand its nature, health, and evolution. Community characteristics and analysis involve understanding groups (people or species) in shared spaces, focusing on structure (diversity, dominance, growth forms), dynamics (succession, resilience, periodicity, interactions like mutualism), and quantitative (e.g., frequency, density) measures to study their unique nature, stability, and how they change over time. Community analysis helps manage and understand ecosystems or societies better, revealing interdependence and roles, from trophic levels in ecology.

2.2. COMMUNITY CHARACTERISTICS

In nature, different kinds of organisms grow in association with each other. A group of several species living together with adjustment. **Community (Biocoenosis/ Biotic**

community) is a group or association of populations of two or more different species occupying the same geographical area at the same time. In a community, organisms share the same habitat growing in a uniform environment. e.g. A forest, grassland, a desert or a pond are natural communities.
Synecology (Community ecology) deals with the study of the ecology of plant communities. It involves the study of structure, nature, organization and development of communities.

Like population, a community too has its own characteristics which are not shown by its individual component species.

The important characteristics of a community include:
1. Species diversity
2. Dominance
3. Structure (Distribution patterns)
4. Trophic structure
5. Community dynamics (Ecological succession)

2.2.1. Species diversity

Each community is made up of different species of plants, animals and microbes that differ taxonomically from each other. Of the total number of species in the whole community, a relatively small percentage of species are usually abundant, and a large percent are rare. These large numbers of rare species determine the diversity of the species.

The ratios between the number of species and importance values (Numbers, biomass, Productivity etc.) of individuals are called **species diversity indices**. Species diversity is low in physically controlled ecosystem (cropland) and it is high in biologically controlled ecosystem.

There are several important ecological principles associated with diversity concepts. Higher diversity means longer food chains and more cases of symbiosis and greater possibilities for negative feedback control which reduces oscillations. Species diversity is very much influenced by the functional relationships between trophic levels.

2.2.2. dominance

Not all organisms in the community are equally important in determining the nature and function of the whole community. Out of hundreds or thousands of kinds of organisms present in a community, only a few species generally exert the major controlling influence by means of their numbers, size, production etc.

Communities have producers, macro consumers and micro consumers (decomposers). Within these species which largely control the energy flow and strongly affect the environment of all other species are called dominants/ ecological dominants.

e.g. In a biotic community in a pasture there is observed, blue grass, white clover, cattle, turkeys, horses and chickens. This taxonomic listing does not give any picture of the pasture. If we add some quantitative parameter, say blue grass is present in 48 acres, white clover in 2 acres, cattle 60 no’s, turkeys 2 no’s, horses 48 no’s and chickens 6 no’s have validity.

From this example, blue grass is dominant among the producers, cattle among the consumers. Generally, dominants have maximum productivity. In land communities, flowering plants are major dominants. In a forest community, there may be one or two species that are dominant. The dominance in all ecological groups is very clear cut in deserts, tundra etc.

2.2.3 Structure (Distribution patterns)

A community is described in terms of major growth forms such as trees, shrubs, herbs, mosses etc. In each form of growth as in trees, there may be different kinds of plants such as broad-leaved trees, evergreen trees. These growth forms determine the structural pattern of a community. The structure that results from the distribution of organisms and their interaction with their environment has been called **pattern**. The communities exhibit a structure / a recognizable pattern in the spatial arrangement of their members. So, structurally, a community may be divided horizontally into sub-communities which are homogenous life forms.

In a grassland community,

1. The subterranean floor contains basal portions of the vegetation such as rhizomes of grass covered by litter and debris of plants and animals.
2. Herbaceous substratum consists of upper parts of the grasses and herbs with fauna.

Stratification in a forest community is most complicated. In this stratification as many as 5 vertical subdivisions may be recognized.

1. Subterranean subdivision
2. Forest floor
3. Herbaceous vegetation
4. Shrubs
5. Trees

2.2.4. Trophic structure

Nutritionally, each community exists as a self-sufficient, perfectly balanced assemblage of organisms. Each community has a trophic structure that determines the flow of energy and material from plants to herbivores to carnivores. Trophic structure is defined as the partitioning of biomass between trophic levels (subsets of an ecological community that gather energy and nutrients in similar ways).

There are 3 broad trophic levels in a community. They are:

1. Producers
2. Consumers
3. Decomposers

The food produced by green plants is consumed directly or indirectly by all kinds of animals (consumers). The dead bodies and excreta of both producers and consumers are decomposed by microbes (decomposers) into simple substances.

2.2.5. Community dynamics

(Ecological succession) – A directional change.

Community dynamics are the changes in community structure and composition over time. Each community has its own developmental history. It has its origin and developmental stages. This directional change (ecological succession) has also been referred to as ecosystem development. A series of progressive changes in the species that make up a community over time is called Ecological succession. Succession often involves a progression from communities with lower species diversity (less stable) to communities with higher species diversity (more stable).

2.3. ANALYSIS OF COMMUNITIES

In nature, different kinds of organisms grow in association with each other. A group of several species living together with adjustment. The assemblage of interacting organisms of different species growing in a particular area. In a community, organisms share the same habitat in an uniform environment.

Analysis of communities offers a rationale and guidance for selecting appropriate and effective analytical methods in community ecology. The community structure, composition and other characteristics can be described by visual observations without measurement. This is a qualitative approach. In quantitative approach, measurements are actually made.

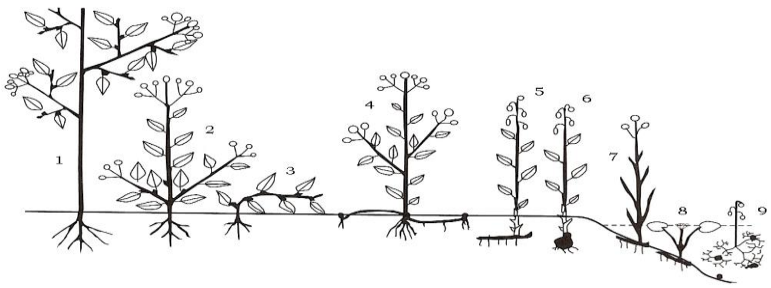
There are so many methods for the analysis of communities.
1. Floristic methods
2. Physiognomic methods
3. Phytosociological methods

1. floristic methods
They are descriptive and now not in common use. This method involves the listing of species. The vegetation is described in terms of flora.

2. physiognomic methods
Physiognomy is the general appearance of vegetation like grassland, desert etc. Classifications are made on the basis of habitat, growth forms etc. The species of communities are studied in terms of their life-forms, general stature, spreads etc. (Growth forms – herbs, shrubs, trees etc.)

Raunkiar`s Life Form method is an important and very common physiognomic method.
This method involves 2 parts.
a. Record of different life forms
b. Biological (Phyto-climatic) spectrum

a. Record of different life forms:
In this, different species are recorded. Then, they are distributed among the different life forms based on position of renewal bud/ organs in the species. Raunkiar classified the communities into 5 life forms based on general appearance and growth. This method is the most widely used throughout the world.



i. Phanerophytes: In trees, shrubs and climbers, , the growing buds are located on the shoot much above the ground surface. These buds are least protected. They are abundant in tropics. They are further classified into 4 sub-life forms depending on the height of the mature plants.

1. **Megaphanerophytes:** Growing over 30 meters.
2. **Mesophanerophytes:** Growing to 8 – 30 meters.
3. **Microphanerophytes:** Growing to 2-8 meters.
4. **Nanophanerophytes:** Smaller than 2 meters.

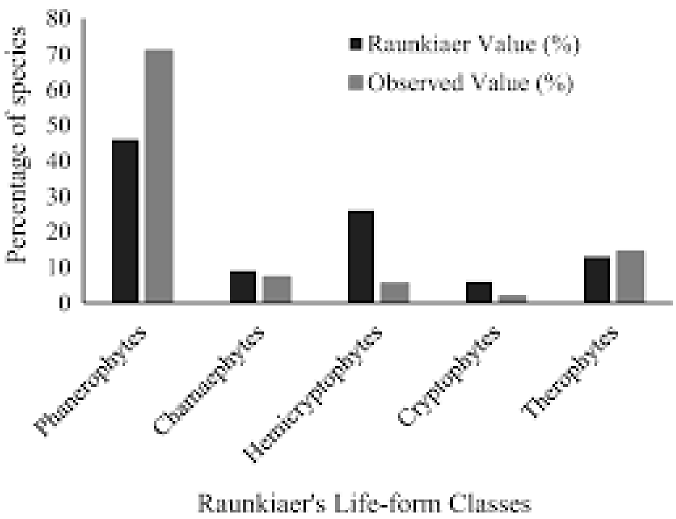
ii. Chamaephytes: They are commonly found in cold regions. The buds are located very close to the ground. maximum height is 25 cm. e.g., *Trifolium*.

iii. Hemicryptophytes: They are also predominant in cold climate. The perennating buds are formed just under the surface soil. e.g., biennial and perennial herbs.

iv. Cryptophytes (Geophytes): The buds are buried in the soil as the bulbs and rhizomes withstand adverse conditions.

v. Therophytes: They survive the adverse season in the form of seeds. They produce flowers and fruits in favourable season. e.g., annuals

b. Biological (Phyto-climatic) spectrum: It represents the per cent (%) distribution of species
among life forms.



3. PHYTOSOCIOLOGICAL METHODS

The earlier floristic and physiognomic method provide information on structure, composition, diversity, growth etc. The phytosociological methods have been developed on some of the characters. For the above methods, various sampling units (a single section selected for the whole) are used. These sampling units include area, line and point. In area and line there is a definite area (suitable size). In thick forests, it is difficult to have a definite area. So, point is taken as a sampling unit.

Based on natural sampling units, there are **3** popular methods for the study of communities. These include:

1. Quadrat method
2. Transect method
3. Point method

1. **Quadrat method**: The sampling unit for this method is a definite area. For this, a quadrat of definite size is used. In shape, the quadrat may be a square, rectangle or a circle. Depending upon the type of vegetation and purpose of study, a quadrat may be

- List quadrat: The species are simply listed.
- List count quadrat: Numerical counts of individuals are made.
- Chart quadrat: Scale growth and distribution of plants in space are recorded on graph
- paper.
- Experimental permanent quadrat: Studying vegetational changes over a period of time during plant successions.

2. **Transect method**: The sampling unit is a line. The sampling strip extends across a strand/ several strands of vegetation. A transect may be

- Line transect: A thin line is used for grassland
- Belt transect: A belt of suitable width used for forests.

3. **Point method**: In this method, a point is a sampling unit. In a Point frame, several movable pins are inserted in a wooden or iron frame. The pins are laid down at random in the study area. Plants hit by pins are recorded used for frequency.

2.4 ANALYTICAL CHARACTERS

The analytical characters are of two types.

1. Quantitative characters
2. Qualitative characters

1. Quantitative characters: For these, measurements are made.

a. Frequency (%): Number of sampling units in which a particular species occurs.

$$\text{Frequency (\%)} = \frac{\text{Number of sampling units of occurrence}}{\text{Total number of quadrats studied}} \times 100$$

After determining the frequency of each species, various species are distributed among Raunkiar`s frequency classes.
Grouping of species into
Raunkiaer’s five Frequency classes

Frequency (%)	Frequency class
1 – 20	A
21 – 40	B
41 – 60	C
60 – 80	D
81 – 100	E

b. Density: It is the numerical strength of a species in any unit area. It gives an idea of degree of composition.

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}}$$

c. Abundance: Number of individuals of any species per sampling unit of occurrence. It gives a little idea of the distribution.

$$\text{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Number of sampling units of occurrence}}$$

d. Cover and basal area: Cover is the area occupied by a plant. It may be herbage cover or basal area. Basal area is the ground penetrated by the stems and is readily observed when the leaves and stems are clipped at the ground area. It gives the **dominance.**

2. Qualitative characters:

a. Physiognomy: Biological spectrum.
b. Phenology and Phenograms: Phenology is the systematic study of seasonal/ periodic changes in relation to their Climate. It is the calendar of events in life history. Phenograms are the events in the life cycle.
c. Stratification (Layering): The study of vertical layers.
d. Sociability: It is the proximity of the plants to one another.
    S1 - Plants grow separately.
    S2 - A group of 4-6 plants at one place.
    S3 - Many smaller scattered groups at one place.
    S4 - Several bigger groups at one place.
    S5 - A large group occupying larger area.

2.5. SUMMARY

The key characteristics of a biotic community and introducing three methods for community analysis: Floristic, Physiognomic, and Phytosociological.

1. Floristic Methods
    - Focus: The textual description characterizes this method as purely descriptive and less commonly used today.
    - Description: The primary activity is listing all the species present within the vegetation, focusing entirely on the "flora" or taxonomic identity of the organisms. It answers the question, "What species are here?"

2. Physiognomic Methods
    - Focus: Classifying communities based on their general appearance (physiognomy), habitat, and dominant growth forms (e.g., grassland, forest, desert).
    - Description: This approach analyzes the *structure* of the community rather than the exact name of the species. It studies species in terms of life-forms, general stature, and spread (herbs, shrubs, trees). A key technique mentioned is Raunkiær's Life Form method, which classifies plants based on the position of their renewal buds to infer adaptation to the climate (e.g., Phanerophytes, Chamaephytes).

3. Phytosociological Methods

- Focus: While only briefly mentioned in the "Analysis of Communities" section of your text, this method is implied to be a more rigorous, often quantitative, approach to community description.
- Description: Unlike simple visual observation (qualitative approach), phytosociological methods involve actual measurements to describe community structure, composition, and other characteristics, using the quantitative data mentioned earlier in your text (dominance values, density, frequency, etc.) to define and classify communities scientifically.

2.6 SELF ASSESSMENT

1. Emphasizes taxonomic identity; involves creating a detailed species list.
2. Classifies by general appearance, structure, and dominant growth forms.
3. Using "Raunkiar's Life Form method" and "growth forms (herbs, shrubs, trees) classify the plants.
4. Described as rigorous and quantitative, involving measurements.

2.7. SUGGESTED READING

- Fundamentals of Ecology by Eugene P. Odum and Gary W. Barrett (Fifth Edition, 2012, Cengage Learning).
- Elements of Ecology by Thomas M. Smith and Robert L. Smith (Eighth Edition, 2012)..
- Ecology, Environmental Science and Conservation by J.S. Singh, S.P. Singh, and S.R. Gupta (2015, S. Chand Publishing).
- Fundamentals of Ecosystem Science by Kathleen C. Weathers and a group of experts (Second Edition, 2021, Elsevier).

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LESSON -3

STRUCTURE OF ECOSYSTEM AND ENERGY FLOW IN ECOSYSTEM

3.0 Objective

- The main objective of this lesson is to understand and maintaining Ecological balance supporting life through unidirectional energy transfer.
- To understand about the Nutrient cycling and recycling by the use of biotic and abiotic components

STRUCTURE OF THE LESSON:

3.1 INTRODUCTION TO ECOSYSTEM

3.2 STRUCTURE OF ECOSYSTEM

3.3 ENERGY FLOW IN ECOSYSTEM

3.3.1 energy flow (calorific flow)

3.3.2 energy flow models

3.4 ECOLOGICAL EFFICIENCY

3.5 SUMMARY

3.6 SELF-ASSESSMENT

3.7. SUGGESTED READING

3.1. INTRODUCTION TO ECOSYSTEM

Ecosystem is the basic functional unit in ecology, since it includes both living and environment. **A. G. Tansley** (1935) first proposed the term "Ecosystem". The ecosystem is the system resulting from the integration of all the living and non-living factors of the environment.

An ecosystem can be defined as a structure and functional unit of biosphere consisting of living and non-living environment both interacting and exchanging materials between them.

3.2. STRUCTURE OF ECOSYSTEM

Two major aspects of ecosystem are structure and function. The structure includes:

1. The composition of biological community includes species, numbers, biomass, life history and distribution in space etc.
2. The quantity and distribution of the non-living materials such as nutrients, water etc.
3. The range and gradient of climatic conditions of existence such as temperature, light etc.

All ecosystems consist of 2 major components.

1. Biotic component (Living)

2. Abiotic (Non-living) component

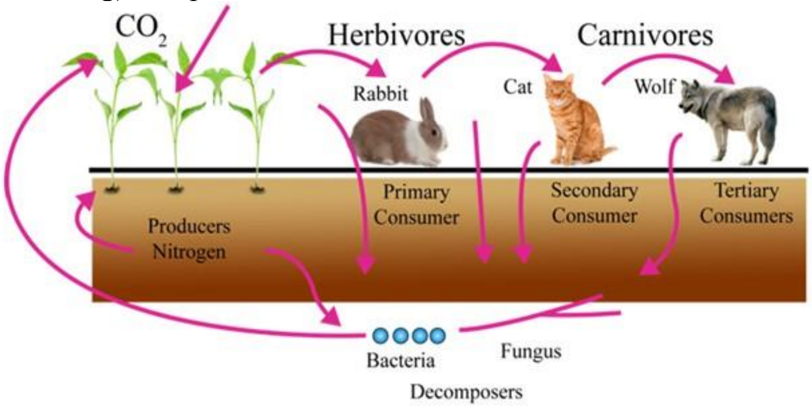


Fig: 3.1 Diagrammatic presentation of ecosystem

BIOTIC COMPONENTS (Living factors)

These comprise all the living organisms. They give shape to the ecosystem. These components are usually divided into 2 groups based on the nourishment (trophic) standpoint.

1. Autotrophs: The organisms that produce their own food from an energy source.
2. Heterotrophs: The 0rganisms that consume other organisms as a food source.

AUTOTROPHS (Producers/ Converters/ Transducers): They include green plants and certain photo synthetic and chemosynthetic bacteria.
The autotrophs are of 2 types.

a. **Photoautotrophs**: They include green plants, algae and Cyanobacteria.
They synthesize their food by utilizing energy from sunlight by the process of photosynthesis.

Light ↘
Complex organic **Photoautotrophs** ⟶ compounds
↗
Simple inorganic compounds

b. Chemoautotrophs: They include methanogenic bacteria, sulfur oxidizing bacteria, sulfur reducing bacteria, nitrifiers etc. They derive energy from chemical reactions and synthesize their own food by the process of chemosynthesis.

Reduced inorganic compounds ↘
Chemoautotrophs ↘
Complex organic compounds

The autotrophs can manufacture their organic compounds from inorganic substances obtained from environment. They can convert the light energy from Sun into potential chemical energy in the form of organic compounds needed for plant growth and development by photosynthesis. O_2 is produced as a by –product of this process, needed by all living organisms for respiration. Hence, the autotrophs are also called Producers (as they produce food), Converters/ Transducers (as they covert/ transduce Sun energy into chemical energy). About 99% of living organisms on earth are made of producers.

HETEROTROPHS (Other nourishing/ Consumers)
They cannot make their organic compounds from inorganic substances. They depend directly or indirectly upon the autotrophs for their food. They are also called Consumers because they consume the materials built up by producers.
These may be subdivided into 2 groups.

1. Macroconsumers
2. Microconsumers

1. Macroconsumers
They are animals which ingest other organisms and obtain their organic matter.
These are of 3 types.

a. Herbivores (Primary consumers): They are plant eaters. They directly feed on plant matter. e.g. rabbits, Deers, cattle, Goats, Horses etc. The herbivores may be
Granivores- seed eaters
Frugivores- feed on fruits
Bark feeders- feeding on bark
Root feeders- feeding on roots
Sucking animals
Grasshoppers- chew of stems and leaves
Goat, cow, deer, elephant – eat up an entire green part
Man- eats plant products.

b. Carnivores (Secondary consumers or Tertiary consumers or Top carnivores))
They are meat eaters. They feed on flesh of other animals. They may be
Secondary consumers (Primary carnivores): They feed on herbivores. e.g. Frog
Tertiary consumers (Secondary carnivores): They feed on secondary consumers. e.g. Snake
Top carnivores: They are not further preyed upon other animals.

c. Omnivores:
They eat plant and animal materials, they may be primary, secondary and tertiary consumers. e. g . Man

2. Microconsumers: They include decomposers, parasites, detervores and scavengers.
a. Decomposers (Saprophytes/ Reducers)
They are mostly saprophytic organisms. e.g. Bacteria- mainly on animals, Fungi – mainly on plants. They break down the complex compounds of dead or living protoplasm and absorb some decomposed products and release inorganic nutrients which are cycled back into environment.

b. Parasites: They obtain food directly from other organisms of all trophic levels. But, they cause disease.

c. Detrivores/ detritivores
They feed on decomposing organic particles of organic matter. e.g. Termites, earth worms

d. Scavengers: They feed on dead bodies. e.g. Vultures

BIOTIC FACTORS OF DIFFERENT ECOSYSTEMS
*Forest ecosystem: Producers - plants

Primary consumers - herbivores
Secondary consumers - snakes, birds, fox
Tertiary consumers - lion, tiger
Decomposers - Fungi, bacteria and actinomycetes

*Grassland ecosystem: Producers - grasses
Primary consumers – herbivores like cows, buffaloes, deers
Secondary consumers - snakes, birds, lizards, fox
Tertiary consumers - hawks
Decomposers – Fungi, bacteria and actinomycetes

*Desert ecosystem: Producers - Thorny bushes, a few grasses, succulents
Consumers - Insects, reptiles, birds, camels
Decomposers – A few thermophilic fungi and bacteria due to low organic matter

*Pond ecosystem: Producers - Submerged, free floating amphibious plants and Photosynthetic bacteria
Primary consumers – zooplankton ciliates, protozoans, flagellates, small crustaceons, annelids
Secondary consumers – small fish, insects
Tertiary consumers – large fishes
Decomposers – Fungi, bacteria and actinomycetes

*Marine ecosystem: Producers - phytoplankton, seaweed
Primary consumers – crustaceons, molluscs, fish
Secondary consumers - fishes
Tertiary consumers – large fishes
Decomposers - Fungi and bacteria

ABIOTIC COMPONENTS (Non-living factors)
Abiotic components are broadly classified into 3 categories.

1. Climatic factors
2. Edaphic factors
3. Chemical factors/ Chemical substances

1. Climatic factors: They include climatic regime and physical factors of environment like light, temperature, humidity, wind, topography etc.

2. Edaphic factors: They include structure and composition of soil including physical and chemical factors of soil like soil and its types, soil water, soil profile, minerals, soil organic matter etc.

3. Chemical factors/ Chemical substances
These are of 2 types.

a. Inorganic substances: They include water, minerals, and gases. These are required for the synthesis of organic substances. Hence, they are called Biogenic substances. The amount of biogenic nutrients in the environment at any time is called 'Standing'. The amount of living matter in different levels is called standing crops. The minerals and atmospheric gases are keen on cycling. They enter into biotic system and after death and decay they return to the soil and atmosphere.

b. Organic substances: They include carbohydrates, lipids, proteins, humic substances. etc.

ABIOTIC FACTORS OF DIFFERENT ECOSYSTEMS:
Forest ecosystem: Inorganic and organic substances found in soil and atmosphere.
Grass ecosystem: Inorganic and organic substances found in soil and atmosphere.
Desert ecosystem: High temperature and low rainfall.
Pond ecosystem: Inorganic and organic substances.
Marine ecosystem: Saline sodium chloride, calcium, magnesium, potassium are present. Water strongly buffered. Dissolved nutrients low.

3.3. ENERGY FLOW IN ECOSYSTEM

Ecological energetics
Energetics is a branch of mechanics that deals with energy and its transformations. Energy is the basic force responsible for running the machine of life. An organism needs energy for metabolic activities. The chief forms of energy are:

1. Radiant energy: It is solar energy travelling in the form of radiation. The light wavelengths between 380 -740 nm are called “visible light”. It is readily converted into heat energy. This energy warms up the earth.
2. Heat energy: This form of energy is transferred between systems with different temperatures.
3. Chemical energy: The light energy entering the chloroplast is taken up by electrons of the chlorophyll and passed on through the series of stages into chemical energy in the bonds of compounds.
4. Mechanical energy: It exists in two forms.
   1. Potential or stored energy
   2. Free or kinetic or useful

Different forms of energy interchange their forms under certain set of rules called “Laws of Thermodynamics”. This Thermodynamics deals with the mechanical actions and reactions.

Laws of Thermodynamics:

They are fundamental concepts to chemical processes.
1. The first law (Law of Conservation of Energy) states that the total inflow of energy into a system must equal the outflow of energy. So, energy is neither created nor destroyed but may transform from one form to another.
2. The second law (Law of Entropy) states that processes involving energy transformation will not occur spontaneously, unless there is a degradation of energy from a non-random to random form. (entropy= amount of unavailable energy)

   or

   The transformations of energy always result in some loss of dissipation of energy. In ecology, energy is measured in Joules/ unit of heat energy. Heat is measured in calories.

The energy used for all plant life processes is derived from solar radiatiearth’srth’s fraction i.e. about 1/50 millionth of total solar radiation reaches the earth atmosphere which is usually visible light.

In ecological energetics, we study
1. Quantity of solar energy reaching an ecosystem.
2. Quantity of energy used by green plants for photosynthesis
3. Quantity of energy flows from producers to consumers.

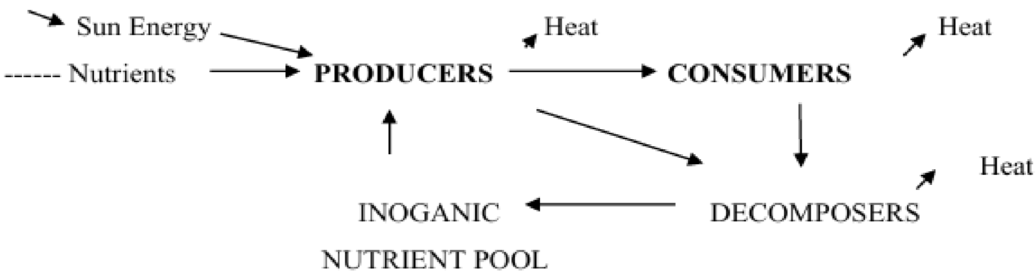
About 34% of sunlight reaching the earth's atmosphere is reflected into atmosphere. 10% of sunlight held by Ozone layer, water vapour etc. 56% reaches the earth surface. Only a fraction of this energy (1-5%) is used by green plants, and the rest is absorbed as heat by ground vegetation/ water.

3.3.1 energy flow (calorific flow)

"The amount of energy that moves/ passes/ transfers through a food chain is called energy flow / calorific flow".

Energy flow takes place through ecosystem in the form of C-C bonds. During respiration, these C-C bonds are broken down and combined with O_2 to form CO_2. This process releases some energy. It is used by organisms that may be lost as heat. It is of great ecological significance to understand in any ecosystem.

1. The efficiency of producers to absorb and convert solar energy into chemical energy.
2. The use of chemical energy by consumers.
3. The total input of energy in the form of food and its assimilation efficiency.
4. The loss of energy through respiration, heat, excretion etc.
5. The gross and net production.



3.3.2 energy flow models:

Three types of energy flow models have been proposed.

1. Single channel energy flow model
2. Y- shaped/ double channel/ Two channel energy flow model
3. Universal model of energy flow.

1. Single (Linear) Channel Energy Flow Model:
The single or linear channel energy flow model is one of the first published models. It is pioneered by **H. T. Odum** in 1956. This model depicts a community boundary and, in addition to light and heat flows, it also includes import, export and storage of organic matter. This model suggests one way flow of energy and there is a progressive decrease in energy at each trophic level.

Producers ⟶ Herbivores ⟶ Carnivores

Decomposer organisms are placed in a separate box as a means of partially separating the grazing and detritus food chains. Decomposers are actually a mixed group in terms of energy levels and their importance in this energy flow model is overlooked. This model will suffice as long as only the imports and exports are considered.

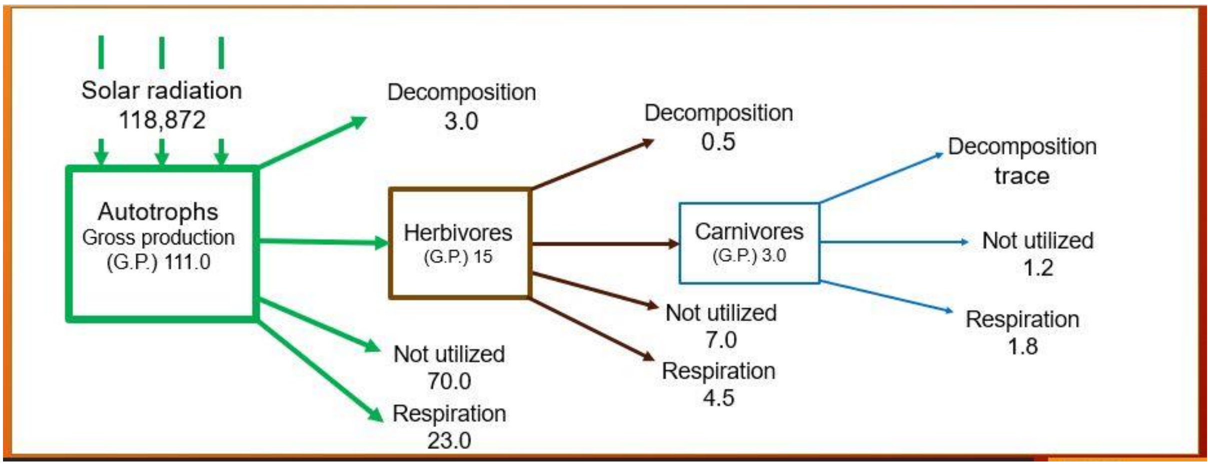


Fig: 3.2 Energy Diagram

Raymond L. Lindeman (1942) was first to give an energy diagram through different trophic levels in Ceder Bog Lake (marshy pond) of Minnesota, USA.

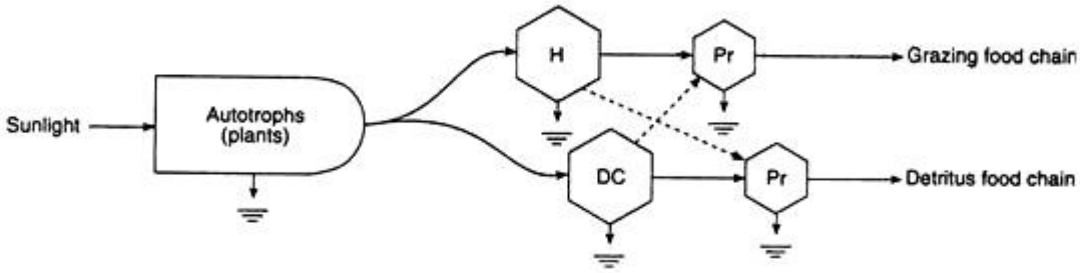
1. The total incoming solar radiation is 118,872 g ca/ cm-2/yr
2. Out of this, 118,761 g cal/cm2/yr (0.10%) remain unutilized. So, gross production (net production + respiration) by autotrophs is 111 g cal/cm 2/year (0.10%)
3. From this, 23 g cal/cm2/yr (21%) is consumed through respiration for metabolic reaction (growth, development and maintenance).
4. Only 15 g cal/ cm2 /yr are consumed by herbivores (17%). Decomposition accounts for 3.4% (3 g cal/ cm2 /yr)
5. About 70 g cal/ cm2 /yr (79.5%) is not utilized but becomes part of the accumulating dements. From this diagram, 2 things become clear.

    1. The energy captured by autotrophs does not revert to solar input (one-way flow) but passes to consumers. Due to this one-way flow, the entire system would collapse if the primary source is cut off.
    2. A progressive decrease in energy at each trophic level through respiration, heat or unutilized.

2. Y- shaped/ Two channel/ 2 channel energy flow model

In this type of model, the grazing and detritus food chains are shown as separate flows**.** This is a more practical working model than the single channel model mainly because:

1. It relates to the basic stratified structure of ecosystem.
2. The direct consumption of living plants and dead organic matter are usually separated in both time and space.
3. Macroconsumers and micro consumers differ greatly in size-metabolism relations and in the techniques required for studying them.



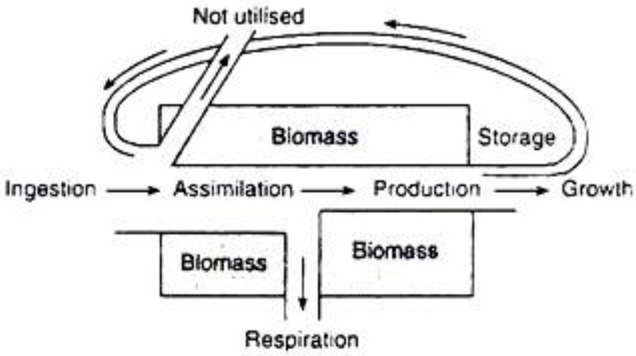
Y- shaped energy flow model shows linkage between 2 food chains

H= herbivores
DC= Detritus consumers
Pr= Predators

The energy flow in case of shallow waters In this diagram, one arm represents Grazing food chain, and another arm represents Detritus food chain. The food chains are sharply separated but not isolated. They are interconnected. Moreover, not all food eaten by grazers is assimilated, as some (feces containing undigested material) are diverted to the detritus pathway. Also, the amount of net production energy that flows down the two pathways varies in different kinds of ecosystems and, often in the same ecosystem; it may vary seasonally or annually. And heavily grazed pastures or grasslands show larger energy flow via the grazing food chain than in the detritus pathway. The reverse is true in case of the forest, marshes and oceans.

Most natural ecosystems operate as detrital system, where 90 percent or more of the autotrophs' production is not consumed by heterotrophs until the leaves, stems and other plant parts die and are processed into particulate and dissolved organic matter in water, soil and sediments.

3. Universal model:
The universal model is applicable to any living component, which may be plant, animal, microorganism, individual, population or community.



Universal model of energy flow

A key feature of the model is the separation of assimilated energy (A) into the production (P) and respiration (R) components. Respiration energy is lost as heat (maintenance energy) and production is transformed to new or different organic matter available to the next trophic level.

At the same time, the non- assimilated component (NU – not utilised), enters the detritus food chain. It is important to note that P component is energy that is available to the next trophic level while NU component is energy that is still available at the same trophic level.

3.4 ECOLOGICAL EFFICIENCY

(Lindeman`s efficiency/ Gross ecological efficiency)
It was proposed by Raymond L. Lindeman (1942).
It is clear from the trophic structure of ecosystem that energy decreases at each subsequent level due to

1. At each level, available energy is lost in respiration/ used in metabolism.

2. A part of energy is lost at each transfer, i.e., moves from lower to higher trophic level. Ecological efficiency is the ratio between amount of energy acquired from the lower trophic level and the amount of energy transferred from higher trophic level.

Lindeman (1942) defined these ecological efficiencies for the first time and proposed 10% rule i.e., if autotrophs produce 100cal, herbivores will be able to store 10 cal and carnivores 1cal. there may be slight variations in different ecosystems and ecological efficiencies may range from 5-35%.

It can be represented as

$$\frac{\text{It x 100}}{\text{It} - 1} = \frac{\text{Ingestion at trophic level t x 100}}{\text{ingestion at previous trophic level - 1}}$$

The Ten percent Law is the transfer of energy from one trophic level to the next. According to this, during the transfer of energy from organic food from one trophic level to the next, only about 10% of the energy from organic matter is stored as flesh. The remaining is lost during transfer/ transfer etc.

3.5 SUMMARY

The structure of an ecosystem and its energy flow are fundamental concepts in ecology that describe how living organisms interact with each other and their non-living environment to maintain life.

1. Structure of an Ecosystem

The structure of an ecosystem is defined by the organization and interaction of its biotic (living) and abiotic (non-living) components.

- Abiotic Components: The non-living physical and chemical elements that provide the environment for life, such as sunlight, water, air (oxygen, carbon dioxide), soil, and temperature.
- Biotic Components: The living parts of the ecosystem, organized into three functional roles:
- Producers (Autotrophs): Green plants and algae that capture solar energy to create food via photosynthesis.
- Consumers (Heterotrophs): Organisms that cannot make their own food and must consume others. These include herbivores (primary consumers), carnivores (secondary/tertiary consumers), and apex predators.
- Decomposers (Saprophytes): Fungi and bacteria that break down dead organic matter, recycling essential nutrients back into the soil or water.

2. Energy Flow in an Ecosystem

Energy flow is the movement of energy through the living components of an ecosystem. Unlike nutrients, which cycle through the system, energy flows in a unidirectional (one-way) path.

- Primary Source: The Sun is the ultimate source of energy for almost all ecosystems.
- Trophic Levels: Energy moves through sequential feeding positions called trophic levels:

1. Level 1: Producers (Plants/Algae).
2. Level 2: Primary Consumers (Herbivores).

3. Level 3: Secondary Consumers (Carnivores).
4. Level 4: Tertiary Consumers (Top Predators).
    - The 10% Rule: On average, only about 10% of the energy at one trophic level is transferred to the next. The remaining 90% is lost, primarily as heat through metabolic processes (respiration) or as waste.
    - Pathways: Energy travels through:
    - Food Chains: Simple, linear sequences showing who eats whom.
    - Food Webs: Complex, interconnected networks of multiple food chains that better reflect natural reality.
    - Models: Modern ecological models include the Single-Channel Model (linear), the Y-Shaped Model (connecting grazing and detritus chains), and the Universal Energy Flow Model.

3.6 SELF-ASSESSMENT

Self-evaluation of ecosystems and energy flow focus on core concepts

1. What are the main components of an ecosystem?
2. Differentiate between a food chain and a food web.
3. What is the role of decomposers
4. Define "trophic level" and provide examples for the first three levels.

3.7. SUGGESTED READING

- Fundamentals of Ecology by Eugene P. Odum and Gary W. Barrett (Fifth Edition, 2012, Cengage Learning).
- Elements of Ecology by Thomas M. Smith and Robert L. Smith (Eighth Edition, 2012)..
- Ecology, Environmental Science and Conservation by J.S. Singh, S.P. Singh, and S.R. Gupta (2015, S. Chand Publishing).
- Fundamentals of Ecosystem Science by Kathleen C. Weathers and a group of experts (Second Edition, 2021, Elsevier).

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LESSON -4

HOMEOSTASIS AND MAJOR BIOMES OF THE WORLD

4.0 Objective
To understand the concepts of Homeostasis and various major biomes.

STRUCTURE OF THE LESSON:

4.1 INTRODUCTION TO ECOSYSTEM

Homeostasis is the ability of an organism or system to maintain a stable internal environment despite a constantly changing external environment. This stability is crucial for optimal cell function and survival. The core concepts include - Dynamic Equilibrium, Regulatory Mechanisms, Feedback Loops.

Major Biomes of the World - Biomes are large ecological regions defined by their specific climate, predominant vegetation, and the adaptations of the organisms that live there. The distribution of biomes is primarily determined by two abiotic factors - temperature and precipitation. The major types include- Tundra, Taiga (Boreal Forest, Temperate Forests, Experience four distinct seasons, moderate precipitation, and are dominated by broad-leaved deciduous trees that shed their leaves annually (e.g., oak, maple). Tropical Rainforests, Grasslands, Deserts, Aquatic Biomes. Biomes are essential for maintaining global ecological balance, supporting biodiversity, and regulating climate and water cycles.

4.2. HOMEOSTASIS (STABILITY CONTROLS)

The term “**Homeostasis”** was coined by **Walter Cannon** in 1930. Homeostasis refers to “the ability or tendency of ecosystem to maintain internal equilibrium by adjusting its physiological processes”.

or

"The tendency of the ecosystems to resist change and remain in a state of equilibrium".

The two basic attributes of all ecosystems are:

1. Cycling materials
2. Flow of energy

Another important attribute of ecosystems is the information content. This content enriches or increases as the system matures. Based on information content, there is better physical and chemical communication and regulation of transfers and flows through the components, giving stability to the ecosystem. The ecosystem is cybernetic in nature. (Cybernetics = Science of controls).

The control provides

1. Resistance (to resist untoward circumstances) against disturbance state to maintain the steady state.

2. Resilience (the ability to recover from change) to the stable state quickly from the disturbed state.

These two help to withstand disturbance and are usually not operative simultaneously in the same ecosystem. If a system is resilient to some adverse factor, for example fire, then the plants may not be fire resistant, but wood soon regenerates after the fire is over. On the other hand, the ecosystem may be fire resistant i.e. they do not burn fully by fire and escape from fire damage. If the fire is prolonged and the trees burn fully, they will not recover after the fire is over as these are lacking resilience against this fire factor.

So, the ability of some ecosystems may be due to resistance and others may be due to resilience. The third may be due to both resistance and resilience to a certain extent. The controls are largely dependent upon the feedback system. The feedback is the information about reactions to a product which is used as basis for improvement. By feedback, the part of the output from any system is put back as an input.

The feedback is of two types.

1. Positive feedback
2. Negative feedback

For example, if money is deposited in a bank, it earns annual interest. If part of the interest (output) is redeposited (input) in the bank, the principal amount increases and in the next year it earns more interest. Like this, if part of the output of an ecosystem is used as feedback, then the system grows year after year. Such feedback that allows growth is called Positive feedback.

In a balanced population, the snake (predator) eats up and reduces the population of frogs. The snake is interacting with frog in a negative way. So, negative feedback is applied in order to check the overgrowth of frogs. The frog population by virtue of its numbers regulating the snake population. This is positive feedback as the frog is responsible in a positive way.

The positive and negative feedback are balanced for maintaining an equilibrium. Negative feedback is responsible for self-regulation or homeostasis. When the populations of trophic organisms increase beyond carrying capacity of the ecosystem, negative feedback mechanism comes into force and brings down the population size to desired level.

Man is the greatest force of disturbing the natural balance. By using advanced technologies for more physical amenities, man is degrading the quality of air, water etc.

4.3. MAJOR BIOMES OF THE WORLD

The word "Biome" was suggested by an ecologist Frederic Edward Clements in 1916. A biome can be defined as a large biological community or biotic region where different types of living organisms including plants, animals and microbes are living in a certain type of climate. There is a close relationship between climate types and the world's distribution of biomes. The biomes are divided into three major types based on climate type.

1. Tundra Biomes
2. Temperate Biomes
3. Tropical Biomes.

Further, these three biomes are divided into sub-types based on dominant vegetations.

4.3.1. tundra biomes:
The word tundra comes from the word tunturi meaning treeless. Tundra= deserted land. There are two types of tundra

a. Arctic tundra
b. Alpine.

The Arctic tundra is a cold and treeless area of low, swampy plains in the north around the Arctic Ocean. It includes the northern lands of Europe (Lapland and Scandinavia), Asia (Siberia), and North America (Alaska and Canada), as well as most of Greenland. The sun does not rise for nearly six months of the year. Permanently frozen subsoil called permafrost is found in the arctic and Antarctic tundra.

The summer temperature may be around 15°C and in winter it may be as low as –57°C in arctic tundra with a very low precipitation of less than 400 mm per year. A short vegetation period of generally less than 50 days between s. Productivity is low.

Typical vegetation of arctic tundra is cotton grass, sedges, willows, lichens etc. e.g. Salix arctica (arctic willow) has a life span of 150 to 300 years. They are protected from chill by the presence of thick cuticle and epidermal hair.

Alpine tundra exists at the tops of high mountains at high elevation. It does not contain trees. The high elevation causes an adverse climate, which is too cold and windy to support tree growth. The flora of the alpine tundra is characterized by dwarf shrubs close to the ground. Large regions of alpine tundra occur in North America, Europe, the Himalaya of Asia etc.

4.3.2. temperate biomes:
Temperate biomes are present between the tropics and the polar regions. The changes between summer and winter are generally moderate, rather than having extreme differences. This allows for numerous types of habitats, including forests and grasslands.

Temperate biomes cover most of the continental United States and Europe. They also cover large parts of Asia. Types of temperate biomes include forests, grasslands, and chaparral.

Temperate Forests: There are two types of temperate forests:

a. Temperate deciduous forests
b. Temperate rainforests

Both types have a temperate climate and good soil. The climate is neither extremely hot nor extremely cold. A temperate climate can be either continental or coastal. Continental temperate climates have cold winters, hot summers, and moderate precipitation. Coastal temperate climates are found near the ocean, and they have mild winters, cool summers, and high precipitation.

Temperate deciduous forests are found in areas with continental temperate climates, such as the eastern United States and Canada and throughout much of Europe. These forests consist mainly of deciduous trees, such as maples and oaks, which lose their leaves in the fall. There are many other species of plants as well.

Temperate rainforests are found in areas with coastal temperate climates, such as the northwestern coast of North America and certain coastal regions of other continents. These forests consist mainly of evergreen trees, such as hemlocks and firs. Mosses, lichens, and ferns grow on the forest floor. There are also many epiphytic plants. Epiphytes are plants that grow on other plants.

Temperate Grasslands: Temperate grasslands consist mainly of grasses. They are found in the midwestern region of North America and in inland areas of most other continents. The climate is continental, and precipitation is relatively low. However, most of the precipitation falls during the growing season when plants need it the most.

A temperate grassland biome is known as prairie in North America, outback in Australia, Pampa in South America, Steppe in central Asia.

The soil of temperate grasslands is the richest, deepest soil on earth. It is densely covered with thick grasses that decompose to add large amounts of organic matter and nutrients to the soil. Grasses also have thick mats of roots that prevent erosion. The low rainfall does not reach many nutrients from the soil, but it does lead to frequent fires. The fires help prevent woody vegetation from moving in if a grassland is disturbed.

4.3.3 tropical biomes:

The tropical biomes are close to the equator, creating biomes unique to their areas. Tropical biomes include their own version of forests and grasslands. Tropical biomes receive more sunlight, and they also have high temperatures year-round. In addition to deserts, tropical biomes include forests and grasslands.

Tropical Forests

There are two types of tropical forests: tropical rainforests and tropical dry forests. Both occur near the equator, so they have plenty of sunlight and warmth year-round. However, they differ in the amount and timing of the precipitation they receive.

a. Tropical rainforests

Tropical rainforests are located around the equator. Rainforests receive 400-1000 cm of rain each year. The largest rainforests are in South America, Africa and Indonesia It is abundant with many species of wildlife and vegetation. Rainforests cover less than two percent of the Earth's surface. They are home to some 50 to 70 percent of all life forms on our planet. Rainforests are the most productive and most complex ecosystems on Earth.

Structure of vegetation in the rainforest: Emergent are the tallest trees and are usually over 50 meters tall. The Kapok tree is an example of an emergency. The under canopy mainly contains bare tree trunks and lianas.
The shrub layer has the densest plant growth. It contains shrubs and ferns and other plants needing less light. Saplings of emergents and canopy trees can also be found here. The forest floor is usually dark and damp. It contains a layer of rotting leaves and dead animals called litter. This decomposes rapidly (within 6 weeks) to form a thin humus, rich in nutrients.

Adaptability: In the tropical rainforest, most trees in the rainforest have wide buttress roots. This is to support them as they grow incredibly tall (over 200ft in some cases) as there is great competition for sunlight. Lianas (vines) grow around trees as they bid to reach sunlight. The leaves of many trees are waxy and have drip tips to allow water to run off them (so that water does not gather on leaves and cause them to rot, it also allows water to reach the roots on the forest floor). Leaf stems are also flexible to allow leaves to move with the sun to maximize photosynthesis.

The plants receive more precipitation than any other biome. They are found near the equator in Central and South America and Africa. The soil is thin and poor, partly because the lush plant growth uses up nutrients before they can accumulate in the soil. Biodiversity of animals as well as plants is greater than in all other biomes combined. Most plants are tall, broadleaf evergreen trees. They form a dense canopy over the forest, so little sunlight reaches the forest floor. The many vines and epiphytes reach sunlight by growing on trees. Numerous animal species also live in trees, including monkeys, sloths, and leopards.

b. Tropical dry forests

Tropical dry forests occur in tropical areas where most of the precipitation falls during a single wet season. As a result, there is a pronounced dry season. Tropical dry forests are found in parts of Central and South America, Africa, and India. Trees and other plants are widely spaced because there is not enough water for denser growth. The plants also have adaptations to help them cope with seasonal drought. For example, many go dormant during the dry season

Tropical Grasslands

Tropical grasslands are tropical biomes with relatively low rainfall where the primary producers are grasses. Tropical grasslands are found mainly in Africa, where they are called savannas. They have high temperatures year-round, but relatively low precipitation. Moreover, most of the precipitation falls during a single wet season, leaving the rest of the year very dry. The soil is also poor.

In addition to grass, there are scattered clumps of trees in most tropical grasslands. The trees are drought-adapted species such as acacia, which have narrow leaves that reduce water loss. Acacia trees also have thorns that discourage browsing by herbivores.

4.4 DESERTS

A desert is an area where little or no life exists because of a lack of water. Scientists estimate that about one-fifth of the earth's land surface is desert. Deserts can be found on every continent except Europe. This biome has a layer of soil that can either be sandy, gravelly, or stony, depending on the type of desert. Deserts usually get at most 50 centimeters of rainfall a year, and the organisms that live in deserts are adapted to this extremely dry climate. Plants in deserts have adaptations to conserve water. For example, cacti have enlarged stems to store water, as well as spines to protect these water reserves from thirsty animals.

The four main types of deserts include:

1. Hot and dry deserts (Arid deserts): The temperatures are warm and dry year-round. eg., Sahara Desert, Arabian Desert
2. Semi-arid deserts: They are a bit cooler than hot and dry deserts. The long, dry summers in semi-arid deserts are followed by winters with some rain. Semi-arid deserts are found in North America, Greenland, Europe, and Asia.
3. Coastal deserts: They are more humid than other types of deserts. eg. The Atacama Desert of Chile
4. Cold deserts: They are still dry but have extremely low temperatures in comparison to the other types of deserts. eg. Antarctica and Gobi Desert, Most of the plants growing in the desert are species of cacti. eg. Yucca, Aloe plants, or the tall saguaro cacti.

4.5 AQUATIC BIOMES

Freshwater: Includes rivers, lakes, ponds, and wetlands with very low salt content (<0.05%).
Marine: Covers the largest portion of Earth's surface (oceans, coral reefs, estuaries) and is characterized by high salinity.

Aquatic biomes are large ecological areas where the dominant life forms are water-based. They are fundamentally characterized by factors such as salinity, water temperature, depth, and flow. These biomes are broadly divided into two main categories: freshwater and marine biomes, each hosting diverse ecosystems.

Freshwater Biomes: Freshwater biomes have a very low salt content, typically less than 0.05%. They are vital for providing drinking water and supporting various forms of plant and animal life.

Rivers and Streams: These are moving bodies of water that flow in one direction, generally originating from a source point like a mountain spring and traveling to a lake or ocean. The faster-moving water near the source is typically rich in oxygen and supports organisms like trout, while slower-moving water downstream often has more sediment and different species of fish and vegetation.

Lakes and Ponds: These are standing bodies of water. Lakes are generally larger and deeper, often with a cold, dark bottom (benthic) zone that cannot support plant life. Ponds are typically smaller and shallower, allowing sunlight to reach the bottom and supporting aquatic plants throughout.

Wetlands: Areas where the soil is saturated with water, either permanently or seasonally. This category includes marshes, swamps, and bogs. Wetlands are highly productive ecosystems that filter pollutants and serve as critical habitats and breeding grounds for a vast array of wildlife.

Marine Biomes: Marine biomes cover the largest portion of the Earth's surface and are defined by a high salt content. They are crucial in regulating the planet's climate and providing a vast amount of oxygen through photosynthesis by marine algae.

Oceans: The largest of all biomes, the ocean is divided into various zones based on depth and distance from the shore, each supporting unique life. Key zones include the sunlit photic zone near the surface, and the dark, high-pressure aphotic zone deep below. Marine life, from microscopic plankton to giant whales, is incredibly diverse.

Coral Reefs: Found in warm, clear shallow waters, coral reefs are among the most diverse and biologically rich ecosystems on Earth, often called "rainforests of the sea". They are built by colonies of tiny coral polyps and support thousands of species of fish, invertebrates, and plants.

Estuaries: These are unique areas where freshwater rivers meet the saltwater ocean, creating a dynamic, brackish-water environment. They are highly productive and serve as essential nursery grounds for many commercially important fish and shellfish species, such as oysters and crabs.

4.5 SUMMARY

Homeostasis is the self-regulating process by which a biological system (an organism or an ecosystem) maintains internal stability while adjusting to changing external conditions. The Earth's major biomes are large geographical regions with distinct climates and characteristic communities of plant and animal species adapting to those conditions.

Homeostasis involves dynamic equilibrium, not a rigid static state, to keep critical variables within an optimal range for survival. This regulation often involves negative feedback loops, where a change in a variable triggers a response that counteracts the initial change to return the system to balance.

Major Biomes of the World
Biomes are primarily classified by climate (temperature and precipitation) and the dominant vegetation. They are broadly categorized into terrestrial (land) and aquatic (water) biomes.

The major terrestrial biomes include:

- Tropical Rainforests: Found near the equator, characterized by high temperatures, abundant rainfall, and the greatest biodiversity.
- Deserts: Defined by low rainfall (less than 35 cm/year) and extreme temperature variations between day and night. Organisms are adapted to conserve water.
- Grasslands (Savannas and Temperate Grasslands): Regions dominated by grasses with few trees. Savannas are tropical with seasonal rainfall, while temperate grasslands have distinct hot summers and cold winters.
- Temperate Forests: Feature moderate temperatures, distinct seasons, and deciduous trees that shed their leaves in winter.
- Boreal Forests (Taiga): The largest land biome, characterized by long, cold winters, short summers, and coniferous evergreen trees (e.g., pine, spruce).
- Tundra: The coldest biome, a treeless plain noted for permafrost, low-growing vegetation (mosses, lichens), and a very short growing season.
- Aquatic biomes, the largest on Earth, include:
- Marine: Covers about 70% of the Earth's surface and includes oceans, coral reefs, and estuaries.

Freshwater: Includes standing bodies of water (lakes, ponds) and moving water (rivers, streams), with low salt content.
These biomes support unique life forms adapted to their specific environmental conditions, demonstrating life's ability to maintain balance within diverse global environments.

4.6 SELF-ASSESSMENT

1. Definition of Homeostasis: What is the process by which an organism maintains a stable internal environment despite changes in the external conditions?
2. Feedback Loops: Which type of feedback loop acts to reverse a change and return a variable to its normal range (set point)?
3. Examples of Negative Feedback: Give two examples of processes in the human body that are regulated by negative feedback loops.
4. Components of a Control System: Name the three main components of a homeostatic control system that work together to monitor and respond to changes.
5. Thermoregulation: Which part of the brain is responsible for regulating body temperature?
6. Blood Glucose Regulation: What two hormones, produced by the pancreas, are responsible for maintaining stable blood glucose levels?
7. Osmoregulation: Which organ is primarily responsible for osmoregulation (water and salt balance) in the human body?
8. Hormonal Control: A person is dehydrated. What happens to the level of Antidiuretic Hormone (ADH) in their blood, and what is the effect on the kidneys?
9. Homeostatic Failure: What common disease is a result of the body's failure to regulate blood glucose levels effectively?
10. Positive Feedback: Describe an example of a normal physiological process that involves positive feedback.

Major Biomes of the World Self-Assessment Questions

1. Defining a Biome: What two primary abiotic factors determine the nature and extent of a major terrestrial biome?
2. Biodiversity Hotspot: Which terrestrial biome has the largest number of plant and animal species (greatest biodiversity)?
3. Forest Types: What type of trees (coniferous or deciduous) are dominant in the Taiga (Boreal Forest) biome?
4. Arid Environments: The desert and tundra biomes are similar in which key environmental characteristic? Discuss.
5. Aquatic Biomes: What are the two main types of aquatic biomes, and which one is the largest?

Note: You can find answer keys and detailed explanations for similar questions through resources such as Study.com and Textbook.

4.7. SUGGESTED READING

- Fundamentals of Ecology by Eugene P. Odum and Gary W. Barrett (Fifth Edition, 2012, Cengage Learning).
- Elements of Ecology by Thomas M. Smith and Robert L. Smith (Eighth Edition, 2012)..
- Ecology, Environmental Science and Conservation by J.S. Singh, S.P. Singh, and S.R. Gupta (2015, S. Chand Publishing).
- Fundamentals of Ecosystem Science by Kathleen C. Weathers and a group of experts (Second Edition, 2021, Elsevier).

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LESSON -5
SOIL PROPERTIES AND TYPES OF SOILS

5.0. OBJECTIVES:
To understand various physical and chemical properties and different types of soils structures

STRUCTURE OF THE LESSON:

5.0. OBJECTIVES:
To understand various physical and chemical properties and different types of soils structures

5.1. SOIL PROPERTIES

5.1.1. Introduction:

Soil is the upper layer of the earth. It is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. It has four important functions:

a. It is a medium for plant growth.
b. It is a means of water storage, supply and purification.
c. It is a modifier of earth's atmosphere.
d. It is a habitat for organisms.

Soil properties can be classified into two categories, viz., physical and chemical properties.

5.1.2. Physical properties

The physical properties of soils, in order of decreasing importance are texture, structure, bulk density, porosity, consistency, temperature, colour and resistivity.

1. Soil texture: It is determined by the relative proportion of the three kinds of soil mineral particles, called sand, silt, and clay. The only soil in which neither sand, silt nor clay predominates is called loam. While even pure sand, silt or clay may be considered as soil. Sand and silt are the products of physical and chemical weathering of the parent rock. Clay, on the other hand, is most often the product of the precipitation of the dissolved parent rock as a secondary mineral.

Sand is the most stable of the mineral components of soil; it consists of rock fragments, primarily quartz particles, ranging in size from 2.0 to 0.05 mm in diameter. Silt ranges in size from 0.05 to 0.002 mm. Clay cannot be resolved by optical microscopes as its particles are 0.002 mm or less in diameter and a thickness of only 10 angstroms.

2. Soil structure: The clumping of the soil textural components of sand, silt and clay causes aggregates to form and the further association of those aggregates into larger units creates soil structures called peds. Soil structure affects aeration, water movement, conduction of heat, plant root growth and resistance to erosion.

3. Soil density: Soil particle density is typically 2.60 to 2.75 grams per cm3 and is usually unchanging for a given soil. Soil particle density is lower for soils with high organic matter content and is higher for soils with high iron-oxides content. Soil bulk density is equal to the dry mass of the soil divided by the volume of the soil; i.e., it includes air space and organic materials of the soil volume. Thereby soil bulk density is always less than soil particle density and is a good indicator of soil compaction.

4. Porosity : Pore space is that part of the bulk volume of soil that is not occupied by either mineral or organic matter but is open space occupied by either gases or water. In a productive, medium-textured soil the total pore space is typically about 50% of the soil volume. Soil texture determines total volume of the smallest pores. Clay soils have smaller pores, but more total pore space than sands, despite of a much lower permeability. Soil structure has a strong influence on the larger pores that affect soil aeration, water infiltration and drainage. The pore size distribution affects the ability of plants and other organisms to access water and oxygen; large, continuous pores allow rapid transmission of air, water and dissolved nutrients through soil, and small pores store water between rainfall or irrigation events.

5. Consistency: Consistency is the ability of soil to stick to itself or to other objects and its ability to resist deformation and rupture. Consistency is measured at three moisture conditions: air-dry, moist, and wet. In those conditions the consistency depends upon the clay content.

6. Temperature: Soil has a temperature range between -20 to 60 °C. Soil temperature regulates seed germination, breaking of seed dormancy, plant and root growth and the availability of nutrients. Soil temperature has important seasonal, monthly and daily variations, fluctuations in soil temperature being much lower with increasing soil depth. Soil temperatures can be raised by drying soils. Soil temperature is important for the survival and early growth of seedlings. Soil temperatures affect the anatomical and morphological character of root systems.

7. Colour: Soil colours is often the first impression one has when viewing soil. Striking colours and contrasting patterns are especially noticeable. In general, color is determined by the organic matter content, drainage conditions, and degree of oxidation. Soil color is primarily influenced by soil minerology. Many soil colours are due to various iron minerals. The development and distribution of colour in a soil profile results from chemical and biological weathering, especially redox reactions.

8. Resistivity: Soil resistivity is a measure of a soil's ability to retard the conduction of an electric current. The electrical resistivity of soil can affect the rate of galvanic corrosion of metallic structures in contact with the soil. Higher moisture content or increased electrolyte concentration can lower resistivity and increase conductivity, thereby increasing the rate of corrosion.

9. Water retention (water holding): Water that enters a field is removed from a field by runoff, drainage, evaporation or transpiration. Water affects soil formation, structure, stability and erosion but is of primary concern with respect to plant growth. The water that plants may draw from the soil is called the available water. Once the available water is used up the remaining moisture is called unavailable water as the plant cannot produce sufficient suction to draw that water in.

10. Soil moisture content: When the soil moisture content is optimal for plant growth, the water in the large and intermediate size pores can move about in the soil and the water is easily used by the plants. Sandy soil will retain very little water, while clay will hold maximum amount.

5.1.3. Chemical properties

Chemical properties of soils can be described under the following heads:
1. Inorganic Matters of Soil: Compounds of Aluminum, Silicon, Calcium, Magnesium, Iron, Potassium and Sodium are chief inorganic constituents of soils. Besides these, the soil also contains small quantities of several other inorganic compounds, such as Boron, Copper, Zinc, Molybdenum, Cobalt, Iodine, Fluorine etc. The amounts of these chemicals vary in soils of different places.

2. Organic Matter in Soil: Organic components of the soil consist of substances of organic origin; living and dead. The sandy soil of arid zone is very poor in organic quantity (one or less than one per cent) but in peaty soil, it may be as high as 90%. When the plants and animals die, their dead remains are subjected to decomposition. As a result of decomposition, several different organic products or compounds are formed from the original residues. During decomposition, the original materials are converted into dark-coloured organic complexes, called humus. Sometimes living micro-organisms add sufficient number of organic matters to soil in the form of metabolic waste.

3. Colloidal Properties of Soil Particles: There are two types of colloids in the soil. These are: (a) Mineral colloids or clay colloids, and
(b) Organic or humus colloids.
The inorganic colloids occur as very fine particles and organic colloids occur in the form of humus particles. The soil colloid particles show almost all the characteristics of typical colloidal system, i.e., adsorption, Tyndal effect, Brownian movement, coagulation, electrophoresis, dialysis etc.

Cation Exchange: Since the soil colloids (clay and organic colloids) have negative charges on them, they attract and hold positive ions (cations). When cations are added to the soils such as Ca^{++} in the form of lime, K^{+} ions in the form of potassium fertilizer, and NH^{++} in the form of ammonium fertilizer, the adsorption of cations will take place on the surface of colloid micelle and this will be accompanied by release of one or more ions held by colloid micelle. This is known as cationic exchange.

Anion Exchange: Soils rich in organic colloids show anion exchange also. In this process, negatively charged ions held by colloids are replaced by OH^-, $H_2PO_4^-$, SO_4^{--}, and NO_3^- ions. The relative order of exchange is $OH^- > H_2PO_4^-, > SO_4^{--} > NO_3^-$.
Among these anions, exchange of PO_4^{--}, ions is most important. $SO_4^{--}$and NO^{--} are not retained in the soil for long period of time, hence not available for anionic exchange. Laterite soils have higher adsorptive and fixation capacity for PO_4^{--} than black soils.

4. Soil Reaction: Some soils are neutral, some are acidic and some basic. The acidity, alkalinity and neutrality of soils are described in terms of hydrogen ion concentrations or pH values. To understand soil reaction, knowledge of pH is very necessary.

5.2. TYPES OF SOIL

There are several types of soil. They are:
Black soil: These soils are also known as black cotton soils. This soil will be usually found in the volcanic regions as it is formed by lava rocks after they undergo a decomposition process. These are black in color and therefore are named black soil. This soil is rich in iron, magnesium and aluminium, but does not have phosphorous, nitrogen and organic matter. They are deep and impermeable, clayey in nature. Wide cracks are seen especially during the dry seasons. Its main component is clay.

Red soil: Red soil is found in regions with warm, moderate and moist climates. This soil is mainly formed due to crumbling and weathering. These soils contain good amounts of iron, whereas mostly they lack phosphoric acid, organic matter and nitrogenous material. It is not good at all in retaining moisture and is little acidic in nature. It is sandy and not clay like black soil.

Laterite soil: The word laterite is derived from the Latin word meaning brick. This soil contains high amount of iron and Aluminium oxide. It is a highly weathered red soil which is found in areas with tropical to moderate climate. They are generally found beneath surface of wide grasslands or forest clearings in areas getting good amount of rainfall. The color ranges from red to black, depending upon the quantity of iron oxide in it. It gets harder when exposed to air. These are used in the construction of the buildings. It can be referred to as porous clay.

Alluvial soil: These soils get deposited by running water and usually develop in a flood plain or delta. It consists of clay, silt, sand, gravel and other materials. Color of these soils differs from light grey to ash grey. They are sandy to silty loam in context to texture. These soils are good for irrigation and therefore cultivation of many crops can take place in these soils.

Desert soil: This soil belongs to a region with arid climate. These soils usually lack organic matter and if it is present then only in a little amount. They are sandy or rocky in texture. Due to the arid climate and extremely low rainfall, these soils are only able to support little vegetation. This soil contains soluble salt. They are developed by mechanical disintegration and deposition by the wind. These are coarsy and contain very low moisture.

Mountain Soil: These soils belong to hill slopes and valleys. These are usually formed when organic matter of the forest settles down. It is quite rich in humus but lacks Potash and lime. This soil is composed of clay, sand and silt and tends to be rich in moisture. However, the texture may vary from rocky to sandy. These are susceptible to soil erosion as top soil is removed when rains occur heavily in the steep slopes. They are not fertile in nature. They are coarse in texture.

Saline and Alkaline soil: Saline soils are formed when soil accumulates in soil and groundwater and by the marine saltwater flooding the land. Slats may also get dissolved in the soil due to chemical weathering of rocks. In case the drainage is not proper, salt remains in the surface and not reaches to the root zone. Saline soils have a large, good amount of natural soluble salts mainly in comparison of chlorides, sulphates and carbonates of calcium, sodium and magnesium. In alkali soils, pH is more than 8.5.

Peaty and Marshy Soil: Peaty soils are found in regions with humid climate. It appears black in color. Peaty soils are developed when organic matter deposits in the soil in excessive quantity. During the rainy season these soils are submerged under water and therefore are suitable for paddy cultivation. Marshy soils are usually found in the coastal regions close to the sea or delta.

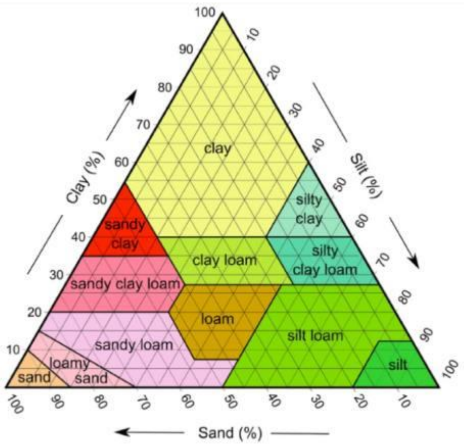

Fig: 5.1 Types of soil

5.3. SOIL PROFILE

A **soil profile** is a vertical cross-section of the Earth's crust that reveals the distinct layers, known as **horizons**, extending from the surface down to the parent rock. Each horizon has unique physical, chemical, and biological properties, such as color, texture, and nutrient content, which develop over thousands of years.

The Master Horizons

A typical, well-developed soil profile consists of several primary layers, often designated by capital letters:

- **Horizon (Organic Layer):** The topmost layer, primarily composed of organic matter like fallen leaves, twigs, and decomposing plant/animal debris. It is usually dark brown or black.
- **A Horizon (Topsoil):** Rich in humus (fully decomposed organic matter) and minerals. This is the most fertile layer, supporting seed germination and most plant roots.
- **E Horizon (Eluviated Layer):** A light-colored subsurface layer characterized by **eluviation** (leaching), where water washes out minerals, clay, and organic matter. It is most common in older forest soils.

- **B Horizon (Subsoil):** A zone of **illuviation**, where minerals and nutrients leached from the A and E horizons accumulate. It is often harder, more compact, and rich in clay or iron oxides.
- **C Horizon (Parent Material/Substratum):** Consists of partially weathered rock fragments. It is the original geologic material from which the upper layers formed and is largely devoid of organic matter.
- **R Horizon (Bedrock):** The bottommost layer of solid, unweathered rock (such as granite, limestone, or basalt) that forms the foundation of the soil profile.

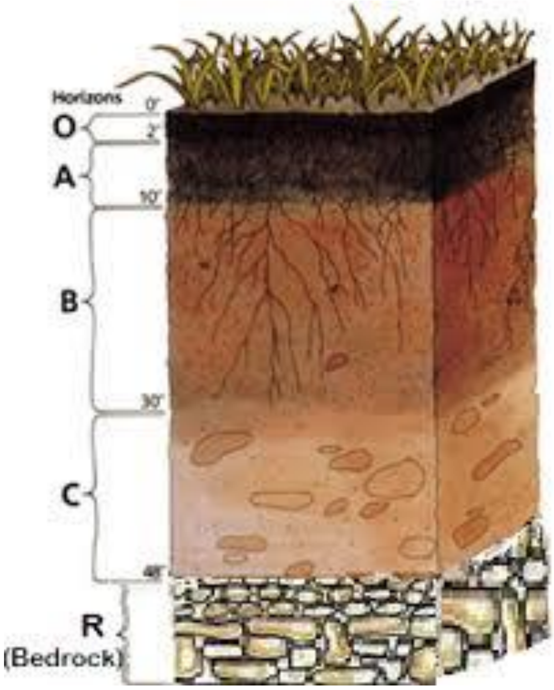

Fig: 5.2 Soil profiles

Factors Influencing Profile Development

The composition and thickness of these horizons are determined by the **ClORPT** factors:

1. **Cl (Climate):** Temperature and rainfall dictate the rate of weathering and leaching.
2. **(Organisms):** Plants, animals, and microbes contribute organic matter and mix soil through "bioturbation".
3. **R (Relief/Topography):** The slope of the land affects water runoff and erosion.
4. **P (Parent Material):** The chemical nature of the starting rock determines the soil's mineral content.
5. **T (Time):** Mature soils with clear horizons take thousands of years to form; young soils may lack distinct layers.

Importance of Soil Profiles

- **Agriculture:** Helps farmers determine fertility, water retention, and the best crops for a specific land area.
- **Construction:** Geotechnical engineers study profiles to ensure soil stability for buildings and roads.
- **Environmental Science:** Used to track nutrient cycling, carbon sequestration, and the impact of pollution.

5.4. SUMMARY

Soil properties are crucial because they influence plant growth, environmental management, nutrients, structural stability and ecosystem balance. Soil types are important because they determine the success of crop growth, support ecosystem health and biodiversity. Understanding soil types is vital for choosing the right plants, ensuring water management etc.

5.5. SELF-ASSESSMENT

1. Describe in detail various properties of soil.
2. 2. Give an account of soil types

5.6. SUGGESTED READINGS

1. Ambasht, R. S. and Ambasht, N. K., 1999. A Textbook of Ecology, CBS Publishers and Distributers, New Delhi.
2. Chapman, J. L. and Reiss, M. J., 2003. Ecology: Principles and Applications, (2 nd Edition) Cambridge University Press, UK.
3. Odum, E. P. and Gary W. Barrett, 2015. Fundamentals of Ecology (5 th Edition), Saunders ISBN.

Dr K.Babu

LESSON- 6
BIOGEOCHEMICAL CYCLES
(Substance turnover/ Cycling of substances)

6.0. OBJECTIVES
To understand various types of biogeochemical cycles and nutrient cycling.

STRUCTURE OF THE LESSON:

6.1. INTRODUCTION

Biogeochemical cycle is a pathway by which a chemical substance moves through both the biotic (biosphere) and abiotic (lithosphere, atmosphere and hydrosphere) components of earth. This cycle of chemical elements involves biological organisms and their geological environment. Hence, this cycle is referred to as “Biogeochemical cycle”. In this term - “Bio” refers to living organisms, and “Geo” refers to the rocks, soil, air, and water of the earth. For each cycle, two compartments/ pools may be recognized.

1. The nutrient pool/ the reservoir pool: The large, slow moving and non-biological component.
2. The exchange /cycling pool: A small but more active portion that is exchanged.

6.2. TYPES OF BIOGEOCHEMICAL CYCLES

There are 3 basic types of cycles.

a. Gaseous cycle: eg. Carbon, Oxygen and Nitrogen cycles
b. The atmosphere constitutes the major reservoir of the element that exists in gaseous phase.
c. Sedimentary cycle: Phosphorus, Sulfur and Iodine cycles. In this type, major reservoir is the lithosphere, from which the elements are released by withering.
d. Water (Hydrologic) cycle: Water cycle

6.3. BIOGEOCHEMICAL CYCLE OF CARBON

Carbon is an essential element in the bodies of living organisms. It is also economically important to modern humans, in the form of fossil fuels. Carbon is often referred to as the "building block of life" because all living organisms are based on carbon. Carbon compounds can exist in solid (coal), liquid (crude oil), or gas (carbon dioxide) forms. Carbon dioxide from the atmosphere is taken up by photosynthetic organisms and used to make organic molecules, which travel through food chains. In the end, the carbon atoms are released in respiration.

Slow geological processes, including the formation of sedimentary rock and fossil fuels, contribute to the carbon cycle over long-time scales. Some human activities, such as burning fossil fuels and deforestation, increase atmospheric carbon dioxide and affect Earth's climate and oceans.

Carbon is part of our bodies, but it is also a part of our modern-day industries. Carbon compounds from long-ago plants and algae make up the fossil fuels, such as coal and natural gas, that we use today as energy sources. When these fossil fuels are burned, carbon dioxide is released into the air, leading to higher levels of atmospheric CO_2. This increase in CO_2 levels affects Earth's climate.

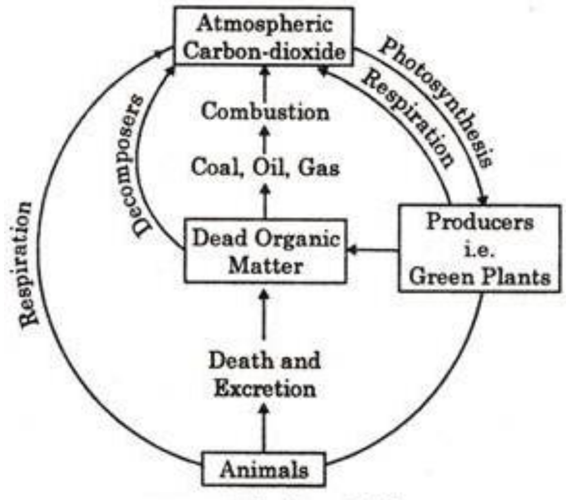

Fig: 6.1 Carbon Cycle

The carbon cycle is most easily studied as two interconnected sub -cycles:

1. The biological carbon cycle (Rapid carbon exchange among living organisms)
2. The geological carbon cycle (Long-term cycling of carbon through geologic processes)

These sub-cycles are linked.

As carbon exists in the air largely as carbon dioxide which dissolves in water and reacts with water molecules to produce bicarbonate. Photosynthesis by land plants, bacteria, and algae converts carbon dioxide or bicarbonate into organic molecules. Organic molecules made by photosynthesizers are passed through food chains, and cellular respiration converts the organic carbon back into carbon dioxide gas.

Long term storage of organic carbon occurs when matter from living organisms is buried deep underground or sinks to the bottom of the ocean and forms sedimentary rock. Volcanic activity and, more recently, human burning of fossil fuels bring this stored carbon back into the carbon cycle. Although the formation of fossil fuels happens on a slow, geologic timescale, human release of the carbon they contain is on a very fast timescale.

The biological carbon cycle:

Carbon enters all food webs, both terrestrial and aquatic, through autotrophs, or self-feeders. Almost all these autotrophs are photosynthesizers, such as plants or algae. Autotrophs capture carbon dioxide from the air or bicarbonate ions from water and use them to make organic compounds such as glucose. Heterotrophs, or other-feeders, such as humans, consume organic molecules, and the organic carbon is passed through food chains and webs.

To release the energy stored in carbon-containing molecules, such as sugars, autotrophs and heterotrophs break these molecules down in a process called cellular respiration. In this process, the carbons of the molecule are released as carbon dioxide. Decomposers also release organic compounds and carbon dioxide when they break down dead organisms and waste products.

Carbon can cycle quickly through this biological pathway, especially in aquatic ecosystems. Overall, an estimated 1,000 to 100,000 million metric tons of carbon move through the biological pathway each year.

The geological carbon cycle:

The geological pathway of the carbon cycle takes much longer than the biological pathway described above. In fact, it usually takes millions of years for carbon to cycle through the geological pathway. Carbon may be stored for long periods of time in the atmosphere, bodies of liquid water, mostly oceans, ocean sediment, soil, rocks, fossil fuels, and earth's interior.

The level of carbon dioxide in the atmosphere is influenced by the reservoir of carbon in the oceans and vice versa. Carbon dioxide from the atmosphere dissolves in water and reacts with water molecules in the following reactions: The carbonate released in this process combines with calcium ions to make calcium carbonate, a key component of the shells of marine organisms. When the organisms die, their remains may sink and eventually become part of the sediment on the ocean floor. Over geological time, the sediment turns into limestone, which is the largest carbon reservoir on Earth.

On land, carbon is stored in soil as organic carbon from the decomposition of living organisms or as inorganic carbon from weathering of terrestrial rock and minerals. Deeper under the ground are fossil fuels such as oil, coal, and natural gas, which are the remains of plants decomposed under anaerobic, oxygen-free, conditions. Fossil fuels take millions of years to form. When humans burn them, carbon is released into the atmosphere as carbon dioxide.

Another way for carbon to enter the atmosphere is by the eruption of volcanoes. Carbon containing sediments in the ocean floor are taken deep within the Earth in a process called subduction, in which one tectonic plate moves under another. This process forms carbon dioxide, which can be released into the atmosphere by volcanic eruptions or hydrothermal vents.

Human impacts on the carbon cycle:

Global demand for Earth's limited fossil fuel reserves has risen since the beginning of the Industrial Revolution. Fossil fuels are considered a nonrenewable resource because they are being used up much faster than they can be produced by geological processes.

When fossil fuels are burned, carbon dioxide is released into the air. Increasing use of fossil fuels has led to elevated levels of atmospheric CO_2. Deforestation, the cutting down of forests, is also a major contributor to increasing CO_2 levels. Some of the extra CO_2 produced by human activities is taken up by plants or absorbed by the ocean, but these processes don't fully counteract the increase. So, atmospheric CO_2 levels have risen and continue to rise.

6.4. BIOGEOCHEMICAL CYCLE OF SULFUR

The sulfur cycle is the collection of processes by which sulfur moves to and from minerals, waterways and living systems. Sulfur is the 10th most abundant element in the environment. It is an essential element for organisms, because it is a constituent of many proteins, amino acids, vitamins, enzymes and cofactors, and sulfur compounds can be used as oxidants or reductants in microbial respiration.

The global sulfur cycle involves the transformations of sulfur through different oxidation states, which play an important role in both geological and biological processes.

The Sulfur cycle: There are different steps in the sulfur cycle. These steps are:

1. Mineralization of organic sulfur into inorganic forms, such as hydrogen sulfide (H_2S), elemental sulfur, as well as sulfide minerals.
2. Oxidation of hydrogen sulfide, sulfide, and elemental sulfur (S) to sulfate (SO_4^{2-}).
3. Reduction of sulfate to sulfide.
4. Incorporation of sulfide into organic compounds (including metal-containing derivatives).

Assimilative sulfate reduction (sulfur assimilation):The sulfate (SO_4^{2-}) is reduced by plants, fungi and various prokaryotes.

Desulfurization : The organic molecules containing sulfur can be desulfurized, producing hydrogen sulfide gas (H2S, oxidation state = –2). An analogous process for organic nitrogen compounds is deamination.

Oxidation of hydrogen sulfide: It produces elemental sulfur (S8), oxidation state = 0. This reaction occurs in the photosynthetic green and purple sulfur bacteria and some chemolithotrophs. Often the elemental sulfur is stored as polysulfides.

Oxidation in elemental sulfur: Sulfur oxidizers produce sulfate.

Dissimilative sulfur reduction: The elemental sulfur can be reduced to hydrogen sulfide.
Dissimilative sulfate reduction: The sulfate reducers generate hydrogen sulfide from sulfate.
Sulfur has six oxidation states in nature, which are -2, 0, +2, +4, and +6. The common sulfur species of each oxidation state are listed as follows:
S_2-: H_2S, FeS, FeS_2, CuS
SO: native, or elemental, sulfur
S^{4+}: SO_2, sulfite (SO_3^{2-})
S^{6+}: SO_4^{2-} (H_2SO_4, $CaSO_4$), SF_6
Sulfur sources and sinks:
Sulfur is found in oxidation states ranging from +6 in SO_4^{2-} to -2 in sulfides. Thus, elemental sulfur can either give or receive electrons depending on its environment. On the anoxic early Earth, most sulfur was present in minerals such as pyrite (FeS_2). Over Earth history, the amount of mobile sulfur increased through volcanic activity as well as weathering of the crust in an oxygenated atmosphere. Earth's main sulfur sink is the oceans SO_4^{2-}, where it is the major oxidizing agent.

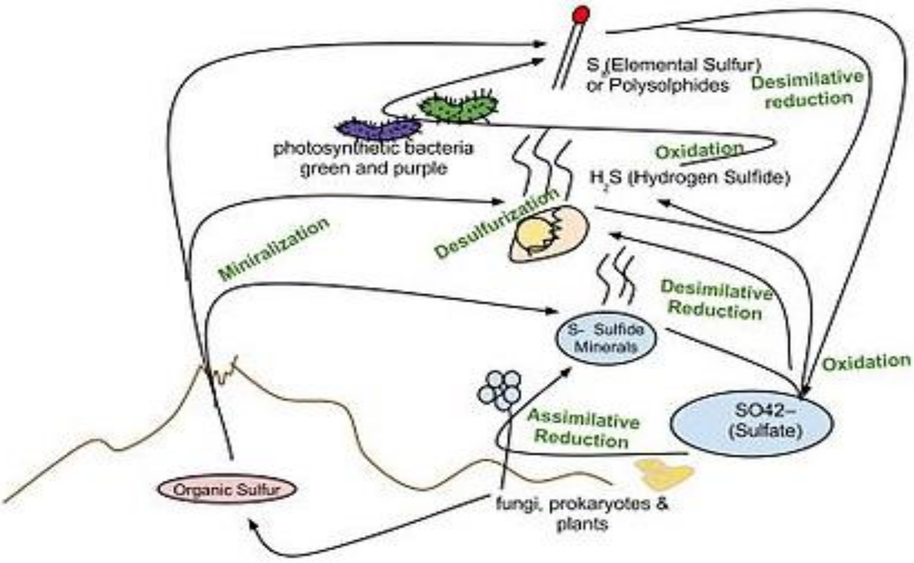

Fig: 6.2 Sulfur Cycle

When SO_4^{2-} is assimilated by organisms, it is reduced and converted to organic sulfur, which is an essential component of proteins. However, the biosphere does not act as a major sink for sulfur, instead the majority of sulfur is found in seawater or sedimentary rocks including: pyrite rich shales, evaporite rocks (anhydrite and baryte), and calcium and magnesium carbonates (i.e. carbonate-associated sulfate).

The amount of sulfate in the oceans is controlled by three major processes:

1. Input from rivers.
2. Sulfate reduction and sulfide re-oxidation on continental shelves and slopes
3. Burial of anhydrite and pyrite in the oceanic crust.

Biologically and thermochemically driven sulphate reduction, sulfur can be reduced both biologically and thermochemically.

1. The microbial process that converts sulfate to sulfide for energy gain.
2. A set of forward and reverse pathways that progress from the uptake and release of sulfate by the cell to its conversion to various sulfur intermediates, and ultimately to sulfide which is released from the cell.

Sulfide and thiosulfate are the most abundant reduced inorganic sulfur species in the environments and are converted to sulfate, primarily by bacterial action, in the oxidative half of the sulfur cycle. Bacterial sulfate reduction (BSR) can only occur at temperature from 0 up to 60–80 °C because above that temperature almost all sulfate-reducing microbes can no longer metabolize. Few microbes can form H2S at higher temperatures but appear to be very rare and do not metabolize in settings where normal bacterial sulfate reduction is occurring.
Thermochemical sulfate reduction (TSR) occurs at much higher temperatures (160–180 °C) and over longer time intervals, several tens of thousands to a few million years.

The main difference between these two reactions is clear, one is organically driven (driven by organisms) and the other is chemically driven. Therefore, the temperature for thermochemical sulfate reduction is much higher due to the activation energy required to reduce sulfate. Bacterial sulfate reductions require lower temperatures because the sulfur reducing bacteria can only live at relatively low temperature (below 60 °C).

Human impact: Human activities have a major effect on the global sulfur cycle. The burning of coal, natural gas, and other fossil fuels has greatly increased the amount of S in the atmosphere and ocean and depleted the sedimentary rock sink. Without human impact, sulfur would stay tied up in rocks for millions of years until it was uplifted through tectonic events and then released through erosion and weathering processes.

When SO_2 is emitted as an air pollutant, it forms sulfuric acid through reactions with water in the atmosphere. Once the acid is completely dissociated in water the pH can drop to 4.3 or lower causing damage to both man-made and natural systems.

6.5. SUMMARY

Biogeochemical cycles describe the natural pathways through which essential chemical elements and compounds are continuously circulating between the living and non-living components of the earth`s ecosystem.

6.6. SELF-ASSESSMENT

1. What is a biogeochemical cycle? How many types of biogeochemical cycles? Explain any one of the biogeochemical cycles studied.
2. Give a detailed account of biogeochemical cycle of carbon.
3. Discuss various steps in biogeochemical cycle of sulfur.

6.7. SUGGESTED READINGS

1. Ambasht, R. S. and Ambasht, N. K., 1999. A Textbook of Ecology, CBS Publishers and Distributers, New Delhi.
2. Chapman, J. L. and Reiss, M. J., 2003. Ecology: Principles and Applications, (2 nd Edition) Cambridge University Press, UK.
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Dr K.Babu

LESSON -7
DYNAMIC PHYTOGEOGRAPHY

7.0. OBJECTIVES

To understand major divisions and basic principles of Phytogeography and other related aspects of it like endemism, continental drift, age and area hypothesis, migration and centre of origin

STRUCTURE OF THE LESSON:

7.1. INTRODUCTION

According to Campbell (1926), the main theme of plant geography is to discover the similarities and diversities in the plants and floras of the present and past found in widely separated parts of the earth.

Wulff (1943) states that Phytogeography is the study of distribution of plant species in their habitats and elucidation of origin and history of development of floras.

According to Croizat (1952), Phytogeography is the study of migration and evolution of plants in time and space.

7.2. MAJOR DIVISIONS OF PHYTOGEOGRAPHY

There are two major divisions of Phytogeography:

(i) Descriptive or Static Phytogeography: This deals with the actual description of floristic or vegetational groups found in different parts of the world. Early plant geographers described floras and attempted to divide earth into floristic and botanical zones.

(ii) Interpretive or Dynamic Phytogeography: This deals with the dynamics of migration and evolution of plants and floras. It explains the reasons for varied distribution of plant species in different parts of the world. It is a borderline science involving synthesis and integration of data and concepts from several specialized disciplines like ecology, physiology, genetics, taxonomy, evolution, palaeontology and geology. Good (1931), Mason

(1936), Cain (1944) and some others have pointed out the factors involved in the distribution of plants.

7.3. BASIC PRINCIPLES

G.H.M. Lawrence (1951) has suggested the following thirteen modern principles of Phytogeography which are classified into four groups:

I. Principles concerning environment:

1. The distribution of plants is primarily controlled by climatic conditions.
2. There has been variation in climate during geological history in the past which affected
3. migration of plants.
4. The relations between land masses and seas have varied in the past. The large land masses split up to form new land masses or continents which separated and reoriented. Land bridges between continents acted as probable routes for migration of plant and animal species. The land bridges became submerged in sea with the passage of time and the possibility for migration of plants and animals from one continent to another disappeared for ever.
5. Soil conditions on plains and mountains of different land masses show secondary control over the distribution of vegetation. Halophytes, psammophytes, calcicols, calcifobs etc. have developed because of edaphic conditions.
6. Biotic factors also play important role in distribution and establishment of plant species.
7. The environment is holocentric, i.e., all environmental factors have combined effects on the vegetation of a place (Ale & Pank, 1939).

II. Principles concerning plant responses:

1. Range of distribution of plants is limited by their tolerances. Each plant species has a range of climatic and edaphic conditions. Therefore, tolerance of a large taxon is the sum of tolerances of its constituent species.
2. Tolerances have a Genetic basis. The response of plants to environment is governed by their genetic makeup. Many of the crops through breeding and genetic changes have been made to grow in wider range of environmental conditions. In nature, hybrid plants have been found to have wider range of tolerances than their parents.
3. Different ontogenetic phases have different tolerances. Different developmental stages of plants show different degrees of tolerance, as for example seeds and mature plants are more tolerant to temperature and moisture variations than their seedlings.

III. Principles concerning the migration of floras and climaxes:

1. Large-scale migrations have taken place. The fossils and palaeoecological evidence reveal that large scale migrations of plants and animals have taken place during Mesozoic era and Tertiary periods.
2. Migration resulted from transport and establishment. In the process of migration plants are dispersed to new habitats through their propagules such as spores, seeds, bulbils etc., and there they are established if environmental conditions are favourable. Plants grow and reproduce there, and progeny perpetuates through ecological adjustments.

IV. Principles concerning the perpetuation and evolution of floras and climaxes:

1. Perpetuation depends first upon migration and secondly upon the ability of species to transmit the favourable variations to the progenies.
2. Evolution of floras and climaxes depends upon migration, evolution of species and environmental selections.

7.4. ENDEMISM

A taxon whose distribution is confined to a given area is said to be endemic to that area. The taxon may be of any rank, although it is usually at a family level or below, and its range of distribution may be wide, spanning an entire continent, or very narrow covering only a few square meters. The concept of endemism is important because in the past the formulation of biogeographic regions was based on it.

The limits of a region are determined by mapping the distributions of taxa where the outer boundaries of many taxa occur. Major regions are still determined as those that have the most endemics or stated another way, those that share the fewest taxa with other regions. As regions are further broken down into subdivisions, they will contain fewer unique taxa.

This has been criticized because it assumes that species ranges are stable, which they are not. An alternative method of determining biogeographic regions involves calculating degrees of similarity between geographic regions. The concept of endemic distribution of plants was put forth by A.P. de Candolle (1813). Engler (1882) suggested two categories of endemic forms; Paleoendemics which are survivors of ancient forms and indigenous or native forms which are confined to a particular place. According to area of distribution, the species may be continental endemics (restricted to a continent, endemic to a country, provincial, regional or local endemics (restricted to valley, hills, islands, etc.).

The endemic species have been grouped into the following categories:

(i) Relics or Palaeoendemics:
They are the survivors of once widely distributed ancestral forms, for example, Ginkgo biloba (restricted to China and Japan), Sequoia sempervirens (confined to coastal valleys of California, U.S.A.). Agathis australis, Metasequoia (Confined to Single valley in China). These species are called Palaeoendemics or epibionts. A great majority of the endemic species belonging to this type have many fossil relatives. They are also called living fossils. Because of little variability the endemics are adapted only to a particular environment and even if they reach new areas, they fail to establish themselves in new environment.

(ii) Neoendemics:
The other endemics may be modem species which have not had enough time for occupying a large area through migration. They are called neoendemics. There are several such genera which are widely endemic or few species of which are endemic. Neoendemics show good variability and have many biotypes, grow in diverse habitats and have wide tolerance for habitats.

Some of the well-known endemic genera in Indian flora are *Mecanopsis* (Papaveraceae) *Chloroxylon swietenia* (Flindersiaceae, formerly Rutaceae). *Catenaria* and *Butea* (Papilionaceae) *Caesulia* (Compositae), *Petalidium* (Acanthaceae), etc. *Eletteria repens* (Zingiberaceae) *Piper longum* (Piperaceae), *Piper nigrum* (Piperaceae), *Ficus religiosa*

(Moraceae), *Shorea robusta* (Dipterocarpaceae), *Vanda caerulea* (Orchidaceae), *Salmalia malabarica* (Bombacaceae) *Eleusine coracana* (Gramineae) are the well known endemic species of Indian flora.

There are some special terms to designate the quality of these endemics, viz. Local endemics which are found in small land features, progressive endemics which tend to spread with time retrogressive endemics in which case the area of distribution is contracting and micro-endemics (i.e., the endemics of lower groups)

(iii) Pseudo endemics:
These endemics arise due to mutation in existing population at a particular place. These pseudo endemics or mutants may or may not persist for long in the area where they originate. Endemism results from the failure on the part of species to disseminate its seeds, fruits, spores or propagules because of existence of great barriers like mountains, oceans and large deserts. The oceanic islands which are isolated from rest of the world by large expanses of water abound in endemic species and water barrier checks the migration of those species outside their original habitat.

7.5. CONTINENTAL DRIFT

The theory of continental drift was propounded by Wegner (1912 - 1924) According to him, the whole land mass of the world was a single super continent during Palaeozoic era. He named it Pangaea. That super continent was surrounded by sea on all the sides which was named Panthalassa.

During Mesozoic, Pangaea split up into two large landmasses: Laurasia in the north and Gondwanaland in south.

The two landmasses were separated by Tethys Sea. Du Toit (1937), however, suggested that Laurasia and Gondwanaland existed from the very beginning. The two large landmasses having characteristic flora and fauna broke up into new landmasses called continents. Laurasia gave rise to Eurasia, Greenland and North America and similarly Gondwanaland gave rise to South America, Africa, India, and Polynesia, Australia Antarctica etc.

About 135 million years ago, reorientation of continents began. The continents were drifted apart by the oceans. This is called Continental Drift. The occurrence of Dinosaurs and many fossil plants lend support to the existence of Laurasia and Gondwanaland. With the separation of continents, the distribution areas of several plant and animal species got separated and gave rise to discontinuous distribution areas.

7.6. AGE AND AREA HYPOTHESIS (Age and area theory)

This hypothesis was proposed by J. W. Willis (1915) based on his extensive studies of geographical distribution of certain plant species in tropics. Based on his findings Willis postulated that the species which evolved earlier occupy greater areas than those which appeared later in the evolutionary sequence. According to this hypothesis, the frequency of a species over an area is directly proportional to its age in scale of evolution and age of species is directly related to the area of its distribution.

Thus, a small area of distribution of a species will indicate its relatively young age. Willis has quoted several examples such as *Impatiens, Primula, Gentiana, Rhododendron* in support of his hypothesis. Genus *Coleus* may be quoted here as an example in support of this hypothesis. There are two species of *Coleus* namely *C. elongatus and C. barbatus*.
The former species is endemic while the latter is widely distributed. Based on areas under distribution of these species Willis considered C. elongatus less evolved and derived from *C barbalins.* Willis has also pointed out that most endemics are found to be members of large and successful genera. The age and area hypothesis, however, is not universal and it has been criticized by many.

7.7. PLANT MIGRATION

The newly evolved species starts migration to new areas and side by side it undergoes further evolutionary changes. The dispersal of gemmules and propagules is brought about by several agencies like wind, water, glaciers, insects, animals, even man. The dispersal is followed by ecasis. Migration may be adversely affected and sometimes even totally stopped by some factors called migration barriers. Barriers in the dispersal of species may be classified as ecological or environmental and geographical.

The climate, an ecological barrier, plays important role in distribution and establishment of species. Unsuitable climatic conditions or change of climate in particular area forces the species to migrate from one place to another and the failure of some species to migrate leads them to gradual extinction. Besides climate, there are geographical barriers, as for example, high mountains, vast oceans or deserts.

The freshwater plants, for example, cannot be dispersed across oceans if their propagules are suitable only for freshwater dispersal and similarly gemmules or propagules of land plants from one country cannot reach other countries separated by vast oceans and mountains. Species are called natives of the place of occurrence if they originated there. Outside the area of its origin, the species is referred to as exotic. Exotic species reach new area through migration. If any species is introduced intentionally in new area by man then it is called introduced species.

7.8. CENTRE OF ORIGIN

A centre of origin (or centre of diversity) is a geographical area where a group of organisms, either domesticated or wild, first developed its distinctive properties. They are also considered centers of diversity. Centers of origin were first identified in 1924 by Nikolai Vavilov.

Locating the origin of crop plants is basic to plant breeding. This allows one to locate wild relatives, related species, and new genes (especially dominant genes, which may provide resistance to diseases). Knowledge of the origins of crop plants is important in order to avoid genetic erosion, the loss of germplasm due to the loss of ecotypes and landraces, loss of habitat (such as rainforests), and increased urbanization. Germplasm preservation is accomplished through gene banks (largely seed collections but now frozen stem sections) and preservation of natural habitats (especially in centers of origin).

Vavilov centres:

A Vavilov Centre (of Diversity) is a region of the world first indicated by Nikolai Vavilov to be an original centre for the domestication of plants. For crop plants, Nikolai Vavilov identified differing numbers of centers: three in 1924, five in 1926, six in 1929, seven

In 1931, eight in 1935 and reduced to seven again in 1940.

Vavilov argued that plants were not domesticated somewhere in the world at random, but that there were regions where domestication started. The centre of origin is also considered the center of diversity.

Vavilov centres are regions where a high diversity of crop wild relatives can be found, representing the natural relatives of domesticated crop plants. Later in 1935 Vavilov divided the centers into 12, giving the following list:

1. Chinese centre
2. Indian centre
3. Indo-Malayan centre
4. Central Asiatic centre
5. Persian centre
6. Mediterranean centre
7. Abyssinian centre
8. South American centre
9. Central American centre
10. Chilean centre
11. Brazilian-Paraguayan centre
12. North American centre

Importance:

In 2016, researchers linked the origins and primary regions of diversity ("areas typically including the locations of the initial domestication of crops, encompassing the primary geographical zones of crop variation generated since that time, and containing relatively high species richness in crop wild relatives") of food and agricultural crops with their current importance around the world in modern national food supplies and agricultural production. The results indicated that foreign crops were 68.7% of national food supplies as a global means, and their usage has greatly increased in the last fifty years.

7.9. SUMMARY

Phytogeography is significant because it helps us to understand and manage ecosystems, identify and conserve biodiversity hotspots and plan for climate change. It provides crucial insights into a region`s ecological history, the influence of physical and biological factors on plant life.

7.10. SELF-ASSESSMENT

1. What is phytogeography? Discuss various principles of dynamic phytogeography.
2. Write short notes on
    a. Endemism
    b. Continental drift
    c. Age and area hypothesis

d. Plant migration
e. Centre of origin

7.11. SUGGESTED READINGS

1. Ambasht, R. S. and Ambasht, N. K., 1999. A Textbook of Ecology, CBS Publishers and Distributers, New Delhi.
2. Chapman, J. L. and Reiss, M. J., 2003. Ecology: Principles and Applications, (2 nd Edition) Cambridge University Press, UK.
3. Odum, E. P. and Gary W. Barrett, 2011. Fundamentals of Ecology (5 th Edition), Saunders ISBN

Dr K.Babu

LESSON -8

CURRENT CONCEPTS, LEVELS OF BIODIVERSITY LIKE SPECIES, ECOSYSTEM AND GENETIC DIVERSITIES

OBJECTIVES:
The chapter on biodiversity typically revolves around understanding its concept, exploring its three main levels, and emphasizing the vital need for its conservation.

STRUCTURE OF THE LESSON:

8.1. INTRODUCTION

Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part. Current concepts emphasize that biodiversity is not just about the number of species but also includes the variety within species and the diversity of ecosystems and ecological functions, which are all intrinsically interconnected.

8.2. CURRENT CONCEPTS OF BIODIVERSITY

8.2.1. Interconnectedness:

A primary concept is the dynamic, evolving, and Interconnected nature of people and place, acknowledging that social and biological dimensions are interrelated. The health of ecosystems, species, and genetic diversity all depend on one another. Statement correctly highlights a crucial contemporary concept in the study of biodiversity: the understanding that ecosystems, species, and genetic diversity are all dynamically and mutually dependent. This interconnectedness is a central theme in modern ecological and conservation science, emphasizing a holistic view of the natural world.

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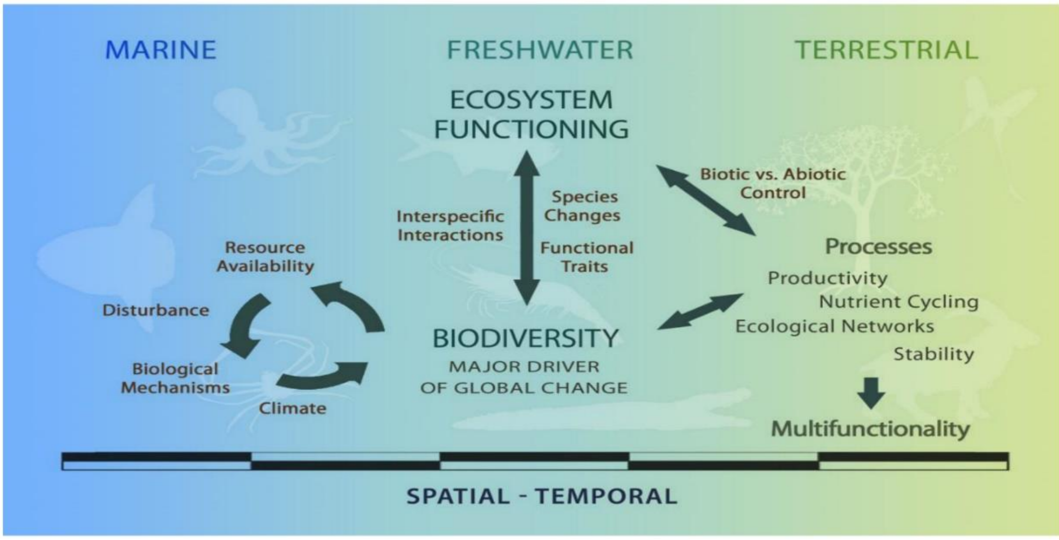

Figure 8.1. Common patterns in the relationship between biodiversity and ecosystem functioning (BEF). Biodiversity interacts with climate, resource availability, disturbance regimes, and ecological processes at different scales to configure ecosystem functioning. Biodiversity effects on ecosystem functioning depend on the functional traits of component species, interspecific interactions, the sequence of species changes, and the relative biotic versus abiotic control over process rates

2. The Significance of Interconnectedness

A. Mutual Dependence: The health of one level of biodiversity directly influences the others. For example, a decline in genetic diversity makes a species less resilient, which can reduce species diversity and, in turn, degrade the overall function and health of an entire ecosystem.

B. Social-Ecological Systems: Modern concepts go further to recognize that human societies ("people") are not separate from nature but are integral parts of complex social-ecological systems. Human actions drive significant changes in biodiversity, and in turn, human well-being relies fundamentally on the services provided by healthy, diverse ecosystems.

C. Holistic Management: Acknowledging these interrelationships shifts the focus from managing single species in isolation to comprehensive, ecosystem-based management and conservation strategies that consider all factors simultaneously. This approach is essential for developing sustainable solutions for biodiversity loss and climate change.

8.2.2. Ecosystem Services:

Modern understanding focuses heavily on the essential "ecosystem services" that biodiversity provides for human well-being and a sustainable planet. These include critical functions like pollination, nutrient cycling, climate regulation, water purification, and disease control. Ecosystem services are the many and varied benefits that nature provides to humanity, free of charge. The modern understanding of biodiversity places these services front and center,

recognizing that human economies, well-being, and indeed, survival, are entirely dependent on the continued, healthy functioning of diverse ecosystems.
A. Categories and Examples of Ecosystem Services
services are generally categorized into four main types:

A.1. Provisioning Services: These are the tangible products people obtain from ecosystems. Biodiversity ensures a wide variety of these resources are available. Examples: Food (crops, livestock, fisheries), fresh water, timber, fiber (cotton, hemp), and genetic resources for medicines and biotechnology.

A.2. Regulating Services: These are the benefits obtained from the regulation of ecosystem processes. Biodiversity enhances the efficiency and stability of these systems. Examples: 1. Pollination: Essential for the reproduction of over 75% of the world's food crops. A diversity of pollinators (bees, butterflies, birds, etc.) ensures crop yields and resilience. 2. Climate Regulation: Forests and oceans absorb carbon dioxide, helping to stabilize the global climate.3. Water Purification: Wetland ecosystems and soil organisms filter pollutants and pathogens from water, providing clean drinking water sources. 4. Disease Control: Diverse ecosystems can regulate the spread of certain infectious diseases by providing a wide range of hosts that dilute the pathogen's ability to jump to humans.

A.3. Cultural Services: These are the non-material benefits people gain from ecosystems through spiritual enrichment, cognitive development, reflection, and aesthetic experiences. Examples: Recreation and tourism (hiking, birdwatching), aesthetic value (landscapes), spiritual and religious significance, and educational opportunities.

A.4. Supporting Services: These are the foundational services necessary to produce all other ecosystem services. Examples: Nutrient cycling (nitrogen, phosphorus), soil formation and fertility, primary production (plant growth), and habitat provision for all species.

A.5.The Link to Biodiversity: A central concept in modern ecology is that the level of biodiversity in an ecosystem directly affects its ability to provide these vital services reliably. High diversity often translates to increased functional redundancy and resilience, ensuring that even if some species decline, others can continue performing essential roles. The ongoing loss of biodiversity is therefore not just an environmental issue, but a critical threat to human prosperity and security.

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Figure 8.2: Categories and Examples of Ecosystem Services

8.2.3. Resilience and Stability:

Diverse ecosystems tend to be more stable, productive, and resilient in the face of environmental stressors and changes (e.g., climate change or pollution). In the context of biodiversity, resilience and stability refer to an ecosystem's capacity to handle and recover from environmental disruptions like disease, climate change, or pollution. High biodiversity is widely considered to be a key factor in increasing both resilience and stability.

A. Key Concepts: In the context of biodiversity, resilience and stability describe an ecosystem's capacity to handle disturbances and maintain its core functions. Biodiversity is a crucial factor in enhancing both these properties. Stability refers to the ability of a system to remain in its original state or return to it quickly after a temporary disturbance. An ecosystem is considered stable if it experiences few or small disturbances, or if its functions and components remain largely unchanged despite disturbances. Resilience is the capacity of a system to absorb changes, undergo disturbance, and still maintain its essential.

B. Definitions:

Stability: Refers to an ecosystem's ability to resist change when confronted by a disturbance, maintaining its current state with minimal variation. A stable ecosystem exhibits consistent functions and species populations over time.

Resilience: The capacity of an ecosystem to absorb a disturbance, adapt to changes, and reorganize while retaining essentially the same function, structure, and identity, or to recover quickly to its original state after a disturbance has occurred. Higher biodiversity contributes significantly to both resilience and stability through several mechanisms:

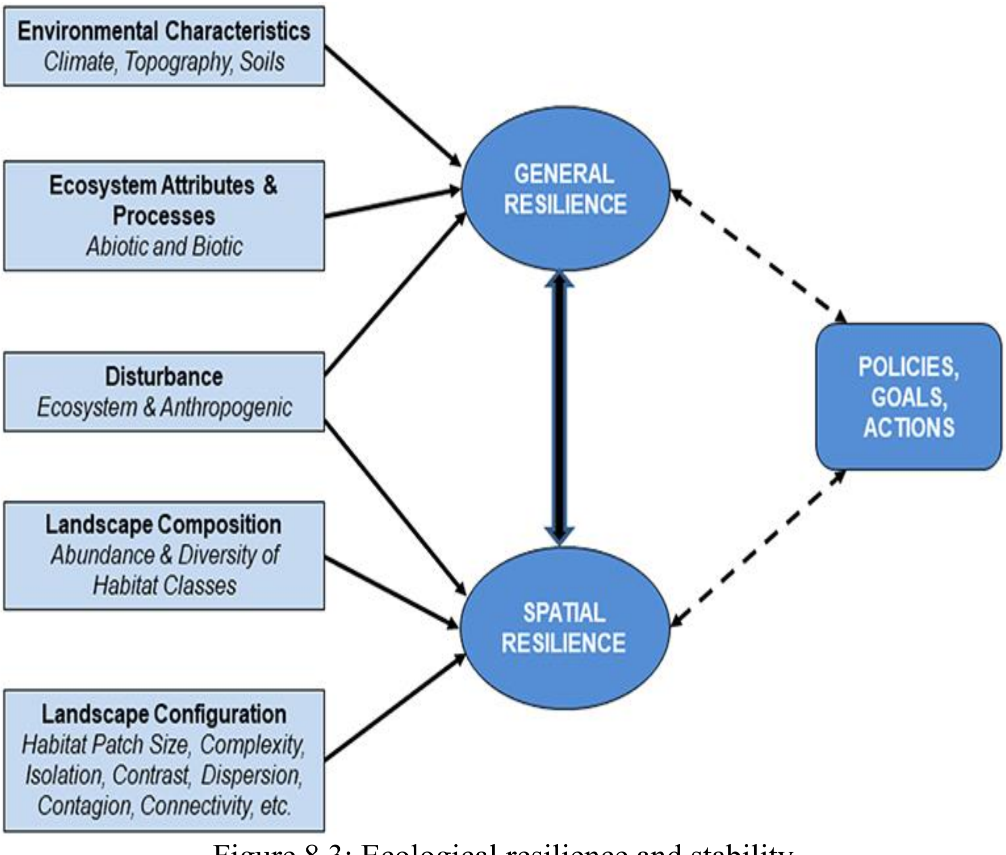


Figure 8.3: Ecological resilience and stability

C. How Biodiversity Enhances Resilience and Stability

C.1.Functional Redundancy: A diverse ecosystem often has multiple species that perform similar or overlapping ecological roles (e.g., several different species of pollinators). If one species is negatively affected by a stressor (like a disease or climate change), another species can fill the gap, ensuring the essential ecosystem function continues uninterrupted. This acts as an "insurance policy" for the ecosystem.

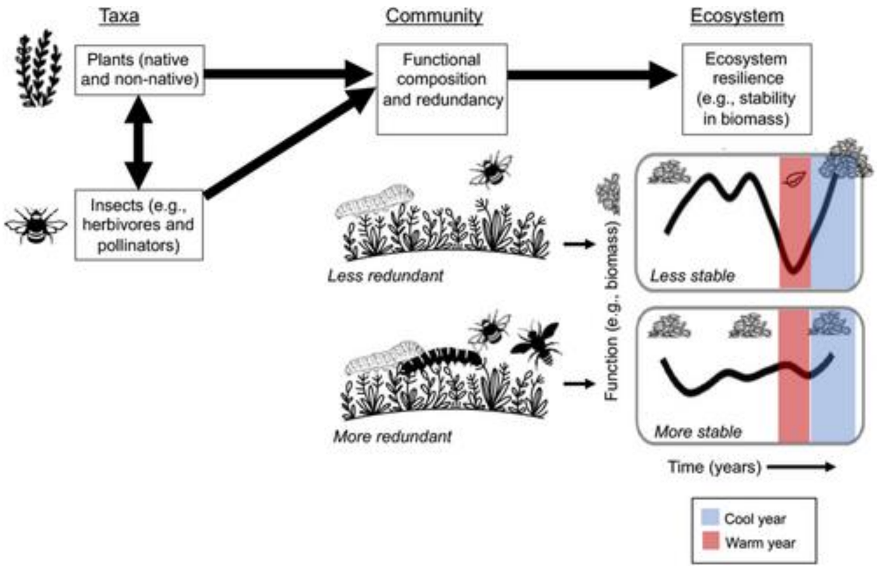


Figure 8.4: Diverse ecosystem overlapping ecological rolls

C.2.Response Diversity: Different species within the same functional group often react to environmental changes in different ways. This variety of responses means that while some species may struggle under new conditions, others may thrive, ensuring that the function of the ecosystem is maintained.

C.3. Genetic Variation: High genetic diversity within a single species increases the likelihood that some individuals will possess traits that make them more tolerant or resistant to new threats, such as new diseases or extreme climate conditions. This allows the species and the ecosystem to adapt and evolve over time, which is key to long-term resilience.

C.4. Asynchronous Dynamics: In a diverse community, different species' populations fluctuate asynchronously over time; a bad year for one species might be a good year for another. These differential responses average out at the community level, leading to greater overall ecosystem stability and consistent biomass production.

C.5. Resource Partitioning: With a greater variety of species utilizing resources in different ways (e.g., different rooting depths or nutrient preferences), an ecosystem makes more efficient use of available resources. This leads to higher overall productivity and leaves fewer resources available for invasive species to exploit, thereby increasing the system's resistance to invasion.

8.2.4. Functional Diversity:

Beyond the number of species or genes, there is a focus on "functional diversity," which refers to the variety of biological roles and functions (e.g., decomposers, pollinators, predators) played by organisms within an ecosystem. This ensures that an ecosystem can operate effectively. Functional diversity is a contemporary concept in ecology that focuses not just on the number of different species, but on the variety of ecological roles or functions that organisms perform within an ecosystem. It addresses the range of traits and functions across all species present.

Key Aspects of Functional Diversity

A. Definition: It measures the value and range of those species traits that influence how an ecosystem operates—such as how efficiently nutrients are cycled, how much biomass is produced, or how resilient the system is to disturbance.

B. Focus on Traits: Instead of focusing on species identity (e.g., this is a pine tree vs. an tree), it focuses on specific functional traits (e.g., rooting depth, leaf nitrogencontent, decomposition rate, type of pollinator).

C. Ecosystem Functioning: A core principle is that the variety and spread of these traits have a direct and powerful impact on essential ecosystem processes like primary production, water filtration, pest control, and soil fertility.

D. Relationship to Species Diversity: While a higher number of species often leads to higher functional diversity, this isn't always the case. Two ecosystems could have the same number of species, but the one with a wider range of functional traits (e.g., incorporating both deep-rooted and shallow-rooted plants) would have higher functional diversity and potentially better overall function.

E. Resilience and Redundancy: Functional diversity is closely linked to ecosystem resilience. Having multiple species that perform similar functions (functional redundancy) ensures that the function persists even if some species are lost.

F. Example of Functional Diversity: Functional diversity helps ecologists understand the mechanisms linking biodiversity to ecosystem services and overall system health.

Consider a grassland ecosystem:

Low Functional Diversity: A grassland composed entirely of a single species of fast-growing, shallow-rooted grass would have low functional diversity. It might be productive in a good year but highly vulnerable to drought or disease.

High Functional Diversity: A grassland composed of various grasses, deep-rooted legumes, and nitrogen-fixing plants would have high functional diversity. The different root systems access water at various depths, and the legumes enrich the soil. This diversity of functions makes the entire ecosystem more productive, stable, and resilient to environmental changes.

8.2.5. Anthropocene and Conservation:

Current concepts acknowledge that human activities are the primary drivers of rapid biodiversity loss, a process often referred to as the sixth mass extinction. This has led to an increased emphasis on urgent conservation efforts, public policy, and sustainable practices.

The concept of the Anthropocene fundamentally acknowledges that human beings have become the dominant force shaping Earth's systems, from climate to geology and biodiversity. This concept has led to significant shifts in how we approach conservation, moving from protecting wilderness "from people" to implementing strategies for "people and planet" in a human-modified world.

A. The Anthropocene as Context for Biodiversity Loss
The Anthropocene is characterized by an unprecedented scale of human impacts, often referred to as “Great Acceleration" since the mid-20th century. These impacts are the primary causes of what many scientists call the sixth mass extinction event:

B. Habitat Destruction and Land-Use Change: Conversion of land for agriculture, urban sprawl, and infrastructure is a leading cause of habitat loss, significantly altering about 75% of the Earth's ice-free land surface.

C. Climate Change: Human-induced climate change is altering ecosystems faster than species can adapt, forcing shifts in species ranges and increasing extinction risks.

D. Overexploitation and Pollution: Overhunting, overfishing, widespread pollution (including plastics and chemicals), and the introduction of invasive species further degrade ecosystems and threaten species survival.

E. Anthropogenic Mass: In 2020, the total mass of human-made materials (buildings, concrete, plastic, etc.) for the first time exceeded the total biomass of all living things on Earth, a stark indicator of human dominance

8.3. LEVELS OF BIODIVERSITY

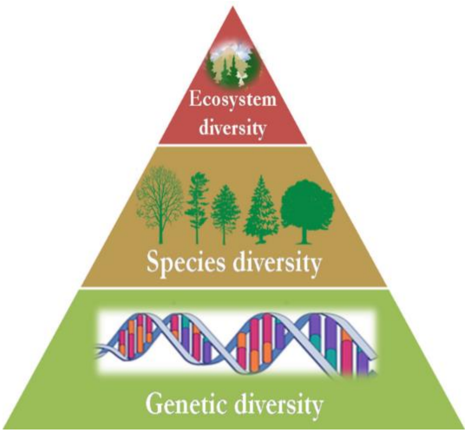


Figure 8.5: Biodiversity is typically discussed and measured at three main hierarchical levels:

8.3.1. Genetic Diversity
This refers to the variety of genetic information contained within all individual organisms of a single species. Genetic diversity encompasses the variations in genes, alleles, and DNA sequences among individuals. This variation is crucial for a species' ability to adapt to new environmental conditions, diseases, or climate change. A higher genetic diversity increases the chances of a species' survival. Example: The presence of approximately 1,000 different varieties of mangoes in India, each with a unique genetic makeup, or the differences in skin color and height among humans, are examples of genetic diversity within a single species.
Key Aspects of Genetic Diversity

Genetic diversity refers to the total number of genetic characteristics that make up the genetic makeup of a species, enabling a population to adapt to both short-term environmental changes and long-term evolutionary pressures.

Definition: It encompasses the variations in genes, alleles, and DNA sequences among individuals within a single species or population. It is the fundamental source of all other levels of biodiversity.

Mechanism of Variation: This diversity arises primarily through genetic recombination during sexual reproduction and random gene mutations.

Adaptation and Survival: High genetic diversity acts as a form of biological "insurance." It increases the likelihood that some individuals in a population will possess traits that make them resistant to new diseases, tolerant of new climate conditions (e.g., drought, heat), or better able to survive environmental stressors.

Vulnerability: Conversely, low genetic diversity, often found in endangered or inbred populations, makes a species highly vulnerable to extinction from a single disease outbreak or sudden environmental shift, as the entire population might share the same vulnerability.
Evolutionary Potential: Genetic diversity provides the raw material for natural selection and evolution, allowing species to adapt over evolutionary timescales.

Examples

1. Humans: The vast differences in skin color, height, blood types, and disease resistance among people are all expressions of high genetic diversity within the human species (Homo sapiens).
2. Agriculture: The existence of thousands of different varieties of crop (e.g., hundreds of types of rice or potatoes) with different traits ensures food security by providing options resistant to specific pests or weather patterns.
3. Wild Animals: Cheetah populations, for example, have very low genetic diversity, which is a major factor in their vulnerability to diseases and conservation challenges.

Importance for Conservation
Maintaining genetic diversity is a crucial goal of conservation biology Conservation efforts often involve establishing protected areas large enough to support large, genetically diverse populations, and managing breeding programs in zoos and botanical gardens to prevent inbreeding and preserve maximum genetic variation.

8.3.2. Species Diversity
This is the variety of different types of species found within a particular region, habitat, or the planet. Species diversity is often measured in terms of species richness (the number of different species in an area) and species evenness (the relative abundance of individuals of each species). Areas like tropical rainforests typically have high species diversity. Example: The vast array of species in a coral reef (e.g., sea turtles, sharks, various fish, and corals) or a rainforest, compared to the lower diversity in a polluted stream, demonstrates species diversity. Species diversity is a measure of the variety of different types of species within a particular area or community, considering both how many species are present and how common they are. It is one of the three fundamental levels of biodiversity and is crucial for maintaining healthy and stable ecosystems.

Components of Species Diversity:
Species diversity is measured using two primary components:
Species Richness: This is the simplest component and refers to the total number of different species found in a specific area. For example, a forest with 50 different species of trees has greater species rich than a forest with only 10 species.

Species Evenness: This describes the relative abundance of individuals within each species in that area. An ecosystem has high species evenness if all species are represented by a similar number of individuals. If one or a few species dominate the area in population size, the evenness is low, even if the species richness is high. A community where species are equally abundant is generally considered to be more diverse overall.

Example: Consider two hypothetical communities, both with 10 different tree species (equal species richness).

Community A has 90 individuals of one species and only one individual for each of the other nine species (low evenness, lower diversity).

Community B has 10 individuals of each of the 10 species (high evenness, higher diversity).
Scales of Species Diversity Measurement

Ecologists also use a framework developed by R.H. Whittaker to measure species diversity across different spatial scales:

Alpha (α) Diversity: This is the species diversity within a single, local habitat or ecosystem (e.g., a single pond or a specific forest patch). It is often expressed as species richness

Beta (β) Diversity: This measures the difference or turnover in species composition between different ecosystems or habitats within a region. A high beta diversity means the two areas being compared share very few species.

Gamma (γ) Diversity: This represents the overall species diversity across a large geographic area or landscape that encompasses multiple ecosystems. It is the total species richness of a region.

Importance of Species Diversity: High species diversity is vital for ecosystem health and stability.

Ecosystem Stability and Resilience: Diverse ecosystems tend to be more stable, productive, and resilient in the face of disturbances like drought, disease, or climate change. The presence of many species performing similar roles (functional redundancy) ensures that if one is lost, others can compensate.

Ecosystem Services: Species diversity underpins essential ecosystem services crucial for human survival, including nutrient cycling, pollination of crops, water purification, and climate regulation.

Resource Efficiency: In species-rich communities, different species often use resources in unique ways (e.g., plants with different root depths accessing water at different levels), leading to more efficient use of available resources and higher overall productivity.

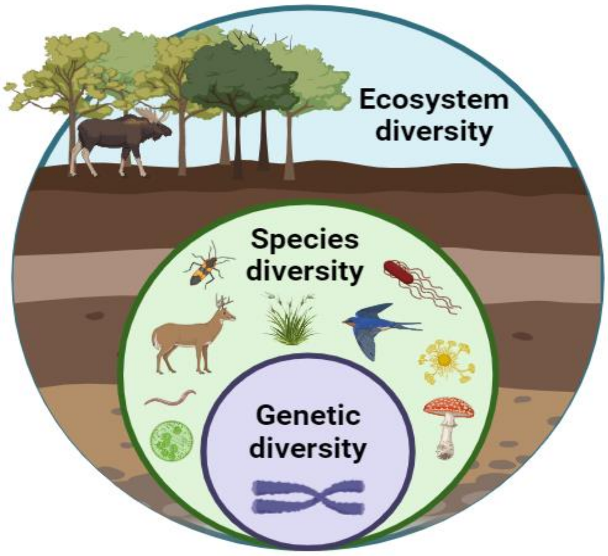


Figure 8.6: Ecosystem diversity

8.3.3. Ecosystem Diversity

Ecosystems can be studied at small levels or at large levels. The levels of organization are described below from the smallest to the largest:

A species is a group of organisms that are genetically related and can breed to produce fertile young. Organisms are not members of the same species if their members cannot produce offspring that can also have children. The second word in the two-word name given to every organism is the species name. For example, in Homo sapiens, sapiens is the species name.

A population is a group of organisms belonging to the same species that live in the same area and interact with one another.

A community is all the populations of different species that live in the same area and interact with one another. A community is composed of all the biotic factors of an area.

An ecosystem includes the living organisms (all the populations) in an area and the non-living aspects of the environment (Figure below). An ecosystem is made of the biotic and abiotic factors in an area. This is the variety of different habitats, biological communities, and ecological processes within a specific geographical area or across the planet. Explanation: It covers the diversity among different types of ecosystems like forests, grasslands, deserts, mountains, wetlands, oceans, and more. This level of diversity ensures a wide range of ecological functions and interactions necessary for the biosphere to function. Example: India, with its diverse range of ecosystems including alpine meadows in the Himalayas, rainforests in the Northeast, deserts in the West, and mangroves on the coast, demonstrates high ecosystem diversity.

Details

Ecosystem diversity is the broadest scale of biodiversity and refers to the variety of habitats, biological communities, and ecological processes within a given area.

Key Aspects of Ecosystem Diversity

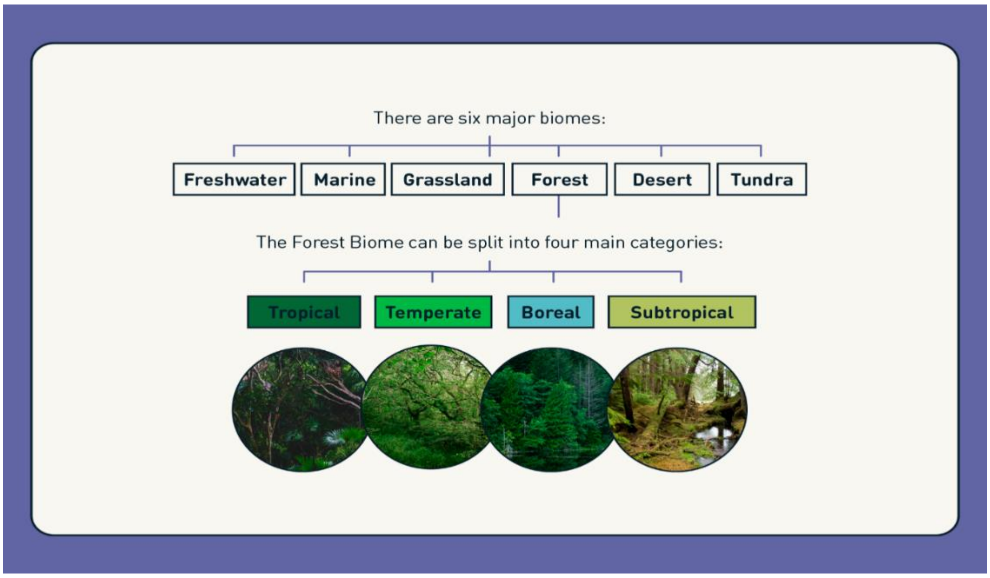


Figure 8.7: Key aspects of Ecosystem diversity

A. Definition: It encompasses the range of different ecosystems present on Earth or within a specific geographic region. Examples of distinct ecosystems include deserts, forests, wetlands, oceans, coral reefs, grasslands, and alpine meadows.

B. Focus on Interactions: Unlike species or genetic diversity, this level focuses on the complexity of the community interactions and physical environments, including factors like climate, geography, soil type, and nutrient availability.

C. Geographical Scope: Ecosystem diversity can be viewed at different scales, from local landscapes containing a mosaic of forests, rivers, and fields, to a continental view of biomes, or a global view of all the planet's ecological systems.

Importance of Ecosystem Diversity

1. Foundation of All Diversity: The variety of ecosystems provides the necessary physical templates and conditions that allow for species diversity and genetic diversity to evolve and be maintained. A wide range of ecosystems naturally leads to a wide range of species adapted to those specific environments.
2. Ecosystem Services: High ecosystem diversity ensures a full spectrum of ecosystem services are provided across a landscape. For example, a region with both forests and wetlands can provide timber production, carbon sequestration, and water filtration simultaneously.
3. Landscape Resilience: A diverse landscape, with a mix of different ecosystem types, is often more resilient to large-scale disturbances. If one ecosystem type is severely impacted (e.g., a forest fire), the surrounding different ecosystems may remain intact and help in recovery efforts.
4. Habitat for Migratory Species: Many species require multiple types of ecosystems to complete their life cycles, such as migratory birds that need breeding grounds, stopover sites, and wintering habitats. Preserving ecosystem diversity ensures these necessary habitats remain available.

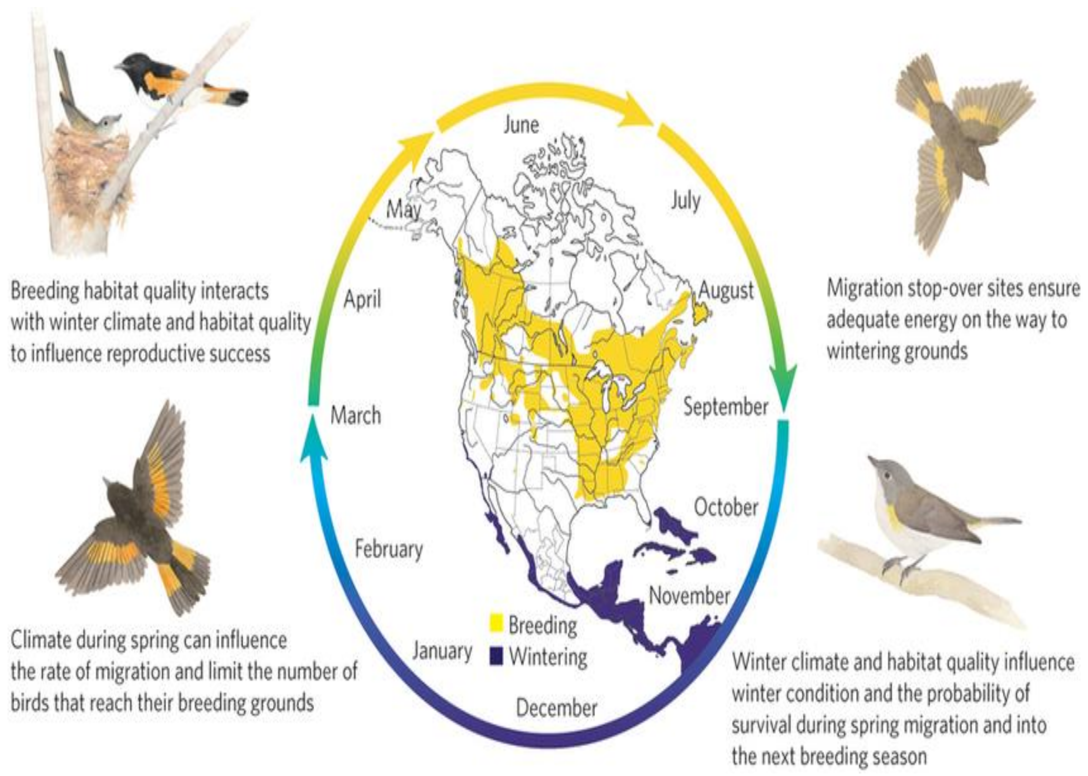
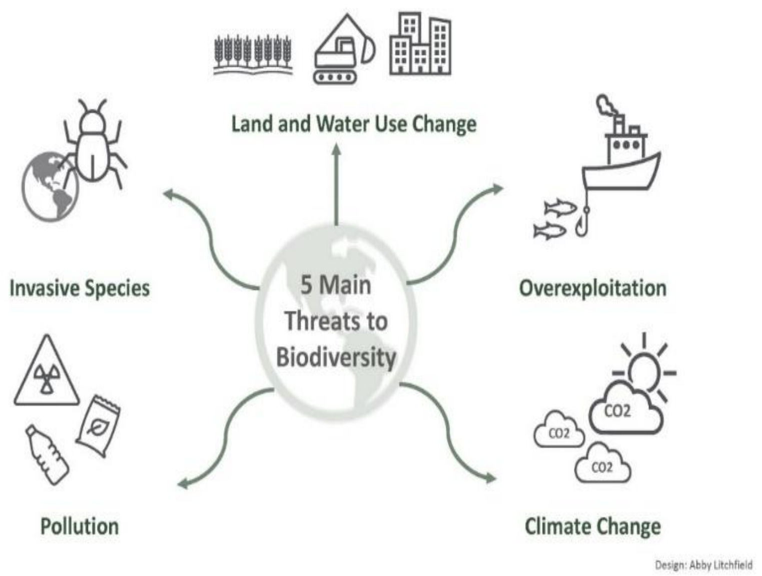


Figure 8.8: Migratory Species

8.4. THREATS AND CONSERVATION

Ecosystem diversity is directly threatened by large-scale habitat destruction and land-use change (e.g., converting a wetland to agricultural land). The goal of conservation at this level is often landscape-level planning that ensures the preservation of a representative sample of all ecosystem types within a region. Managing landscapes for ecosystem diversity is vital for maintaining the overall health and function of the biosphere.



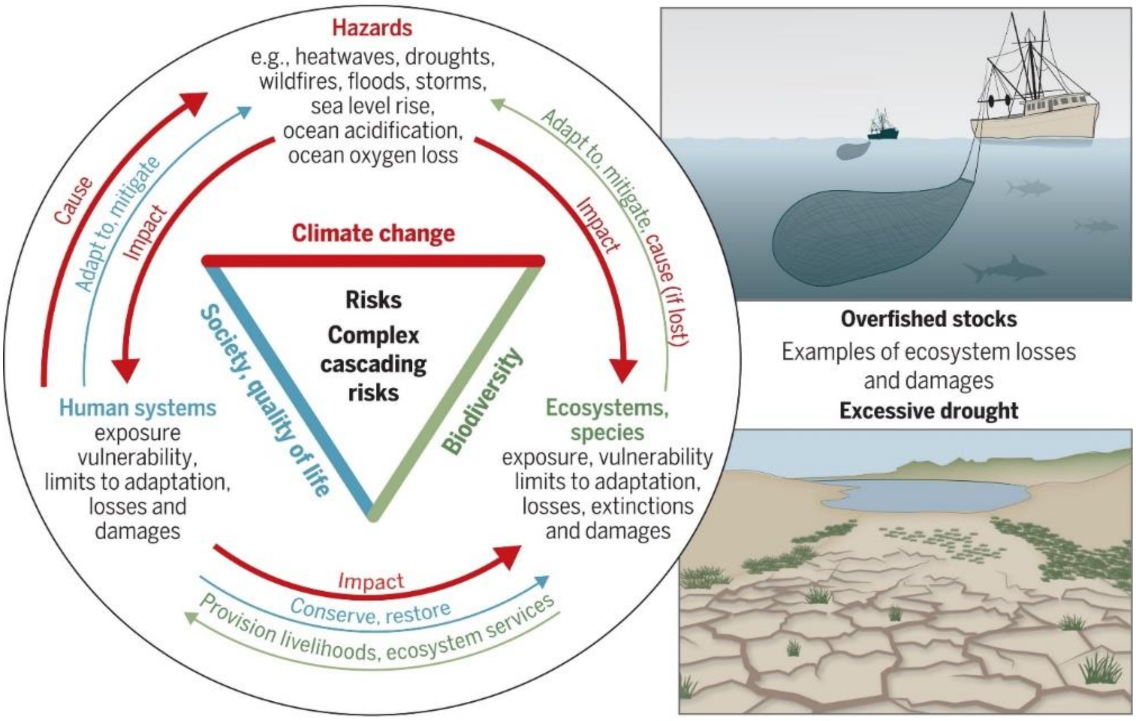


Figure 8.9: Climate, biodiversity, and human society are coupled through dynamic interactions across scales.

Human-caused exploitation and climate change are increasingly threatening biodiversity and nature's contributions to people, causing losses and damage exemplified through overfished stocks and excessive drought that harm productive habitats.

8.5 SUMMARY

Biodiversity is one of the most significant concepts in biology, referring to the incredible variety of life on Earth. From the genetic differences within species to the diversity of ecosystems, biodiversity is vital for ecosystem stability, human well-being, and the survival of countless species. Understanding biodiversity helps us appreciate and preserve the natural world around us. Biodiversity means the variety of living organisms on our planet, including plants, animals, fungi, and microorganisms. It covers diversity within species (genetic diversity), between species, and across entire ecosystems. This diversity forms the web of life, supporting essential services such as clean air, food, medicine, and climate regulation. Biodiversity can be divided into three main types, each playing a unique role in the environment. Understanding these levels helps highlight the complexity and resilience of life on Earth. Genetic Diversity: Variations found within a species, such as different breeds of dogs or varieties of rice. Species Diversity: The variety of species in a particular region, like the different mammals found in a forest. Ecosystem Diversity: The diversity of habitats, such as forests, deserts, wetlands, and oceans that support different communities of organisms. The importance of biodiversity cannot be overstated. It is the backbone of life-supporting systems on Earth, providing direct and indirect benefits to humans and other species.

Food Security: Over 75% of global food crops depend on natural pollinators and diverse ecosystems. Health and Medicine: More than half of modern medicines are derived from natural sources, including traditional medicinal plants and fungi. Climate Stability: Forests store about 80% of terrestrial biodiversity and absorb carbon dioxide, reducing climate change impacts. Clean Air and Water: Biodiversity supports the purification of air and water, with wetlands and forests acting as natural filters. Economic Value: Loss of biodiversity can result in significant economic loss, estimated around US$10 trillion globally each year.

Some notable examples of biodiversity that impact on our daily lives and planet health:

1. Amazon Rainforest: Home to around 10% of the known species on Earth.
2. Coral Reefs: Support thousands of marine species and provide coastal protection.
3. Medicinal Plants: Neem and turmeric are used in traditional medicine worldwide.
4. Agricultural Diversity: Varieties of rice, wheat, and maize have been developed from wild species to ensure food security.

8.6 SELF-ASSESSMENT

1. Define Biodiversity, Write Concept of Biodiversity?
2. Explain interconnectedness in Biodiversity?
3. Explain Different levels of Biodiversity?
4. Write about Functional Biodiversity?
5. Explain Ecosystem Biodiversity with examples?
6. How Biodiversity Enhances Resilience and Stability?
7. Explain Biodiversity threats and conservation?

8.7 SUGGESTED READING

1. An Advanced Textbook On Biodiversity: Principles And Practice Paperback – 30 March 2018 by K.V. Krishnamurthy
2. Biodiversity: Concepts and Conservation (English, Hardcover, B.B. Hosetti, S. Ramkrishna).
3. Biodiversity (PB) By William.
4. Biodiversity: Concept, Conservation and Biofuture By Fatik Baran Mandal

Prof A.Amrutha Valli

LESSON- 9

IUCN CATEGORIES OF THREAT; CAUSES OF BIODIVERSITY LOSS; KEYSTONE SPECIES

OBJECTIVES

The chapter deals with IUCN categories of threat, Causes of biodiversity loss and Keystone species, Structure of the categories level of threat exploring its three main levels.

STRUCTURE OF THE LESSON:

9.1. INTRODUCTION

9.2. HISTORY OF IUCN RED LIST CATEGORIES

9.3. USES OF IUCN RED LIST

9.4. NATURE OF THE CATEGORIES

9.5. ROLE OF THE DIFFERENT CRITERIA.

9.6. THE CRITERIA FOR CRITICALLY ENDANGERED, ENDANGERED AND VULNERABLE

9.7. INTRODUCTION OF BIODIVERSITY LOSS

9.8. CAUSES OF BIODIVERSITY LOSS

9.9. THE EFFECTS OF BIODIVERSITY LOSS ON THE ENVIRONMENT.

9.10. HOW BIODIVERSITY LOSS AFFECTS HUMANS?

9.11. KEYSTONE SPECIES

9.12. SUMMARY

9.13. SELF ASSESSMENT

9.14. SUGGESTED READING

9.1. INTRODUCTION

Assessing newly recognized species, the IUCN Red List also re-assesses the status of some existing species, sometimes with positive stories to tell. For example, good news such as the downlisting (i.e. improvement) of several species on the IUCN Red List categories scale, due to conservation efforts. The bad news, however, is that biodiversity is declining. Currently, there are more than 172,600 species on The IUCN Red List, with more than 48,600 species threatened with extinction, including 44% of reef building corals, 41% of amphibians, 38% of trees, 38% of sharks and rays, 34% of conifers, 26% of mammals, 26% of freshwater fishes and 11.5% of birds. Despite the high proportions of threatened species, we are working to reverse, or at least halt, the decline in biodiversity. Increased assessments will help to build The IUCN Red List into a more complete 'Barometer of Life'. To do this, we need to increase the number of species assessed to at least 260,000 and to reassess 142,000 of those species to ensure the information on their status is up to date so that we can monitor trends in change of status

9.2. HISTORY OF IUCN RED LIST CATEGORIES

The IUCN Red List is established in 1964, The International Union for Conservation of Nature's Red List of Threatened Species has evolved to become the world's most comprehensive information source on the global conservation status of animal, fungi and plant species.

9.3. USES OF IUCN RED LIST

The IUCN Red List is a critical indicator of the health of the world's biodiversity. Far more than a list of species and their status, It is a powerful tool to inform and catalyse action for biodiversity conservation and policy change, critical to protecting the natural resources we need to survive. It provides information about range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions.

The IUCN Red List is used by government agencies, wildlife departments, conservation-related non-governmental organisations (NGOs), natural resource planners, educational organisations, students, and the business community. The Red List process has become a massive enterprise involving the IUCN Biodiversity Assessment and Knowledge Team staff, partner organisations and experts in the IUCN Species Survival Commission and partner networks who compile the species information to make The IUCN Red List the indispensable product it is today.

To date, many species groups including mammals, amphibians, birds, freshwater fishes, reef building corals and trees have been comprehensively assessed. This will improve the global taxonomic coverage and thus provide a stronger base to enable better conservation and policy decisions.

The IUCN Red List is crucial not only for helping to identify those species in need of targeted recovery efforts, but also for focusing the conservation agenda by identifying the key sites and habitats that need to be protected. Ultimately, The IUCN Red List helps to guide and inform future conservation and funding priorities.

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It provides information about range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions.

9.4. NATURE OF THE CATEGORIES

Extinction is a chance process. Thus, a listing in a higher extinction risk category implies a higher expectation of extinction, and over the timeframes specified more taxa listed in a higher category are expected to go extinct than those in a lower one (without effective conservation action).

However, the persistence of some taxa in high-risk categories does not necessarily mean their initial assessment was inaccurate. All taxa listed as Critically Endangered qualify for Vulnerable and Endangered, and all listed as Endangered qualify for Vulnerable. Together these categories are described as ‘threatened’. The threatened categories form a part of the overall scheme. It will be possible to place all taxa into one of the categories

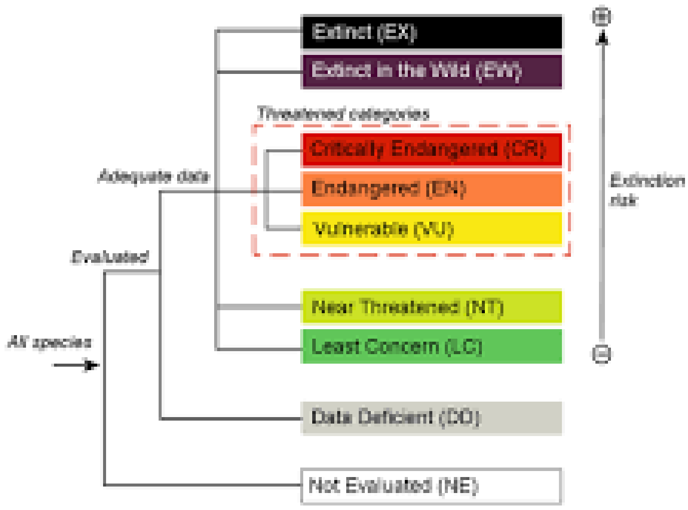

Figure 9.1: Structure of the categories level of threat

9.5. ROLE OF THE DIFFERENT CRITERIA

For listing as Critically Endangered, Endangered or Vulnerable there is a range of quantitative criteria; meeting any one of these criteria qualifies a taxon for listing at that Figure. It will never be clear in advance which criteria are appropriate for a particular taxon, each taxon should be evaluated against all the criteria, and all criteria met at the highest threat category must be listed.

The IUCN Red List is a comprehensive inventory of the global conservation status of biological species. It classifies species into the following categories based on their risk of extinction:

Not Evaluated (NE): Species that have not yet been assessed against the IUCN criteria.
Data Deficient (DD): Species for which there is inadequate information to assess their risk of extinction.
Least Concern (LC): Species that are widespread and abundant, not qualifying for any of the threatened categories.
Near Threatened (NT): Species that do not currently qualify as threatened but are close to qualifying soon.
Vulnerable (VU): Species facing a high risk of extinction in the wild.
Endangered (EN): Species facing a very high risk of extinction in the wild.
Critically Endangered (CR): Species facing an extremely high risk of extinction in the wild

Extinct in the Wild (EW): Species that no longer exist in their natural habitat but are still alive in captivity or cultivation.
Extinct (EX): Species that no longer exist anywhere on Earth.

Details of different criteria
Extinct (EX)
A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Extinct in the wild (EW)
A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

CRITICALLY ENDANGERED (CR)
A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

ENDANGERED (EN)
A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild

VULNERABLE (VU)
A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.

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

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

DATA DEFICIENT (DD)
A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat.

Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data is available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period has elapsed since the last record of the taxon, threatened status may well be justified.

NOT EVALUATED (NE)
A taxon is Not Evaluated when it has not yet been evaluated against the criteria.

9.6. THE CRITERIA FOR CRITICALLY ENDANGERED, ENDANGERED AND VULNERABLE

Critically endangered (CR)
A taxon is Critically Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing an extremely high risk of extinction in the wild:
A. Reduction in population size based on any of the following:
1. An observed, estimated, inferred or suspected population size reduction of ≥90% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
- (d) actual or potential levels of exploitation

Endangered (EN)
A taxon is Endangered when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a very high risk of extinction in the wild:
A. Reduction in population size based on any of the following:
1. An observed, estimated, inferred or suspected population size reduction of ≥70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible AND understood AND ceased, based on (and specifying) any of the following:
- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat
- (d) actual or potential levels of exploitation
- (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

Vulnerable (VU)
A taxon is Vulnerable when the best available evidence indicates that it meets any of the following criteria (A to E), and it is therefore considered to be facing a high risk of extinction in the wild:
A. Reduction in population size based on any of the following:
1. An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction

are clearly reversible and understood and ceased, based on (and specifying) any of the following:

(a) direct observation
(b) an index of abundance appropriate to the taxon
(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat 20
(d) actual or potential levels of exploitation
(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

9.7. INTRODUCTION OF BIODIVERSITY LOSS

Biodiversity refers to the variety of life on Earth, including the diversity of species, genes and ecosystems. It is the result of billions of years of evolution and is essential for the stability of ecosystems and environmental regulation, such as air purification, carbon sequestration and population control. The main causes of biodiversity loss are habitat destruction and fragmentation, overexploitation of species, climate change, pollution, and the introduction of invasive species. Human activities, such as industrialization, deforestation for agriculture, and pollution from waste, are the primary drivers of these issues, leading to a rapid decline in the variety of life on Earth. Biodiversity loss has far-reaching and long-lasting consequences. Here are its causes and effects on humans and the environment. However, destructive human activities and the worsening climate crisis are resulting in the loss of this biodiversity through the extinction and endangerment of species, which results in far-reaching consequences for the environment, as well as for human beings.

9.8. CAUSES OF BIODIVERSITY LOSS

1. Habitat loss and fragmentation

Cause: This is the most significant cause, driven by human activities like converting natural habitats into farmland, urban areas, and infrastructure. The conversion of natural habitats into agricultural land, urban areas and infrastructure development leads to the destruction and fragmentation of habitats, which is the primary cause of biodiversity loss. As humans take over previously wild lands, we reduce the available space for native species to live, feed and reproduce, and also disrupt the connections between different ecosystems.

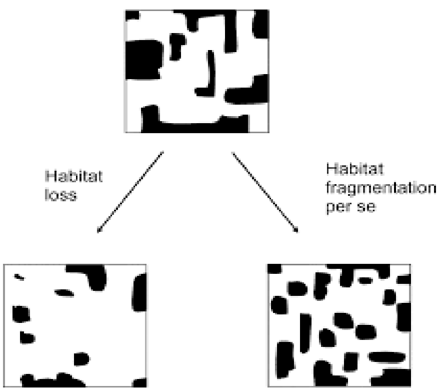

Fig: 9.2 Example: Deforestation, particularly in tropical rainforests, destroys homes for a vast number of species.

2. Overexploitation

Cause: Unsustainable hunting, fishing, and logging lead to the depletion of species populations. Overhunting: Overhunting of a species to meet high demand for meat or animal byproducts, for sport, or due to pest control is one of the main drivers of species extinction.

Industrialised hunting does not take into account the effects of species deterioration on the rest of the ecosystem and quickly depletes populations. For example, the sharp commercialisation of otter fur in the 18th and 19th centuries in the United States and Russia nearly drove the species extinct, which catalysed the secondary effects of losing kelp forests and depleting fish populations.

3. Overfishing:

Industrialised fishing has led to the depletion of highly-demanded species like tuna, whales and salmon to meet the world's demand. Unsustainable methods of fishing, like bottom trawling, have also destroyed sea-floor habitats, which are important nursery areas for many species. This has had the knock-off effect of changing marine ecosystem structures by increasing the populations of predators at the expense of their prey.

Fig: 9.3 Example: Overfishing can have a domino effect on the entire marine food web, leading to the extinction of other species.

4. Climate change

Cause: Changes in temperature and weather patterns disrupt ecosystems and make it difficult for species to adapt. Global warming and the resulting changes in climate patterns have altered habitats, making it challenging for organisms to perform their natural functions or adapt to new conditions. Changes in temperatures or rain patterns, for example, make it different for certain plants to grow or survive, which also affects the species that depend on them.

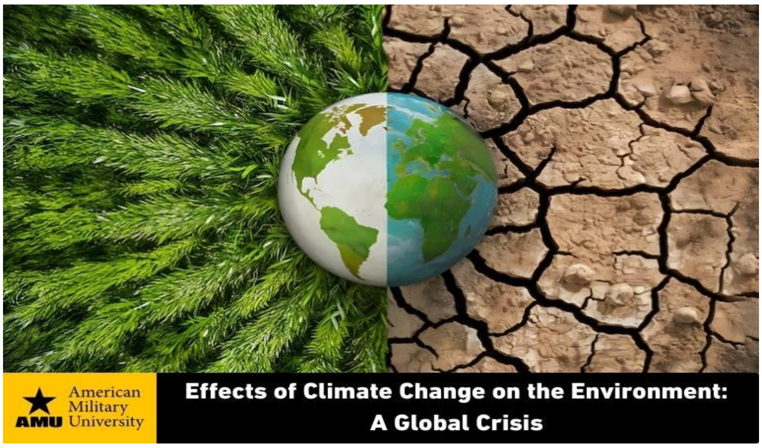

Fig: 9.4 Example: Rising global temperatures can force species to move to new areas, but if they cannot adapt or find suitable new habitats, they may die out.

5. Pollution

Cause: The accumulation of harmful chemicals from industrial, agricultural, and urban runoff contaminates air, water, and soil, harming ecosystems and species. Air, soil and water pollution can harm species by degrading their habitats, physically harming them, or increasing their vulnerability to diseases or predation. Some pollutants, such as pesticides and heavy metals, can be passed up the food chain, therefore contaminating many levels of the ecosystem. Example: Excess fertilizers can cause nutrient runoff into waterways, creating dead zones where little can survive.

6. Invasive species

Cause: Non-native species, introduced either intentionally or unintentionally, can outcompete native species for resources, introduce diseases, or disrupt food chains. As ecosystems have evolved to maintain a relative stability of species populations, non-native species introduced to new environments can outcompete native species for resources, prey on them, or transmit diseases. When invasive species are at higher levels of the food chain, they can deplete populations of the prey they feed on. Conversely, when invasive species are in the middle or bottom of the food chain, the native species that feed on them may spike in population as they have an abundance of food, which could have repercussions on the rest of the ecosystem. Example: An invasive plant species might outcompete native plants for sunlight and nutrients, leading to the decline of native wildlife that depends on them.

7.Disease:

The spread of infectious diseases, often facilitated by human activities, can devastate wildlife populations. Organisms have developed natural defenses against disease-inducing microbes native to their region. However, when human activity contaminates ecosystems with non-native microbes, indigenous species are not equipped to combat them.

8.Genetic pollution:

The release of genetically modified organisms or the hybridization of closely related species can lead to the loss of genetic diversity, which is crucial for species' adaptability and resilience.

9.Ocean acidification:

Increases in carbon dioxide levels are responsible for the acidification of oceans, which makes it difficult for marine organisms, like corals, plankton or shellfish, to maintain their protective coating. The result is a decline in these species' populations, as well as those of species that rely on them for food and shelter.

10.Ecosystem simplification:

The conversion of complex, diverse ecosystems into simplified ones, such as monocultures or urban areas, reduces the number of niches available for species and decreases ecosystem resilience.

9.9. THE EFFECTS OF BIODIVERSITY LOSS ON THE ENVIRONMENT

Biodiversity loss has a cascading effect on ecosystems and the environment, leading to a decline in ecosystem services and reduced resilience to disturbances. Some of the consequences include:

1. Loss of ecosystem stability:
Biodiverse ecosystems are more stable and resilient to disruptions such as climate change, disease outbreaks or invasive species. Loss of biodiversity can reduce an ecosystem's ability to recover from these disturbances and increase the risk of ecosystem collapse.

2.Decline in ecosystem services:
Healthy, diverse ecosystems provide essential services, such as water and air purification, soil formation pollination, carbon sequestration and climate regulation. Biodiversity loss can impair these services, leading to a decline in environmental quality.

3.Loss of genetic resources:
Biodiversity is a reservoir of genetic resources that can be used for the development of new crops, medicines and for cultural expression.

4.Altered biogeochemical cycles:
Biodiversity loss can affect the cycling of nutrients, such as carbon, nitrogen and phosphorus, in ecosystems. This can lead to changes in ecosystem productivity, water quality, and greenhouse gas emissions.

5.Increased risk of species extinction:
The loss of individual species can have cascading effects on other species within the same ecosystem, leading to further declines in biodiversity and increasing the risk of extinction for multiple species.

9.10. HOW BIODIVERSITY LOSS AFFECTS HUMANS?

The loss of biodiversity has significant implications for human health, well-being and economic development. Some of the ways in which biodiversity loss affects humans include:

Reduced food security: Biodiversity is essential for food production, as it provides genetic resources for crop and livestock improvement, pollination services and natural pest control. Declining biodiversity can reduce agricultural productivity and increase the vulnerability of food systems to pests, diseases and climate change.

Decline in human health: Biodiversity plays a critical role in the development of new medicines, as many pharmaceuticals and homoeopathic remedies are derived from plants or animals. Losing species could mean losing potential sources of new treatments for diseases. Additionally, the decline in ecosystem services, such as water and air purification, can lead to increased exposure to pollutants and pathogens, negatively affecting human health.

Economic losses: Biodiversity supports many industries, including agriculture, forestry, fisheries and tourism. Loss of biodiversity can reduce the productivity and sustainability of these industries, leading to economic losses and reduced employment opportunities.

Loss of cultural values: Biodiversity has cultural and spiritual significance for many people, particularly indigenous communities. The loss of species and ecosystems can result in the loss of cultural heritage, traditional knowledge and spiritual connections to nature.

Increased vulnerability to natural disasters: Healthy, diverse ecosystems can help protect human communities from natural disasters, such as floods, storms and landslides. Biodiversity loss can reduce the ability of ecosystems to buffer these events, increasing the vulnerability of human settlements to natural disasters.
Reduced resilience to climate change: Biodiversity is crucial for ecosystem resilience to climate change. Loss of biodiversity can reduce the capacity of ecosystems to adapt to changing climate conditions, potentially exacerbating the impacts of climate change on human societies.

9.11. KEYSTONE SPECIES

Keystone Species - Background

Robert T. Paine, a zoologist, first proposed the concept of the keystone species in 1969. To explain his observations and studies on the interactions between marine invertebrates in the intertidal zone, such as starfish and mussels, Paine devised the theory. He cleared the starfish from a spot and recorded how the ecology was affected. *Pisaster ochraceus*, a kind of starfish commonly referred to as an ochre starfish, and *Mytilus californians*, a species of mussel, were used by Paine as the major examples for the keystone species notion.

The ochre starfish is a generalist predator that consumes decapod crustaceans as well as chitons, limpets, snails, barnacles, and echinoids. Mussels are a fierce competitor for space on the rocks and are the preferred meal of this starfish. Along with its other food, the ochre starfish controls the population of mussels, allowing other seaweeds, sponges, and anemones to coexist that the ochre starfish do not eat.

The other species were swiftly displaced when Paine removed the ochre starfish because the mussels quickly surpassed them.

The idea gained traction in conservation, where it was applied to a variety of situations and mobilized to increase support for conservation, especially where human activity had harmed ecosystems, such as by removing keystone predator

Keystone Species - Common Examples

American Alligator: The populations of various species are regulated by alligators. Additionally, they dig burrows to stay warm, and as they move, the burrows fill with water that various animals can use.

Bees: Bees aid in plant reproduction by pollinating plants. These insects find cover in the plants, where they later become food for birds.

Large Mammalian Predators: Huge ecosystems depend on keystone species like large mammalian carnivores. They eat a wide range of animals and aid in keeping the ecosystem in balance by doing so. A few examples of huge mammalian predators include lions, tigers, and jaguars.

Sea Stars: When there are no natural predators nearby, sea stars eat mussels. The abundance of mussels would skyrocket if sea stars were eliminated from an ecosystem, which would have a negative impact on the resources available to other species.

Hummingbirds: The pollination process is carried out by hummingbirds. In areas with few hummingbirds, new plant species proliferate.

Tiger Sharks: Tiger sharks control the dugong and turtle populations that would otherwise trample on the seagrass. When the seagrass is destroyed, the fish population is reduced because the fish lay their eggs there.

Bats: When the bat population is reduced, regeneration of specific plants becomes more difficult. This alters the vegetation structure, which has a negative impact on the dependent animals.

Sea Otter: They limit the number of sea urchins by feeding on them. Sea urchins would consume seaweed, a significant source of food for the ecology if their number was not kept in check.

Keystone Species - Mutualists Organisms known as "keystone mutualists" engage in interactions that are mutually beneficial and whose extinction would have a significant negative effect on the ecosystem.

For instance, there is a time each year when Banksia promotes (acorn banksia), which is a key component in the pollination of many plant species, serves as the only supply of nectar for honeyeaters in the Avon Wheatbelt region of Western Australia. Therefore, the population of honeyeaters would likely collapse because of the extinction of just one species of tree, having significant effects on the ecosystem.

Another illustration is the distribution of various tree seeds by frugivores like the cassowary. Some seeds need to pass through a cassowary to germinate.

Conclusion

Conservationists should pay special attention to keystone species. The conservation of keystone species encourages the conservation of all other relevant species. However, the concept of Keystone species has drawn criticism for oversimplifying complicated ecological systems, despite being regarded as a descriptor for particularly strong inter-species interactions and facilitating simpler communication between ecologists and conservation policymakers.

9.12. SUMMARY

It is one whose presence or absence in an ecosystem causes significant changes in the abundance or occurrence of at least one other species. Certain species in an ecosystem are thought to be more important in determining the presence of many other species. The complex web of connections that makes up an ecosystem is held together by keystone species. They could be microbes, plants, or animals. All top predators (Tiger, Lion, Crocodile, and Elephant) are considered keystone species because they indirectly regulate the populations of all other animals. As a result, top predators are given special consideration in conservation. A few apex predators are also keystone species, like the wolf.

A keystone species is one that plays a specific role in the structure, functioning, or productivity of a habitat or ecosystem (habitat, soil, seed dispersal, etc). The extinction of such species may cause significant ecosystem change or dysfunction, with far-reaching

consequences. Conservation actions for keystone species may help to preserve the structure and function of a wide range of habitats that are linked with that species throughout their life cycle. When keystone species become extinct, the entire ecosystem suffers. Certain plant species, for example, rely solely on bats for pollination (ebony tree, Indian laurel). Although not invariably, a keystone species is a predator. Keystone species can also include herbivores. For instance, elephants are a keystone species in African savannas. It manages the tree population, causing the grass to flourish and support grazing.

9.13. SELF ASSESSMENT

1. Discuss the ecological role of keystone species and their importance in biodiversity conservation.
2. Evaluate the impact of human activities on keystone species and propose conservation strategies to mitigate these impacts.
3. Analyze the relationship between keystone species and ecosystem services.
4. Assess the implications of losing keystone species on ecosystem functioning and biodiversity. Discuss potential conservation measures.
5. What are keystone species?
6. Why are keystone species important for ecosystem stability?
7. Can you provide examples of keystone species?
8. How do human activities impact keystone species?
9. What conservation strategies are effective for protecting keystone species?
10. What are the IUCN categories of threats to biodiversity?
11. What are the causes of IUCN biodiversity loss?
12. What are the 5 major threats to biodiversity?
13. Explain IUCN Red List categories with examples

9.14. SUGGESTED READING

1. Jonathan Baillie, Craig Hilton-Taylor, S. N. Stuart · 2004. 2004 IUCN Red List of Threatened Species: A Global Species.
2. IUCN Red List Categories and Criteria: Version 3.1.

Prof A.Amrutha Valli

LESSON -10
BIODIVERSITY HOTSPOTS OF INDIA AND WORLD

OBJECTIVES

To understand more about a high number of endemic species and have experienced significant habitat loss.

STRUCTURE OF THE LESSON:

10.1. INTRODUCTION

The word “hotspot” describes regions with a high priority for conservation because of their abundant biodiversity, high endemism, and significant vulnerability. Hotspots for biodiversity are places with a high concentration of indigenous species. In the case of marine hotspots, fish, snails, lobsters, and coral reefs are all considered. Most hotspots are found in tropical and subtropical areas, where high temperatures and humidity are typical all year round. With an elevation above sea level and ocean depth, animal diversity and ecosystem diversity change. Only 2.5 per cent of the Earth’s land surface is taken up by the 36 hotspots that exist today, yet they are home to about 43 per cent of the world’s bird, mammal, reptile, and amphibian species, as well as more than half of its plant species.

India contains four of the world's 36 recognized biodiversity hotspots: the Himalayas, the Western Ghats, the Indo-Burma region, and Sundeland. These areas are globally significant because they have a high number of endemic species and have experienced significant habitat loss. This region includes parts of North-East India and is known for its high plant diversity, with many endemic species and endangered animals like the Wild Asian Water Buffalo and the One-horned Rhino.

Himalayas: This hotspot includes the Andaman and Nicobar Islands and is another area with high levels of unique flora and fauna. Western ghats: A mountain range running along the western edge of peninsular India, it is home to thousands of plant species, including many endemic ones, as well as hundreds of species of birds, mammals, reptiles, and amphibians. Indoburma: This large region spans parts of India and several other Southeast Asian countries and has been the site of discoveries of several new species of large mammals in recent years. Sundalands: This hotspot includes the Andaman and Nicobar Islands and is another area with high levels of unique flora and fauna.

10.2 WORLD'S BIODIVERSITY HOTSPOTS

There are 36 recognized biodiversity hotspots globally, all meeting the criteria of having a high number of endemic species and significant habitat loss. In addition to the four in India, other global hotspots include the Tropical Andes, the Mediterranean Basin, and the North American Coastal Plain. Biodiversity is referred to as the diversity of plant and animal species in a specific habitat. The two main factors that make up biodiversity are species evenness and species richness.

Hotspots in India: India is renowned for having a diverse ecosystem, and 23.39% of its land is covered in trees and forests with nearly 91,000 identified animal species and 45,500 documented plant species. Four of the world's 36 biodiversity hotspots are in India: The Himalayas, Western Ghats, Indo-Burma area, and Sundaland. Two of these, the Indo-Burma area and Sundaland, are distributed throughout South Asia and are not precisely contained within India's formal borders.

Criteria to be satisfied for a biodiversity hotspot
A region must satisfy two strict requirements to be considered a biodiversity hotspot:
Include at least 1,500 vascular plant species that are unique to the planet (known as "endemic" species). They have lost most of their native vegetation by at least 70%. In other words, it must be threatened.

Who Declares Biodiversity Hotspots?
Hotspots were first defined and promoted by Conservation International. Conservation International was founded in 1989, just one year after scientist Norman Myers published the article that popularised the idea of safeguarding these beautiful places.
Biodiversity Hot Spots in India

There are four Biodiversity Hotspots in India:

1. Himalaya
2. Indo-Burma
3. Western Ghats
4. Sundaland

10.3. HIMALAYAS

All the world's mountain peaks higher than 8,000 meters, including Mt. Everest (8,849 meters), are found within the Himalayan hotspot, which spans more than 3,000 kilometers across northern Pakistan, Nepal, Bhutan, and the northwest and northeastern states of India. It also has several of the deepest river gorges in the world.

The Himalayan Mountain range is nearly 7.5 million square kilometres in size and is divided into the Eastern Himalaya, which includes parts of Nepal, Bhutan, the northeastern Indian states of West Bengal, Sikkim, Assam, and Arunachal Pradesh, and the Western Himalaya, which includes parts of Kumaon-Garhwal, northwest Kashmir, and northern Pakistan.

The Himalayan mountains are home to a variety of ecosystems, including:

- Mixed conifer and conifer forests in the higher hills,
- Alpine meadows above the tree line, the tallest alluvial grasslands in the world, Subtropical broadleaf forests along the foothills
- Temperate broadleaf forests in the mid hills
- Even at heights higher than 6,000 meters, vascular plants have been discovered. Numerous big bird and mammal populations, including vultures, tigers, elephants, rhinos, and wild water buffalo, can be found in the hotspot.

The worldwide hotspot regions were reviewed and revised considering species distribution, threats, and changes in threat status. The Himalayan hotspot was delineated and identified as separate from the Indo-Burma hotspot.

10.3.1. Threats to Himalayan Biodiversity

Promoting both outside immigration and internal migration and leading to an exponential increase in the human population in some of the locations with the greatest biodiversity. Due to widespread legal and illegal logging, especially on steep slopes, as well as the substantial removal of forests and meadows for farming, there has been serious erosion. During the summer, the area is frequently burned to make way for livestock, which provides an extra hazard to the forest because fires can occasionally go out of control. Rapid deforestation and habitat fragmentation were the results of the conversion of forests and grasslands for agriculture and settlements, mainly in Nepal and the Indian states of Sikkim, West Bengal (Darjeeling), and Assam.

Additionally, certain forest ecosystems have been severely harmed by anthropogenic activities such as domestic cattle overgrazing, overharvesting plants for traditional medicine, collecting fuel wood, and extraction of non-timber forest products.

Unplanned and poorly managed tourism operations exacerbate environmental damage.
In the Himalayas, illegal poaching is a significant problem; tigers and rhinoceroses are targeted for their body parts for use in traditional remedies, whilst snow leopards and red pandas are targeted for their stunning pelts.

10.4 THE INDO-BURMA HOTSPOT

1. 1.The Indo-Burma hotspot is the largest of the world's 36 recognised hotspots, covering a total area of 2,373,000 km2.The Indo-Burma hotspot formerly encompassed parts of northeastern India, Bangladesh, and Malaysia.
2. However, Bangladesh, India, and Malaysia are regarded as extralimital to the hotspot for the purposes of the ecosystem profile because northeastern India is included in the Himalayan hotspot and the hotspot only barely extends into Bangladesh and Malaysia.
3. The hotspot has an incredible geographic diversity, ranging from the tallest peak in Southeast Asia to coastlines along the Bay of Bengal, Andaman Sea, Gulf of Thailand, and South China Sea.
4. Along with several of Asia's greatest rivers and their lush floodplains and deltas, it also comprises the eastern extensions of the Himalayas, remote massifs, and plateaus.
5. Due to the diversity of its landforms and climatic zones, the Indo-Burma hotspot supports a wide range of habitats and, as a result, a high level of overall biodiversity.
6. In the past 12 years, six new species of big mammals have been identified in this area:
   1. Large-antlered Muntjac
   2. Annamite Muntjac
   3. Grey-shanked Douc
   4. Annamite Striped Rabbit
   5. Leaf Deer
   6. Saola

The majority of the endemic freshwater turtle species found in this hotspot are in danger of going extinct because of overfishing and habitat destruction. The severely endangered White-eared Night-heron, Grey-crowned Crocias, and Orange-necked Partridge are among the 1,300 bird species that exist. The hotspot's most diverse ecosystems are its forests. From evergreen forests with a great diversity of canopy tree species to semi-evergreen and mixed deciduous forests with few tree species, the hotspot supports a wide range of forest types. The hotspot's limestone karst formations are home to extremely rare ecosystems with high levels of endemism, especially in plants, reptiles, and molluscs—species that are entirely unique and are found nowhere else.

10.4.1 Threats to Indo-Burma

1. Indo-Burma is one of the top five most endangered biodiversity hotspots, according to Conservation International, due to the rate of resource extraction and habitat loss.
2. The greatest threats to this hotspot's biodiversity are logging, over-exploitation of natural resources, industrial agriculture, trade and consumption of wildlife, the building of massive infrastructures including dams, highways, and ports, and climate change.
3. In Indo-Burma, commercial timber exploitation ranks second among the causes of deforestation.
4. The loss of habitat has had an effect on other landforms, including wetlands and freshwater floodplain swamps.
5. Large tracts of mangroves have been contained within aquacultural ponds, and many rivers have been dammed and altered.
6. Mangroves, lagoons, marshes, and other natural wetlands, including several Ramsar sites in the hotspot's coastal zones, have undergone substantial conversion into shrimp and fish farms or have been removed for charcoal and fuelwood.

10.5. WESTERN GHATS HOT SPOT

1. The Western Ghats sometimes referred to as the Sahyadri Hills locally, are made up of the Malabar Plains and a group of mountains that extend 30 to 50 kilometres inland and parallel to India's western coast.
2. With just the 30 km Palakkad Gap in between, they span 1,600 km from the southernmost point of the nation to Gujarat in the north, covering an area of over 160,000 km2.
3. By blocking the southwestern monsoon winds, the Western Ghats control the amount of rain that falls on peninsular India.
4. Every year, a lot of rain falls on the western slopes of the mountains, with most of it falling during the southwest monsoon between June to September.
5. Rainfall drops off as you move from south to north, while the eastern slopes are drier.
6. Numerous rivers, including the three main eastward-flowing rivers on the peninsula, originate in these highlands. As a result, they serve as essential sources of power, irrigation, and drinking water.
7. There are many different types of vegetation in the Western Ghats due to the region's complicated geography and varying rainfall patterns.
8. They include scrub forests in low-lying rain shadow regions and on the plains, deciduous and tropical rainforests up to a height of roughly 1,500 m, and an exceptional mosaic of montane forests and rolling grasslands above that altitude.

10.5.1 Threats to the Western Ghats

The forests of the Western Ghats have been heavily fragmented and selectively cut across their whole range. For monoculture plantations of tea, coffee, rubber, oil palm, teak, eucalyptus, and wattle as well as to make room for reservoirs, highways, and railways, forests have been removed. More forests are lost due to encroachment into protected areas. On slopes that were once covered in forest, cattle and goat grazing inside and close to protected zones severely erodes them. Most of the remaining forest cover is made up of disturbed secondary growth or wood plantations. Intense hunting pressure, fuelwood extraction, and the harvesting of non-timber forest products are placed on the few surviving forest sections. Other concerns include unrestrained tourism and forest fires. The conflict between humans and wildlife has increased as a result of population growth in protected zones and other woods. To stop more harm, wild animals are routinely killed or hurt, and farmers are typically under-compensated.

10.6. SUNDALAND HOTSPOT

The Sundaland hotspot includes the western half of the Indo-Malayan archipelago, which is made up of about 17,000 equatorial islands. Borneo (725,000 km2) and Sumatra are two of the largest islands in the world (427,300 km2).

Almost all of Malaysia including Peninsular Malaysia and the East Malaysian states of Sarawak and Sabah in northern Borneo, Singapore at the tip of the Malay Peninsula, Brunei Darussalam, and the western half of Indonesia, including Kalimantan, are included in Sundaland. A small portion of southern Thailand the provinces of Pattani, Yala, and Narathiwat is also included the Indonesian portion of Borneo, Sumatra, Java, and Bali. India oversees the Nicobar Islands, which are also included. The Philippines Hotspot are direct to the northeast of Wallacea, which is separated from Sundaland Hotspot by the renowned Wallace's Line.

10.6.1 Threats to Biodiversity in Sundaland

The stunning flora and wildlife of the Sundaland Hotspot are being rapidly destroyed by industrial forestry on these islands

Global traffic in animals uses tigers, monkeys, and turtle species for food and medicine in other nations. Only in this area are orangutans located, and their population is rapidly declining. The Indonesian islands of Java and Sumatra are also home to some of the final refuges for two Southeast Asian rhino species. Like many other tropical regions, the forests are being destroyed for business. The production of pulp, oil palm, and rubber are three of the most harmful factors endangering biodiversity in the Sundaland Hotspot.

Conclusion

India is renowned for having the world's richest flora, with over 18000 species of blooming plants, and has a diverse climate, topography, and habitat. Three thousand different plant species can be found in India's eight primary floristic zones, which are the Western and Eastern Himalayas, the Indus and Ganges, Assam, the Deccan, Malabar, and the Andaman Islands.

The good climatic conditions, fertile soil, suitable temperature, and an abundance of precipitation, which promote the growth of numerous plants, are the causes of the vast diversity of Indian biodiversity hotspots. These regions are heavily wooded, with savanna grasslands and tropical and subtropical forests.

They are distinguished by the nation's largest rivers, have rich alluvial soil, and can therefore support a wide variety of animals and plants. In terms of ecology and energy production, these regions are incredibly productive.

10.7. BIODIVERSITY HOTSPOTS OF WORLD

There are 36 globally recognized terrestrial biodiversity hotspots, each defined as a biogeographic region with exceptional endemism and extensive habitat loss. There are 36 recognized terrestrial biodiversity hotspots worldwide; the list below gives each hotspot and its main countries or region.

Americas

1. California Floristic Province – USA (California) and small part of Mexico.
2. Madrean Pine–Oak Woodlands – Southern USA, northern and central Mexico.
3. North American Coastal Plain – Atlantic and Gulf coasts of the USA.conservation
4. Caribbean Islands – Greater and Lesser Antilles, Bahamas, Turks and Caicos.
5. Tumbes–Chocó–Magdalena – Coastal Colombia, Ecuador, northwest Peru, Panama; includes Galápagos (Ecuador).
6. Tropical Andes – Andes of Venezuela, Colombia, Ecuador, Peru, Bolivia, northern Argentina and Chile.
7. Mesoamerica – Southern Mexico to Panama (including Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica).

8. Atlantic Forest – Eastern and southern Brazil, northeast Argentina, eastern Paraguay. Cerrado – Central Brazil. Chilean Winter Rainfall–Valdivian Forests – Central Chile and adjacent southwest Argentina.

Europe, North Africa, West Asia, Central Asia

1. Mediterranean Basin – Southern Europe, North Africa, and the Levant/Middle East around the Mediterranean Sea.
2. Caucasus – Armenia, Azerbaijan, Georgia, parts of Russia, northeastern Turkey, northwest Iran.
3. Irano–Anatolian – Central and eastern Turkey, parts of Iran, Iraq, Armenia, Azerbaijan, Turkmenistan.
4. Mountains of Central Asia – High mountain systems of Afghanistan, Pakistan, Tajikistan, Kyrgyzstan, Kazakhstan, Uzbekistan, western China.

Africa and Western Indian Ocean

1. Cape Floristic Region – Southwestern tip of South Africa
2. Succulent Karoo – Coastal and inland areas of western South Africa and southern Namibia.
3. Maputaland–Pondoland–Albany – Southeastern South Africa, southern Mozambique, Eswatini.
4. Coastal Forests of Eastern Africa – Coastal Kenya, Tanzania, Mozambique and small parts of Somalia.
5. Guinean Forests of West Africa – Sierra Leone to Cameroon (including Liberia, Côte d'Ivoire, Ghana, Nigeria etc.).
6. Eastern Afromontane – Discontinuous Mountain chains from Saudi Arabia and Yemen through Ethiopia, East African Rift mountains to Malawi and Mozambique.
7. Horn of Africa – Arid and semi-arid areas of Ethiopia, Somalia, Eritrea, Djibouti, parts of Kenya.
8. Madagascar and the Indian Ocean Islands – Madagascar, Comoros, Seychelles, Mascarene Islands (Mauritius, Réunion, Rodrigues).

South Asia and Southeast Asia (including India)

1. Western Ghats and Sri Lanka – Western peninsular India and Sri Lanka.
2. Himalaya – Mountain chain across Nepal, Bhutan, northern and northeastern India, southern Tibet, northern Myanmar.
3. Indo Burma – Northeast India, much of Myanmar, Thailand, Cambodia, Laos, Vietnam, parts of southern China, coastal Bangladesh.
4. Sundaland – Peninsular Malaysia, Singapore, Borneo (Indonesia, Malaysia, Brunei), Sumatra, Java, Bali and nearby islands; Nicobar Islands (India) lie within this hotspot.
5. Wallacea – Islands between Sundaland and New Guinea, including Sulawesi, the Moluccas, Lesser Sundas (excluding Bali).
6. Philippines – Philippine archipelago.

East Asia

1. Mountains of Southwest China – Hengduan and associated ranges in southwest China plus adjacent parts of Myanmar, India.

2. Japan – Japanese main islands and some adjacent islands.

Australia, New Zealand and Pacific

1. Southwest Australia – Southwest corner of Australia.
2. Forests of East Australia – Eastern coastal and montane forests from Queensland through New South Wales to Victoria.
3. New Caledonia – New Caledonia archipelago in southwest Pacific.
4. New Zealand – New Zealand's main and outlying islands.
5. East Melanesian Islands – Solomon Islands, Vanuatu, Fiji and nearby island groups northeast of Australia
6. Polynesia–Micronesia – Many small islands across central and western Pacific (e.g., Hawaii, Micronesian states, parts of Fiji–Tonga–Samoa region).

10.8. SIGNIFICANCE OF BIODIVERSITY HOTSPOTS

Biodiversity hotspots are globally significant because they pack huge amounts of unique biodiversity into very small, highly threatened areas, making them top priorities for conservation investment.

1. Disproportionate biodiversity value
Hotspots together cover only about 2–2.5% of Earth's land surface but contain well over half of all terrestrial plant species as endemics and a very large share of terrestrial vertebrate endemics. This concentration means that protecting relatively small regions can safeguard a major fraction of global biodiversity.

2. High threat and irreplaceability
Each hotspot has already lost at least 70% of its original natural vegetation, so remaining habitats are both irreplaceable and at high risk of further loss. Conservation here prevents extinction of species that often occur nowhere else on Earth, especially plants, amphibians, reptiles, and small vertebrates.

3.Conservation planning and funding
The hotspot concept guides governments, NGOs, and global funds (e.g., Global Environment Facility, Critical Ecosystem Partnership Fund) in targeting limited resources where they will have the greatest impact per unit area. Many national protected area expansions, REDD+ projects, and restoration programs prioritize hotspot regions for maximum biodiversity and climate co benefits.

4. Ecosystem services and human well being
Hotspots provide essential ecosystem services such as water regulation, soil protection, pollination, and climate regulation to hundreds of millions of people living in and around them. They are also centres of agrobiodiversity and wild relatives of crops and medicinal plants, underpinning food security, health, and future breeding and biotech options.

5. Climate and evolutionary significance
Many hotspots overlap with major carbon stores (e.g., tropical forests) so conserving them helps mitigate climate change by avoiding emissions and maintaining carbon sinks. They are also engines of evolution, with complex topography and climates that drive rapid speciation, making them critical for the long term resilience and adaptive capacity of life on Earth.

10.9. SUMMARY

These hotspots are biologically rich and ecologically significant with high species endemism and conservation importance.

10.10. SELF ASSESSMENT

1. Define Hotspots
2. Explain Hotspots of India

10.11. SUGGESTED READING

1. Indian Hotspots, Volume 1: Vertebrate Faunal Diversity, Conservation and Management (Springer, 2019) provide a comprehensive overview of India's four biodiversity hotspots—Himalaya, Indo-Burma, Western Ghats & Sri Lanka, and Andaman & Nicobar Islands—covering plant and animal diversity, endemism, threats, and conservation strategies.

2. Biodiversity Hotspot of the Himalaya (T. Pullaiah, Routledge/Apple Academic Press, 2024) details the Himalayan region's geomorphology, climate, plant genetic diversity, algae, herpetofauna, butterflies, birds, and climate change impacts, with chapters on threats like deforestation and conservation efforts.

3. Biodiversity Hotspot of the Western Ghats and Sri Lanka (T. Pullaiah, Apple Academic Press, 2024) explores species richness in plants, forests, mammals, birds, insects, and amphibians across these hotspots, emphasizing habitat fragmentation, population pressures, and preservation needs.

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LESSON -11

ORGANIZATIONS INVOLVED IN BIODIVERSITY CONSERVATION: IUCN, WWF, UNEP AND UNESCO

OBJECTIVES:

The main objectives of a biodiversity organizations are to conserve biodiversity, promote its sustainable use, and ensure the fair and equitable sharing of benefits arising from the use of genetic resources. These missions also aim to strengthen biodiversity science, create a bio-based economy, and engage the public in protecting and restoring nature to address challenges like climate change and to support human well-being and livelihoods.

STRUCTURE OF THE LESSON:

11.1. INTRODUCTION

The organizations IUCN, WWF, UNEP and UNESCO are all major international bodies that work in different but complementary ways for biodiversity conservation, from setting scientific standards and policies to running field projects and protecting natural and cultural heritage.

IUCN

a. The International Union for Conservation of Nature (IUCN) is a membership union of governments, NGOs, and experts that acts as a global authority on the status of the natural world and how to safeguard it.

b. It is known for the IUCN Red List of Threatened Species and for shaping global conservation policy and strategies such as the World Conservation Strategy and contributions to the concept of sustainable development.

WWF

a. The Worldwide Fund for Nature (WWF) is a large international NGO focused on conserving endangered species, protecting ecosystems, and addressing global issues like climate change and habitat loss.

b. WWF works through field projects, advocacy, and partnerships with governments, businesses, and communities to promote sustainable use of natural resources and to reduce human impact on biodiversity.

UNEP

a. The United Nations Environment Programme (UNEP) is the leading UN body on the environment, providing leadership and encouraging partnership in caring for the environment, including biodiversity and ecosystems.

b. UNEP supports countries with policies, financing mechanisms, and projects on biodiversity conservation, including implementing multilateral agreements, ecosystem-based management, and Global Environment Facility (GEF)–funded biodiversity projects.

UNESCO

a. The United Nations Educational, Scientific and Cultural Organization (UNESCO) contributes to biodiversity conservation mainly through its World Heritage Sites, Biosphere Reserves, and programmes that link cultural and natural heritage.

b. UNESCO promotes conservation and sustainable use of biodiversity by integrating ecological, social, and economic dimensions, working with local communities and governments to manage protected areas and associated landscapes.

11.2. IUCN

A. History of IUCN

The International Union for Conservation of Nature (IUCN) is an international organization working in the field of nature conservation and sustainable use of natural resources. Founded in 1948, IUCN has become the global authority on the status of the natural world and the measures needed to safeguard it

IUCN (International Union for Conservation of Nature) was established on 5 October 1948 in the French town of Fontainebleau. As the first global environmental union, we brought together governments and civil society with a shared goal to protect nature. Established in 1948, the IUCN has the tools and knowledge repository to help the world conserve nature and ensure sustainable development.

Logo IUCN The World Conservation Union

When it was first set up in Fontainebleau (France), it was the first international environmental union. Its objective was to promote international cooperation and provide scientific knowledge and tools to aid conservation action. It established the IUCN Red List of Threatened Species in 1964.

It also played a huge role in the formation of major international conventions such as the Ramsar Convention on Wetlands, the Convention on International Trade in Endangered Species, the World Heritage Convention and the Convention on Biological Diversity.

In 1980, partnering with the UNEP and the World Wildlife Fund (WWF), the IUCN published the World Conservation Strategy, a document which helped define the concept of 'sustainable development' and shaped the global conservation and sustainable development agenda.

In 1992, considering the growing environmental concerns, the United Nations granted official observer status to the IUCN. Currently, the IUCN is the biggest and most diverse environmental network. IUCN is the world's oldest and largest global environmental organization. The International Union for Conservation of Nature (IUCN) published the Red List of Threatened Species (also known as the IUCN Red List or Red Data List) in the year 1964.

IUCN is a membership Union uniquely composed of both government and civil society organisations. It provides public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together.

The International Union for Conservation of Nature (IUCN) does not have a global headquarters in India; its world headquarters are in Gland, Switzerland. However, the IUCN has a Country Office in India, which is located in New Delhi. This office serves as the main hub for the IUCN's operations and collaborations within India.

B. India as State Member of IUCN

India joined as a State Member of International Union for Conservation of Nature (IUCN) in 1969 through the Ministry of Environment, Forest and Climate Change. In 2007 The IUCN India Country Office was established in New Delhi. The IUCN is a non-governmental organization (NGO) and is also a membership union that includes government and civil society organizations. It is a unique hybrid organization that works with governments, NGOs, scientists, and other experts to address environmental challenges and promote sustainable development.

B1 Membership: The IUCN has a diverse membership base that includes over 1,400 member organizations, which are both governments and NGOs. It also has a large network of volunteer experts, staff, and other partners.

B2. Purpose: Its mission is to "influence, encourage and assist societies throughout the world to conserve nature and to ensure that any use of natural resources is ecologically sustainable,"
B3. Activities: The IUCN works on a wide range of issues, including scientific research, managing field projects, and developing policy and best practices.

Purpose of the India Office: To work with IUCN members in India to address conservation challenges related to poverty, food security, and climate change.

C. The 2025 IUCN World Conservation Congress

It was hosted in Abu Dhabi, United Arab Emirates, from October 9–15, 2025. The event, which is held every four years, brings together conservation experts, leaders, and decision-makers to set the global conservation agenda.

Host City: Abu Dhabi, United Arab Emirates

Dates: October 9–15, 2025

Significance: The congress is the largest gathering of conservation professionals worldwide and serves as the IUCN's highest decision-making body, where members vote on resolutions and the IUCN Programme.

D. The 9 categories of IUCN

It divides species into nine categories: Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild and Extinct

The International Union for Conservation of Nature (IUCN) is an organization that focuses on nature conservation and sustainable use of natural resources. It is not directly under UNESCO, UNO, or WWF. However, it collaborates with the United Nations Environment Programme (UNEP) on various environmental issues.

Foundations and trusts provide critical funding for both operations and specific initiatives. They are often the first to invest in new ideas, which provides important leverage for innovation

The IUCN has member organizations from over 170 countries. These members include governmental bodies, non-governmental organizations (NGOs), and indigenous peoples' organizations. The union has a global network and projects in more than 50 countries.

Membership: Over 1,400 member organizations from more than 170 countries.

Geographic presence: Operates in over 50 countries with a network of over 17,000 scientists and experts.

Membership types: Includes states, government agencies, national and international NGOs, and indigenous peoples' organizations.

Newest member: Armenia officially became a State Member in October 2025. The announcement was made at the IUCN World Conservation Congress in Abu Dhabi. Armenia's membership supports its objectives to accelerate biodiversity goals and implement nature-based solutions in its national policy. Through IUCN, Armenia will access global expertise, tools, and international partnerships to enhance its conservation efforts.

The three components of IUCN

As an organization, IUCN has three components:

1. the member organizations,
2. the six scientific commissions and
3. the secretariat

The IUCN is an international organization that works in the field of conservation of the world’s flora and fauna. This is an important international body, especially in light of the IUCN Red List. In this article, you can read all about the IUCN, its origins and fields of work, for the UPSC Exam environment and ecology sections.

Global Youth Summit on nature to be held online from 6th to 16th April 2021. More than 10,000 young people will connect and exchange ideas online at the first-ever International Union for Conservation of Nature (IUCN) Global Youth Summit. The Global Youth Summit will address topics including the relationship between people and nature, climate change, marine and freshwater conservation, technology and innovation, and rights, governance and social justice. The IUCN is a global union composed of both government as well as civil society organisations. With more than 1400 organisations as its members, the IUCN is an international authority on the status of the natural world. It works in the domain of sustainable development and also recommends measures to tackle the depletion of resources. It works to conserve the various species of flora and fauna. Its members include States, non-governmental organizations, indigenous peoples' organisations, experts, government agencies, etc.

Working procedure of IUCN

a. The IUCN convenes the IUCN World Conservation Congress every four years.
b. The Congress brings together its various members, who vote on recommendations and set the agenda for the global conservation efforts.
c. The chief governing body of the IUCN is the IUCN Council, that guides the organisation in between the Congress sessions.
d. The members elect Commission Chairs who serve for a four-year term.
e. The IUCN's Secretariat is in Gland, Switzerland. The Secretariat is headed by a Director-General. The IUCN has 8 regional offices and other offices in over 50 countries.

11.3. WORLD WIDE FUND FOR NATURE (WWF)

WWF most commonly refers to the World Wide Fund for Nature, a large international conservation organization focused on wilderness preservation and reducing human impact on the environment. It was founded in 1961, is headquartered in Switzerland, and works in areas like protecting biodiversity, promoting sustainable use of natural resources, and reducing pollution.

Mission: To stop the degradation of the planet's natural environment and build a future where humans and nature can thrive.

Activities:
Conserving biodiversity and habitats.
Promoting sustainable use of natural resources.
Reducing pollution and the effects of climate change.
Working with individuals, businesses, and governments to achieve conservation goals.
Global presence: Operates in over 100 countries with offices on six continents.

Logo: The giant panda.

WWF, or the Worldwide Fund for Nature, is an international non-governmental organization founded in 1961 that works to conserve nature and reduce humanity's impact on the environment. It focuses on areas like climate, forests, food, freshwater, oceans, and wildlife, aiming to create a future where humans live in harmony with nature. WWF operates globally, with offices in nearly 100 countries, and works with various partners to achieve its conservation goals.

What WWF does

To conserve worldwide biological diversity
To promote the sustained use of renewable resources
To reduce pollution and wasteful consumption
WWF-India works in the following landscapes and critical regions for its conservation

programme:

1. Satpuda Maikal
2. Terai Arc
3. Western Ghats-Nilgiris
4. Sunderbans
5. North Bank
6. Kaziranga Karbi Anglong
7. Kanchendzonga
8. Western Arunachal
9. Western India
10. Western Himalayas
11. Bharatpur
12. There are a few priority species for which WWF-India plans its work:
13. Bengal tiger
14. Asian elephant
15. Indian or greater one-horned rhino
16. Ganges river dolphin
17. Snow leopard
18. Red panda

What does the World Wide Fund for Nature do

The mission statement of the WWF is to conserve nature and alarm the world of the ecological pressing issues. Their work spans across issues relevant to climate, food, forests, freshwater, oceans and wildlife.

What is the new name of the World Wildlife Fund?
World Wide Fund for Nature (WWF) is the new name of the World Wildlife Fund.

Who owns the World Wildlife Fund?
Carter Roberts is the President and CEO of the WWF.

What is the logo of WWF?
WWF Logo is the Panda. Choice of Panda as the logo of the worldwide fund for nature came from the giant Panda named Chi-Chi who was brought to London Zoo in 1958 before the establishment of WWF.

11.4. THE UNITED NATIONS ENVIRONMENT PROGRAMME UNEP

It is responsible for coordinating responses to environmental issues within the United Nations System. The UNEP headquarters is located in Nairobi, Kenya. This makes it the only major UN agency with its headquarters in a developing country, a decision made to emphasize global environmental challenges and the importance of addressing them from the Global South. The official address is United Nations Avenue, Gigiri, Nairobi, Kenya.

Location: Nairobi, Kenya
Address: United Nations Avenue, Gigiri, Nairobi, Kenya
Significance: It is the only major UN agency headquartered in a developing country.
Establishment: UNEP was established in 1972 after the United Nations Conference on the Human Environment in Stockholm, Sweden.
UNEP, through its World Conservation Monitoring Centre (UNEP-WCMC), defines and maps the 36 global biodiversity hotspots, including India's four—Himalayas, Indo-Burma, Western Ghats & Sri Lanka, and Sundaland (Nicobar Islands)—as biologically rich areas with at least 1,500 endemic vascular plants and 70% original habitat loss.

LOGO:

UNEP

Key UNEP Contributions:
UNEP-WCMC provides datasets on hotspots for conservation planning, highlighting overlaps with "darkspots" of understudied plant diversity, such as in India's hotspots where data gaps persist despite high endemism. Their 2023-2024 Impact Report details global biodiversity action, including hotspot monitoring and threat assessments relevant to climate change and habitat loss in India.

India-Specific Reports
India's reports to the Convention on Biological Diversity (CBD), supported by UNEP frameworks, document over 91,000 animal and 45,500 plant species across 10 biogeographic zones, with hotspots facing deforestation and fragmentation. UNEP-backed initiatives emphasize Northeast India's hotspots, holding 30% of national biodiversity including 50% of

flowering plants.
These resources aid plant molecular biology research by providing baseline data on endemism and threats for genetic engineering in endemic species.
Structure of UNEP
It includes 8 divisions.
Science Division: aims to provide scientifically credible environmental assessments and information for sustainable development. It reports on the state of the global environment, assesses policies, and aims to provide an early warning of emerging environmental threats. It is responsible for the monitoring and reporting of the environment regarding the 2030 Agenda and Sustainable Development Goals.
Policy and Programme Division: makes the policy and programme of the UNEP. This division ensures other divisions are coordinated.

Ecosystems Division: supports countries in conserving, restoring and managing their ecosystems. It addresses the environmental causes and consequences of disasters and conflicts. It helps countries reduce pollution from land-based activities, increase resilience to climate change, and think about the environment in their development planning.

Economy Division: assists large businesses in their efforts to be more environmentally conscious. It has three main branches: Chemicals and Health, Energy and Climate, and Resources and Markets.

Governance Affairs Office: engages member states and other relevant groups to use UNEP's work. The office serves UNEP's governing body, the United Nations Environment Assembly, and its subsidiary organ, the Committee of Permanent Representatives, and manages their meetings. It helps strengthen the visibility, authority and impact of the Assembly as an authoritative voice on the environment.

Law Division: helps to develop environmental law. Works with countries to combat environmental crime and meet international environmental commitments. The law division aims to improve cooperation between lawmakers around the world who are making environmental laws.

Communication Division: develops and disseminates UNEP's messages. It delivers them to governments and individuals through digital and traditional media channels.

Corporate Services Division: handles UNEP's corporate interests such as management and exposure to financial risk.

UNEP's main activities are related to

- Climate action
- Disasters and conflicts ("to minimize the environmental causes and consequences of crises")
- Nature Action ("conservation, restoration and the sustainable use of nature")
- Global environmental governance (the UNEP website states that "UNEP is committed to supporting countries in developing and implementing integrated environmental policies").
- Data collection and reporting (UNEP provides information and data on the global environment to stakeholders including governments, non-governmental organizations and the public for them to engage in realizing the Sustainable Development Goals. For example, the UN environment Live Platform and Online Access to Research in Environment (OARE) provide transparent information collected by UNEP.
- Chemicals and waste
- Resource efficiency

11.5. UNESCO

It is involved in biodiversity conservation through various programs and networks, including the Man and the Biosphere (MAB) Programme, the World Heritage Convention, and the UNESCO Earth Network. These initiatives focus on integrating human needs with environmental sustainability, identifying and protecting biodiversity hotspots like World Heritage and Biosphere Reserve sites, and facilitating international cooperation on conservation efforts.

LOGO:

A. Key programs and initiatives

a. Man and the Biosphere (MAB) Programme: This program promotes sustainable development by linking natural and social sciences to improve livelihoods and protect ecosystems.
b. World Heritage Convention: This initiative identifies and protects natural sites of outstanding universal value, such as national parks and forests, which often have high biodiversity.
c. UNESCO Earth Network: This network connects UNESCO-designated sites to share best practices for biodiversity conservation and sustainable development.
d. Rapid Response Facility (RRF): A joint initiative with Fauna and Flora International, the RRF provides rapid grants to protect natural World Heritage sites during emergencies like natural disasters or armed conflict.
e. Other activities: UNESCO also works on projects like creating the Ocean Biodiversity Information System (the world's largest marine biodiversity database) and conducting environmental DNA (eDNA) expeditions in marine World Heritage sites.

UNESCO's work contributes

UNESCO's programs support the integration of people and nature, helping to reduce poverty, improve human well-being, and enhance resilience to climate change.

It provides crucial support to protect biodiversity in emergency situations through initiatives like the Rapid Response Facility.

By creating data systems like the Ocean Biodiversity Information System, it makes scientific data available for sustainable ocean management.

Through networks like the World Network of Biosphere Reserves, UNESCO helps manage and share expertise across a global network of sites.

UNESCO works on the conservation of biodiversity and the sustainable use of its components through UNESCO designated sites, including biosphere reserves, World Heritage sites and UNESCO Global Geoparks. In 2018, UNESCO designated sites protected over 10 million km2, an area equivalent to the size of China. These conservation instruments have adopted policies and strategies that aim to conserve these sites, while supporting the broader objectives of sustainable development. One such example is the policy on the integration of a sustainable development perspective into the processes of the World Heritage Convention.

UNESCO is also the depository of the Convention on Wetlands of International Importance. Countless species of plants and animals depend on these delicate habitats for survival.

UNESCO International Union for Conservation of Nature 2023 The first comprehensive assessment of species that live within World Heritage sites reveals just how critical they are to preserving the diversity of life on Earth.

The MAB Programme and the World Network of Biosphere Reserves: connecting landscapes and reconciling conservation with development Biosphere reserves are designated under UNESCO's Man and the Biosphere (MAB) Programme and promote solutions reconciling the conservation of biodiversity with its sustainable use at local and regional scales.

This dynamic and interactive network of sites works to foster the harmonious integration of people and nature for sustainable development through participatory dialogue, knowledge sharing, poverty reduction, human wellbeing improvements, respect or cultural values and efforts to improve society's ability to cope with climate change. Progress has been achieved in connecting landscapes and protected areas through biosphere reserves, however further efforts are needed.

UNESCO mandate
As the only United Nations organization with a mandate for education, sciences and culture, UNESCO develops and coordinates global standards and programmes with an approach linking nature and culture to conserve biodiversity and use it sustainably. The Organization leads three main frameworks for the protection of natural areas which interact and complement each other: World Heritage, the Man and the Biosphere programme and the UNESCO Global Geoparks. UNESCO also supports numerous research programmes and networks to find solutions and share knowledge.

Biosphere Reserves A place where people share a way of living with nature that builds a future, we're proud of something of value to us all

UNESCO Global Geoparks
Advance the protection and use of geological heritage in a sustainable way while promoting the well-being of the people who live there.

World Heritage
Cultural and/or natural sites considered as of outstanding universal value The UNESCO-LINKS approach is to find opportunities for dialogue between different knowledge holders. A trans-disciplinary approach has emerged over two decades that emphasises the need to respect the integrity of Indigenous knowledge and Indigenous institutions, with an emphasis on helping Indigenous Peoples value, sustain, promote and transmit their knowledge in the manner which they see as appropriate and which is associated with UN human rights norms and standards.

Indigenous knowledge systems are an integral part of Indigenous economies, livelihoods, cultural and spiritual systems. The vitality of Indigenous institutions and languages are key in ensuring the constant evolution of knowledge, sustaining taxonomies, historical memory and building resilience to emerging challenges and pressures. UNESCO notes the wide diversity of the conceptualisation of gender in relation to knowledge production, custodianship and transmission.

actions focus on:
Researching and describing natural resource knowledge, practices and governance.
Identifying knowledge of and practices that support the sustainable use and conservation of biodiversity and ecosystems.

Community-led research and documentation on a range of specific biodiversity and ecosystems issues, including fresh water biodiversity and ecosystems; savannah fire knowledge, Arctic biodiversity knowledge, knowledge on Small Island Developing States; biodiversity knowledge related to climate change in Africa; Support to initiatives to protect, safeguard and reward Indigenous knowledge, for example documentation of Indigenous tracker training and data collection on species health and trends.

11.6. SUMMARY

IUCN, WWF, UNEP, and UNESCO are key global players in biodiversity conservation, with IUCN offering scientific authority (Red List, protected areas), UNEP focusing on global policy (CBD, monitoring), WWF executing field projects and fundraising, and UNESCO contributing through education, cultural sites (Man and Biosphere, World Heritage), and training for sustainable ocean/land management. They often collaborate, like in the World Conservation Strategy, bridging science, policy, and on-the-ground action to protect nature.

11.7. SELF ASSESSMENT

1. Define biodiversity and explain why its conservation is important for both the environment and human well-being, mentioning key services provided by ecosystems.
2. Differentiate between inter-governmental organizations (IGOs) and non-governmental organizations (NGOs), and classify IUCN, WWF, UNEP, and UNESCO accordingly.
3. Explain the primary mission and approach of each organization (IUCN's scientific/policy focus, WWF's public campaigns/field projects, UNEP's UN system coordination, UNESCO's education/culture/science mandate).
4. Describe the significance of the IUCN Red List of Threatened Species as a key indicator of global biodiversity health and how it influences conservation policy and action.
5. Discuss how UNEP facilitates international cooperation and agreement in biodiversity conservation, specifically mentioning its role in hosting the secretariats for major Multilateral Environmental Agreements (MEAs) such as the Convention on Biological Diversity (CBD) and CITES.
6. Analyze the unique approach of UNESCO in biodiversity conservation through its designated sites, such as Biosphere Reserves and World Heritage sites, and the integration of sustainable development perspectives.
7. Evaluate the role of the WWF in on-the-ground conservation efforts, public awareness campaigns, and funding projects, highlighting its pragmatic, project-based approach.
8. Compare and contrast the respective roles and effectiveness of a governmental/scientific focused body like IUCN and a publicly funded NGO like WWF in mobilizing resources and implementing global conservation strategies.
9. Assess the challenges faced by these organizations in balancing biodiversity conservation with economic development priorities, especially in developing countries.
10. Argue how the collaborative efforts (e.g., the development of the World Conservation Strategy by IUCN with UNEP and WWF support) can be more impactful than individual organizational actions.
11. Propose a hypothetical scenario where all four organizations collaborate on a specific global conservation challenge (e.g., protecting a major rainforest or coral reef system) and describe how their individual strengths would contribute to the overall success.

11.8 SUGGESTED READING

1. Silent Spring by Rachel Carson.
2. The Sixth Extinction: An Unnatural History by Elizabeth Kolbert.
3. Half-Earth: Our Planet's Fight for Life by Edward O. Wilson.
4. International Union for Conservation of Nature (IUCN)
5. The Green Web – A Union for World Conservation (available on the IUCN Library System).
6. The IUCN Red List: 50 Years of Conservation (available for free download from IUCN).
7. IUCN Red Data Books/Lists.
8. Saving the World's Wildlife: WWF – the first 50 years by Alexis Schwarzenbach. World Wildlife Fund (Organizations That Help the World) by Margaret Haerens.
9. The UNEP Biodiversity Programme and Implementation Strategy: A Framework for Supporting Global Conservation and Sustainable Use of Biodiversity. This is an official publication outlining UNEP's specific strategy and role in global conservation efforts.
10. Global Environment Outlook (GEO) reports by UNEP (available on UNEP's website). These comprehensive scientific assessments communicate the status of urgent environmental issues, including biodiversity loss, and the opportunities to solve them.
11. Caring for the Earth: A Strategy for Sustainable Living. For the most up-to-date and in-depth information, directly consulting the official publications and reports on the organizations' respective websites is recommended.

Prof A.Amrutha Valli

LESSON- 12
STRATEGIES FOR *IN SITU* CONSERVATION

Objectives :

1. By maintaining a variety of protected places, such as national parks, wildlife sanctuaries, and biosphere reserves, in situ conservation initiatives aim to preserve species in their native environments.
2. To preserve entire ecosystems and populations of wild species in situ, create and efficiently administer national parks, wildlife sanctuaries, nature reserves, and biosphere reserves.
3. To protect important habitats, corridors, wetlands, mangroves, coral reefs, and marine ecosystems while permitting controlled, suitable uses, establish conservation reserves, community reserves, and other types of protected areas

STRUCTURE OF THE LESSON:

12.1. INTRODUCTION

The key strategy is to establish protected areas, designating land for conservation, ranging from strictly protected zones to areas allowing sustainable use. National Parks are places set aside for the preservation of wildlife where grazing and forestry are prohibited. Wildlife sanctuaries are areas set aside for the preservation of wildlife and their habitats. Biosphere Reserves are places that manage human usage while promoting the preservation of ecosystems, cultural variety, and biodiversity. Sacred groves and community reserves are places set aside for conservation, sometimes with local community participation or conserved because of their cultural significance. Marine and coastal protected areas are places set aside in the ocean and along coastlines to safeguard marine ecosystems.

Habitat and Ecosystem Management can be done by preserving natural processes by safeguarding the entire ecosystem, including grasslands, marshes, and forests. Threat management, is putting in place stringent laws and enforcement to stop poaching, illicit logging, and habitat degradation. Species-Specific Projects deal with conservation initiatives concentrated on flagship species (elephants, tigers) within their native habitats. Community Involvement can be achieved by collaborating with nearby communities to combine conservation with human development. Protected Area Networks work on creating broader, more resilient conservation landscapes by connecting protected areas. **Legislation** by using laws like India's Wildlife (Protection) Act, 1972, to establish and manage protected areas. By **Integrated Management** Combining governance, stakeholder collaboration, and robust management plans for success. One essential tactic for safeguarding endangered ecosystems and species is in situ conservation. This conservation strategy greatly enhances ecological and human well-being by preserving ecosystem integrity, fostering genetic variety, and encouraging sustainable resource use. The purpose of this chapter is to thoroughly examine in situ conservation, its significance, and several approaches, such as etc.

12.2. IMPORTANT STRATEGIES OF PROTECTED-AREA

12.2.1. Landscape and habitat management

Maintain or restore habitat connectivity through ecological corridors and buffer zones so that gene flow, migration, and dispersal can continue across fragmented landscapes
Implement habitat restoration (reforestation, invasive species control, soil and water conservation) inside and around protected areas to improve ecosystem resilience and support viable populations in situ.

12.2.2. Measures focussing on species and sites

Determine and legally safeguard vital habitats that are necessary for the life cycles of threatened species, such as wetlands, nesting beaches, breeding grounds, spawning grounds, and important biodiversity areas.

To help vulnerable taxa recover within their natural range, implement species recovery programs in the wild (anti-poaching, decreasing human-wildlife conflict, limiting harvest, and bolstering populations).

12.2.3. community-based and traditional systems.

Strengthen community-conserved areas, sacred groves, and indigenous territories where local norms, customary laws, and cultural values maintain high biodiversity in situ.

Integrate sustainable resource use (non-timber forest products, community forestry, eco-tourism, co-management agreements) so that local livelihoods and conservation incentives are aligned.

12.2.4. Conservation of agrobiodiversity on farms .

Encourage the conservation of crop genetic resources on farms by providing assistance to farmers that maintain traditional varieties and a variety of landraces in their production systems.

In traditional agricultural, horticultural, or agroforestry environments, sustain in situ diversity of crops and their wild/weedy relatives through the use of economic incentives (payments, niche markets, seed networks).

12.3. MANAGEMENT AND REGULATORY STRATEGIES

To lessen immediate threats and guarantee adherence to conservation regulations, protected areas and other in situ conservation sites employ these traditional management and regulatory techniques.
They are most effective when paired with monitoring, community involvement, and well-defined legal frameworks.

12.3.1.Threat reduction (hunting, fishing, and poaching)

Establish explicit prohibitions or limitations on the hunting, fishing, and gathering of protected species, along with legally specified species lists and seasons (e.g., wildlife and fisheries acts).
Use neighbourhood guards, patrols, and trained rangers to identify illicit activity and punish criminals consistently and proportionately.

12.3.2.Reduction of pollution

Use water, air, and environmental protection legislation to enforce regulations on solid waste, agricultural runoff, and industrial effluents close to protected areas.

Use zoning, eco-sensitive zone notifications, and environmental impact assessments as measures to limit high-impact infrastructure and polluting enterprises near important habitats.

12.3.3. Preventing deforestation

Use forest conservation and land use rules, such as permit systems and explicit fines, to impose stringent limits on tree felling, land use change, and encroachment.

When feasible, combine community-based forest management with routine forest patrols, satellite or GIS-based monitoring, and quick action against illicit logging.

12.3.4. Governance and law enforcement.

Enhance coordination between enforcement agencies, define institutional missions, and fortify legislative frameworks (wildlife, forest, biodiversity, and pollution control acts).

By ensuring that sanctions are implemented uniformly, incorporating local stakeholders in governance, and providing legal, low-impact livelihood options to lessen the incentive for unlawful usage, law enforcement can be made more accountable and equitable.

12.3.5. Law enforcement and governance.

Strengthen legal frameworks (wildlife, forest, biodiversity, and pollution control acts), clarify institutional mandates, and improve coordination among enforcement agencies.
Enhance accountability and fairness in law enforcement by ensuring sanctions are applied consistently, involving local stakeholders in governance, and offering legal, low-impact livelihood options to reduce incentive for illegal use.

12.4. COMPARISON OF SPECIES CANTERED AND ECOSYSTEM BASED IN SITU STRATEGIES

While ecosystem-based solutions manage entire habitats or ecosystems to ensure the survival of all related species and ecological processes, species-cantered in situ conservation focusses on specific threatened species and their populations.

While species-cantered approaches are more limited and taxon-specific, ecosystem-based approaches are more comprehensive and process-oriented.

Species-centered: Concentrates on protecting specific species (typically flagship or threatened) by directly addressing their populations and important habitats.

Ecosystem-based: This approach indirectly benefits numerous species at once by preserving the composition, structure, and functioning of entire ecosystems or landscapes.

12.4.1.Typical objectives

Species-centred: Prevent extinction, increase population size, maintain genetic diversity, and secure critical life-cycle sites of target species.
Ecosystem-based: Preserve ecosystem integrity, resilience and processes such as nutrient cycling, pollination, disturbance regimes and food-web interactions.

12.4.2.Typical management techniques

Species-centered measures include reintroduction or translocation of the focal species, anti-poaching, control of particular dangers (such as selective hunting prohibitions), and targeted protection of nesting and breeding habitats.

Ecosystem-based: Large-scale protected area establishment and management, habitat restoration, ecosystem-scale invasive species control, landscape design, and corridor construction are examples of ecosystem-based practices.

12.4.3. Scale and data requirements

Species-centred: Operates at local to regional scales focused on the distribution of the target species; requires detailed ecological and demographic data for that species.
Ecosystem-based: Operates at habitat, ecoregion or landscape scales; uses broader data on vegetation types, ecosystem processes and land-use patterns rather than on single species.

12.4.4. Advantages and limitations.

Species-centered:This strategy may ignore uncommon species and broader ecosystem functioning, but it is very effective for highly charismatic or critically endangered taxa.

Ecosystem-based: Captures numerous species (including little-known ones) and processes at once, but unless supplemented with species-level metrics, it might not pay adequate attention to critically endangered species with very specific needs.

12.5. SUMMARY TABLE: SPECIES- VS ECOSYSTEM-BASED IN SITU STRATEGIES.

area	*in situ* strategies Species-centred	Ecosystem-based in situ strategies
Main focus	Individual threatened species	Habitat, biotic and abiotic components of that environment
Role	Stopping extinction	Integrity and resilience maintenance
Management level	A group of species.	Ecosystem, habitat type or ecoregion
Practices	Species recovery plans, site protection	Protected areas, habitat restoration

12.6. KEY STEPS TO ESTABLISH A PROTECTED AREA FOR IN SITU CONSERVATION

Establishing a protected area for in situ conservation involves a sequence of legal, scientific, and social steps from site identification to long-term management and monitoring. The process must secure biodiversity values while gaining legal backing and local support so that conservation is effective and durable.

12.6.1. Identification and evaluation of the site

(i) Identify candidate sites based on species richness, endemism, presence of threatened species, ecological representativeness, and level of threat or degradation.
(ii) Conduct baseline surveys to document biodiversity, habitat types, ecosystem services, land tenure, and current land uses, including dependence of local communities. Consultation and boundary delineation
(iii) Determine potential locations according to species richness, endemism, the existence of endangered species, ecological representativeness, and the degree of degradation or threat.
(iv) To record biodiversity, habitat types, ecological services, land tenure, and existing land uses—including the reliance of nearby communities—conduct baseline surveys.

12.7.2. Delineation of boundaries and consultation

1. Consult stakeholders (local communities, indigenous groups, landowners, government agencies, NGOs) to discuss objectives, potential impacts, and benefit-sharing.
2. Delineate clear boundaries and internal zoning (core, buffer, and transition or multiple-use zones) using ecological criteria and social considerations.

12.7.3. Legal designation and governance..

1. Choose a suitable legal classification (such as a national park, wildlife sanctuary, conservation reserve, community reserve, or marine protected area) and fulfil the required notification and declaration processes.
2. Create institutional and governance structures, outlining the duties of park authorities, co-management organisations, or neighbourhood organisations for enforcement and decision-making.

12.7.4. Planning for management and allocating resources

1. Create a management plan that outlines conservation goals, activities that are allowed and forbidden, threat reduction tactics (such as controlling poaching, managing invasive species, and managing fires), and choices for community livelihood.
2. Obtain sustainable funding, personnel, infrastructure, and capacity building for outreach, research, patrolling, and eco-development initiatives.

12.7.5. Monitoring, flexible leadership, and execution

1. Put into practice management and protection measures on the ground, such as community-based projects, controlled tourism, habitat restoration, and law enforcement.

2. Establish long-term ecological and socioeconomic monitoring, evaluate its efficacy on a regular basis, and modify management strategies as circumstances and knowledge evolve.

12.7. OTHER STRATEGIES

They support the long-term effectiveness of protected areas and species-centred measures. In addition to legal protection and site management, social and ecosystem level tactics like raising public awareness and protecting entire habitats can enhance in situ conservation. The long-term efficacy of species-centered policies and protected areas is bolstered by these "other strategies."

12.8. PUBLIC AWARENESS STRATEGIES

a. To help people comprehend the importance of biodiversity for livelihoods, culture, and well-being, incorporate biodiversity and conservation themes into community meetings, local training programs, and school and college curriculum.

b. To foster favourable attitudes, promote rule compliance, and garner public and political support for conservation, use campaigns, media, citizen science initiatives, eco clubs, and guided tours to protected areas.

12.9. ECOSYSTEM PRESERVATION STRATEGIES.

Through national parks, biosphere reserves, or community conserved areas, give priority protection to ecologically distinctive or extremely diverse ecosystems (such as wetlands, coral reefs, mangroves, and biodiversity hotspots) so that numerous species and processes are preserved together in situ.

Use ecosystem-based management to preserve the structure, function, and resilience of the entire ecosystem rather than just a few flagship species. This can be achieved by maintaining vast, contiguous habitats, connecting fragments with corridors, and restoring degraded patches.

12.10. ADVANTAGES OF *IN SITU* CONSERVATION

1. Ecosystem Preservation: Ensures the survival of interdependent species by safeguarding whole ecosystems.
2. Ecosystem Integrity: Preserves the natural dynamics, interactions, and processes necessary for the resilience and health of ecosystems.
3. Preservation of Genetic Diversity: Preserving species in their native environments permits and preserves the inherent diversity across populations. The capacity of a species to adapt to shifting environmental conditions depends on this.
4. Balanced Approach: It promotes a balance between conservation and human needs by enabling local people to exploit natural resources sustainably.
5. Cultural Preservation: It frequently supports the protection of traditional knowledge and cultural legacy, especially in regions where indigenous customs aid in the preservation of biodiversity.
6. Economical: In the long run, this is frequently more economical than ex-situ conservation.
7. Public Awareness: Provides chances for public awareness and environmental education.
8. Scientific Research: Offers useful information for ecological research.

12.11.THE DRAWBACKS AND DIFFICULTIES OF IN SITU CONSERVATION

1. Human-Wildlife Conflict: When human populations are close to protected areas, there may be conflicts that complicate conservation efforts, such as poaching or wildlife damaging crops.
2. Habitat Loss and Fragmentation: As a result of human activities like infrastructure development and urbanisation, species are isolated and genetic flow is decreased.
3. Resource Constraints: Inadequate finance, poor infrastructure, and a shortage of skilled workers frequently impede successful conservation initiatives.
4. Illegal Activities: Encroachment, deforestation, and poaching continue to be serious problems.
5. climatic Change: As habitats are altered by shifting climatic patterns, animals may need to move or adapt. Protected Areas might not be the best places for certain animals in such a situation.
6. Invasive Species: By outcompeting, predating, or infecting native species, non-native species can upset ecosystems.

12.12. SUMMARY

In Situ Conservation is an essential component of biodiversity conservation efforts. Despite the challenges, effective implementation of this method of conservation through protected areas, community involvement, and integrated management approaches can safeguard the rich biodiversity of our planet. A balanced approach that integrates In-Situ and Ex-Situ conservation strategies is crucial for ensuring the long-term survival of species and the health of ecosystems.

12.13. SELF ASSESSMENT QUESTIONS

1. What is the key concept of in situ conservation?
2. Is National Park in situ conservation? Explain.
3. What is the full form of in situ? Explain management and regulatory strategies of In situ conservation
4. Explain challenges & disadvantages of *in situ* conservation
5. Explain advantages of *in situ* conservation
6. Explain challenges & disadvantages of *in situ* conservation
7. Explain species- vs ecosystem-based in situ strategies

12.14. SUGGESTED READING

1. Wildlife Conservation and Management by N. Arumugam, T.C. Mahesh,

Dr Madhuri Vajha

LESSON- 13

PROTECTED AREAS: SANCTUARIES, NATIONAL PARKS, BIOSPHERE RESERVES AND MANGROVES

Objectives:

To get awareness on protected areas Sanctuaries, National Parks, Biosphere Reserves and Mangroves

STRUCTURE OF THE LESSON:

13.1. INTRODUCTION

Protected areas such as national parks, wildlife sanctuaries, and biosphere reserves must preserve endangered species, their natural habitats, and ecosystems from threats like poaching and human exploitation. They prevent species extinction, contribute to preserving ecological balance, and provide a safe haven for plants and animals.
These locations also support biodiversity, promote public awareness and recreation, and aid in scientific research.

13.2 SIGNIFICANT IDEAS OF PROTECTED AREAS

1. Preventing extinction. They save rare and threatened plant and animal species from becoming extinct due to dangers including poaching, habitat degradation, and hunting.
2. Habitat conservation: They safeguard the natural environments and habitats that are vital to a species' existence and well-being.
3. Conservation of the natural ecological balance and biodiversity: These areas support the rebuilding and maintenance of biodiversity and the equilibrium of the environment by protecting whole ecosystems and food chains.
4. Maintenance of biodiversity. These areas ensure the survival of many plant and animal species.

5. Promoting education and research: They provide vital sites for scientific research, education, and environmental awareness efforts.
6. Promoting sustainable land use: In particular, biosphere reserves maintain a balance between resource preservation and human usage, including local cultures.
7. Offering recreational activities They provide chances for leisure, learning, and outdoor enjoyment in a safe setting.

13.3. WILDLIFE SANCTUARIES

One of the world's seventeen most varied nations is India. Despite making up just 2.4% of the world's geographical area, 16.7% of its people population, and 18% of its cattle, it supplies around 8% of all known global biodiversity, placing a tremendous strain on our natural resources. In addition to having the greatest population of wild tigers in the world, India is home to a unique collection of internationally significant endangered species, including the Asiatic lion, Asian elephant, One-horned rhinoceros, Gangetic River Dolphin, Snow Leopard, Kashmir Stag, Dugong, Gharial, Great Indian Bustard, and Lion Tailed Macaque. India's Protected Area Network: The Prime Minister of India chairs the National Board for Wildlife (NBWL), which offers to promote ecosystems' overall health, which is crucial for sustaining life on Earth.

Areas designated for the conservation of different kinds and their habitats are known as wildlife sanctuaries. They are crucial for preserving biodiversity and providing a secure habitat for endangered species. This provide information about the traits, objectives, classification, significance, and challenges faced by wildlife sanctuaries. Wildlife sanctuaries serve as protected areas designated for the conservation of species and their associated ecosystems. The primary objective of wildlife sanctuaries is to provide an atmosphere of security and safety for various species, especially those that are endangered. Unlike national parks, they often larger in size, species sanctuaries allow some degree of human activity, such as tourism and sustainable resource use.

History of Wildlife Sanctuaries in India

India's increased awareness of the value of wildlife conservation and habitat preservation is reflected in the country's creation of wildlife sanctuaries. The origins of conservation efforts may be traced back to the historical practices of monarchs establishing royal hunting grounds, which inadvertently protected particular species, and holy woodlands, which were preserved for religious purposes.

The establishment of reserves to protect forests and game animals during the British colonial era marked a significant shift that culminated in the Indian Forest Act of 1865. Wildlife sanctuaries were formally created in the mid-1900s. Nanda Devi Sanctuary was the first sanctuary, founded in 1982 primarily to preserve its unique ecosystem. Conservation efforts have their roots in the historical customs of rulers designating royal hunting areas that unintentionally safeguarded specific species, as well as holy woods that were kept for religious reasons.A major change occurred during the British colonial era with the creation of reserves to save forests and game species, which culminated in the Indian Forest Act of 1865.In the middle of the 20th century, wildlife sanctuaries were formally established. The first sanctuary was Nanda Devi Sanctuary, which was established in 1982 mainly to save its distinctive environment. After India became dependent, the Wildlife Protection Act of 1972 was established, greatly expanding the number of sanctuaries.

By including locals in management strategies, recent projects have decreased human-wildlife conflict and encouraged sustainable resource usage. The integration of these sanctuaries into global conservation initiatives has boosted their effectiveness, underscoring their critical role in safeguarding India's rich natural heritage and biodiversity.

India's Wildlife Sanctuary Classification

India's wildlife sanctuaries can be categorised according to a number of factors, such as location, ecosystems, and conservation initiatives for certain species.

A. Geographical classification

This categorisation separates wildlife sanctuaries according to their geographic locations, which have a big impact on the local flora and fauna.

a) Himalayan Sanctuaries: These northern sanctuaries are distinguished by alpine and sub-alpine environments. Khangchendzonga Wildlife Sanctuary and Nanda Devi Wildlife Sanctuary are two exa
b) Western Ghats Sanctuaries: Known for its abundant biodiversity, this area is home to sanctuaries that preserve tropical and subtropical woods, such as Wayanad Wildlife Sanctuary and Silent Valley Wildlife Sanctuary.
c) Desert Regions:
The goal of sanctuaries in arid and semi-arid areas, like Rajasthan's Desert National Sanctuary, is to protect desert ecosystems and the rare species that have adapted to them.

B. Ecosystem-based classification

Sanctuaries can also be divided into the following categories according to the ecosystems they safeguard. \

a) Forest Ecosystems: Sanctuaries that mainly protect forested regions, such as Bhadra animals Sanctuary and Bandipur Wildlife Sanctuary, offer homes for a variety of animals.
b) Wetland Ecosystems: Sanctuaries like Rajasthan's Keoladeo Wildlife Sanctuary, which is essential for migrating birds, concentrate on preserving wetlands, lakes, and rivers.
c) Grassland Ecosystems: Sanctuaries like Gujarat's Velavadar Blackbuck Wildlife Sanctuary, which is well-known for its blackbuck population, that work to preserve grasslands and the wildlife that inhabits them.

C. Classification on basis of Species Conservation

Certain species or groups of plants /animals are the main focus of several wildlife sanctuaries.

a) Tiger Sanctuaries: These are essential for tiger conservation; two prominent examples are the Sundarbans Wildlife Sanctuary and Kanha Wildlife Sanctuary, which offer Bengal tigers essential habitats.
b) Bird Sanctuaries:Sanctuaries like the Chilika Lake Wildlife Sanctuary and the Bhitarkanika Wildlife Sanctuary in Odisha are places for preserving bird species, especially migratory birds.
c) Elephant Sanctuaries: The preservation of elephants is given top priority in these sanctuaries. Periyar Wildlife Sanctuary and Mudumalai Wildlife Sanctuary are two examples that aim to lessen conflicts between humans and elephants while safeguarding elephant habitat

Flora and Fauna in Wildlife Sanctuaries in India

(i) Overview of Biodiversity:
India's wildlife sanctuaries provide a haven for a variety of species, from big animals to smaller, lesser-known creatures.

a) They safeguard a variety of ecosystems, such as wetlands, forests, grasslands, and marine habitats.
b) Famous animals including the Bengal tiger, Indian elephant, one-horned rhinoceros, and numerous birds, reptiles, and amphibians can be found in these sanctuaries.

(ii) Endemic and Endangered Species:
Endemic and endangered species, which are essential to preserving ecological equilibrium, may be found in many wildlife sanctuaries. (For instance, the Kaziranga Wildlife Sanctuary is renowned for its one-horned rhinoceros population, while the Western Ghats sanctuaries safeguard the endangered Nilgiri tahr.

Conservation Projects:
Numerous animal sanctuaries are essential to national and international conservation initiatives. Initiatives like Project Elephant (started in 1992) and Project Tiger (started in 1973) are historic conservation efforts that safeguard these important animals and their ecosystems.

The Value of Wildlife Sanctuaries for the Environment and Ecology

a) Function in Ecosystem Balance: By safeguarding species and their habitats, wildlife sanctuaries are essential to preserving ecosystem balance. They serve as hotspots for biodiversity, allowing a variety of species including prey and predators—to cohabit and flourish, which is essential for natural processes like pollination, seed distribution, and nutrient cycling.

Several wildlife sanctuaries are integral to national and global conservation efforts. Projects like Project Tiger, launched in 1973, and Project Elephant, initiated in 1992, are landmark conservation initiatives aimed at protecting these keystone species and their habitats.

Environmental and Ecological Importance of Wildlife Sanctuaries

a) **Role in Ecosystem Balance**: Wildlife sanctuaries play a critical role in maintaining ecosystem balance by protecting species and their habitats.
They act as biodiversity hotspots, ensuring that various species, including predators prey, coexist and thrive, which is vital for natural processes like pollination, seed dispersal, and nutrient cycling.

b) **Mitigation of Environmental Issues**: Important environmental problems including habitat loss, climate change, and conflict between humans and wildlife are also lessened by wildlife sanctuaries.
(1) Sanctuaries lessen the effects of urbanisation and deforestation by creating safe areas for animals, giving species a place to live and adapt to shifting environmental conditions.

c) **Tourism and Ecotourism**: By drawing visitors, wildlife sanctuaries play a crucial role in fostering ecotourism, which strengthens local economies. The money made by wildlife safaris, bird watching, and eco-lodges raises awareness of conservation while also generating jobs and revenue for the local populations surrounding these protected regions.

d) **Sustainable Tourism Practices**: Sanctuaries have implemented sustainable tourism efforts to strike a balance between tourism and conservation.
These include restricting the amount of visitors, promoting environmentally beneficial behaviours, and including local people in the sanctuary's administration.

e) **Popular Activities**: Wildlife safaris, which allow visitors to see creatures like tigers, elephants, and rhinos in their natural environment, are popular activities in wildlife reserves.
Another popular pastime is bird viewing, especially in sanctuaries that draw migrating birds, including Keoladeo Wildlife Sanctuary.

Challenges faced by Wildlife Sanctuaries in India

a) Human Invasion and Habitat Loss:
Human encroachment is one of the most urgent problems that wildlife sanctuaries must deal with. Wildlife is being forced from its native habitats due to changes in land use and habitat fragmentation brought on by rapid urbanisation, agricultural growth, and infrastructural development.

b) Poaching and illegal Wildlife Trade: Despite strict regulations, poaching and the illicit wildlife trade continue to poses serious risks to wildlife sanctuaries.) Illegal hunting is still fuelled by the demand for goods like tiger pelts, rhino horns, and elephant ivory, which significantly lowers the population of endangered animals.

c) Climate Change and Environmental Degradation: Wildlife sanctuaries face long-term difficulties as a result of climate change. The ecosystems that sanctuaries safeguard are changing due to shifting weather patterns, increasing temperatures, and catastrophic occurrences like droughts and floods.

d) Financial and Resource Limitations: Indian wildlife sanctuaries frequently experience financial and resource limitations, which restrict their capacity to efficiently administer and safeguard their ecosystems

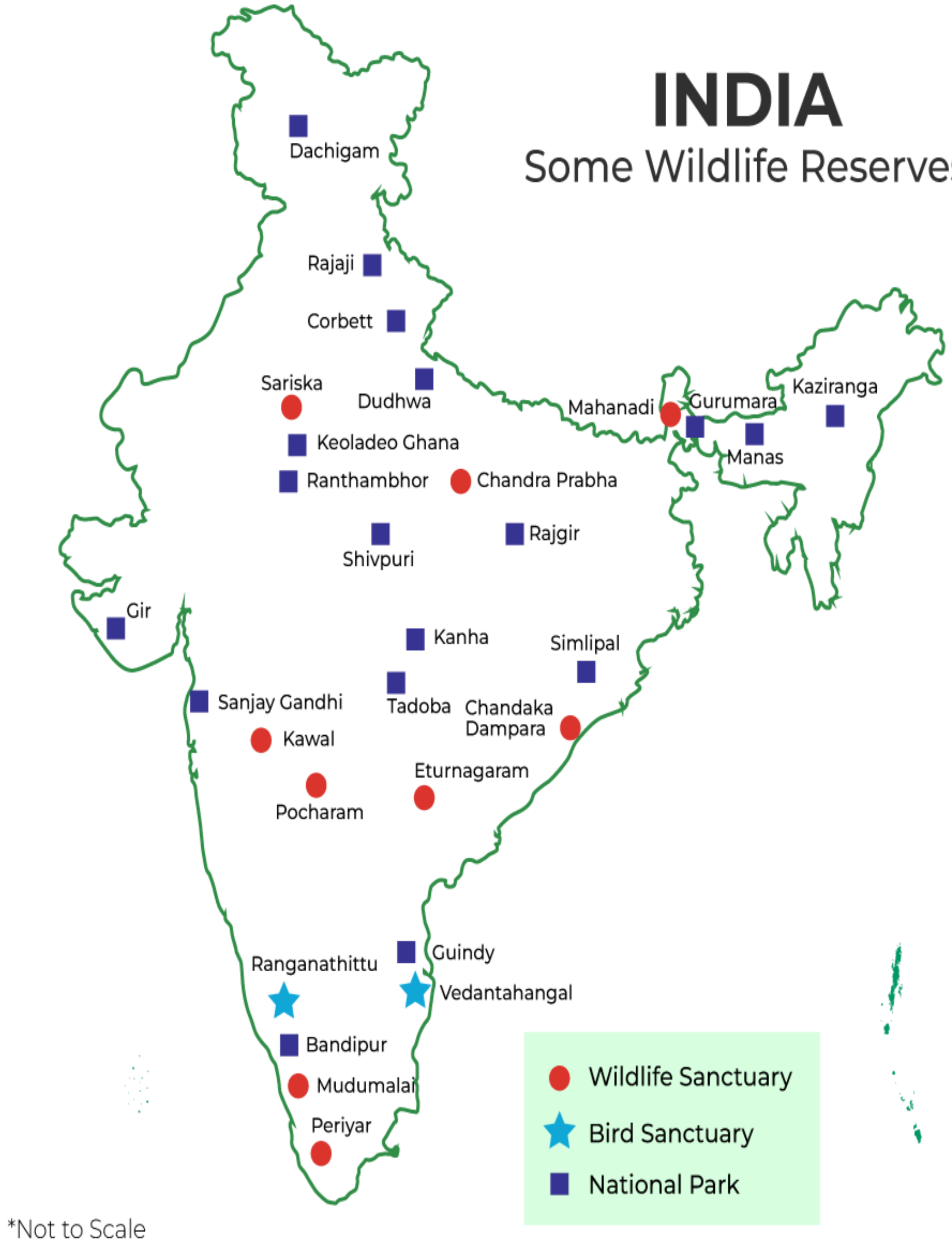
Future Prospects of wildlife sanctuaries

a) Fighting illicit activity and improving wildlife protection need bolstering legal frameworks such as the Wildlife Protection Act and enforcing harsher penalties for infractions.
b) For wildlife sanctuaries to be successful, local communities must be involved in conservation activities.
c) Local reliance on sanctuary resources may be decreased and improved collaboration between park officials and the community can be fostered through community-led projects, eco-development efforts, and alternative livelihoods.
Using cutting-edge techniques, including GPS tracking, video traps, and surveillance

drones, can increase animal protection and boost the effectiveness of conservation initiatives.

d) Long-term conservation effectiveness depends on raising public awareness through education efforts.

List of Wildlife Sanctuaries in India



13.4.12. Summary

Wildlife sanctuaries are critical in preserving biodiversity, protecting endangered species, and maintaining ecological balance. Despite challenges like habitat loss, poaching, and climate change, these sanctuaries remain vital to conservation in India.

13.4. National Parks

As vital parts of a nation's Protected Area Network (PAN) to preserve natural heritage, national parks are government-designated, strictly protected areas that are essential for preserving ecosystems, biodiversity, and wildlife. They forbid the majority of human activities, such as mining, logging, and grazing, and only permit controlled research and tourism. They are globally recognised (such as IUCN Category II), offer the greatest level of protection, have well defined limits, provide vulnerable creatures with secure refuges and promote awareness of the environment.

Key Characteristics

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(i) Strict Protection: The highest level of protection is provided by laws such as India's Wildlife (Protection) Act, 1972, which prohibits most human intervention.
(ii) Defined geographical limits: National Parks, in contrast to sanctuaries, have permanent, well-defined limits that are challenging to change.
(iii) Banned acts: It is completely illegal to engage in hunting, poaching, mining, commercial logging, or animal grazing.
(iv) Approved Procedures: research in science, education about the environment, and restricted tourism are all permitted.
(v) Governance: State forest departments look after some species under the supervision of national organisations like the National Tiger Conservation Authority (NTCA).

Function as Areas of Protection.

(i) Sustainability: Maintain distinctive natural environments, biodiversity, and ecosystems.
(ii) Nature habitat: Give endangered and vulnerable animals, such as rhinos, elephants, and tigers, secure, unaltered habitats.
(iii) Ecosystem equilibrium: Sustain genetic variety and important ecological processes.
(iv) Community Education: Promote public appreciation of nature by acting as hubs for eco-tourism and environmental education.

Indian examples (IUCN Category II)

India's first national park, Hailey National Park, was created in 1936. It is currently called Uttarakhand's Jim Corbett National Park, is well-known for its tigers.
Kaziranga National Park: Known for its one-horned rhinoceros.
he Asiatic lion may be found at Gir National Park.

National Parks are essentially the pillars of conservation, striking a balance between minimal human involvement and preservation to safeguard the natural legacy for future generations.

Maintaining inborn Ecosystems: National Parks as Key Conservation Reserves in India

A national park is a state-designated protected area designated to preserve its ecological, faunal, floral, geomorphological, or zoological value. It is included on the IUCN list's second schedule. For instance, some of India's national parks are Papikonda, Dihing Patkai, Gir, etc.

13.5.6. List of National Parks in India

Year	Name of National Park	State
1936	Corbett National Park	Uttarakhand
1955	Kanha National Park	Madhya Pradesh
1955	Tadoba National Park	Maharashtra
1959	Madhav National Park	Madhya Pradesh
1968	Bandhavgarh National Park	Madhya Pradesh
1974	Kaziranga National Park	Assam
1974	Bandipur National Park	Karnataka
1974	Bannerghatta National Park	Karnataka
1975	Gir National Park	Gujarat
1975	Gugamal National Park	Maharashtra
1975	Navegaon National Park	Maharashtra
1975	Pench National Park	Madhya Pradesh
1976	Blackbuck National Park	Gujarat
1976	Guindy National Park	Tamil Nadu
1977	Keibul-Lamjao National Park	Manipur
1977	Khangchendzonga National Park	Sikkim
1977	Dudhwa National Park	Uttar Pradesh
1978	Eravikulam National Park	Kerala
1979	Vansda National Park	Gujarat

1979	Van Vihar National Park	Madhya Pradesh
1980	Simlipal National Park	Odisha
1980	Ranthambore National Park	Rajasthan
1980	Gulf of Mannar Marine National Park	Tamil Nadu
1981	Guru Ghasidas (Sanjay) National Park	Chhattisgarh
1981	Dachigam National Park	Jammu & Kashmir
1981	Hemis National Park	Jammu & Kashmir
1981	Kishtwar National Park	Jammu & Kashmir
1981	Panna National Park	Madhya Pradesh
1981	Sanjay National Park	Madhya Pradesh
1981	Satpura National Park	Madhya Pradesh
1981	Keoladeo Ghana National Park	Rajasthan
1982	Indravati National Park	Chhattisgarh
1982	Kanger Valley National Park	Chhattisgarh
1982	Marine National Park	Gujarat
1982	Periyar National Park	Kerala
1982	Nanda Devi National Park	Uttarakhand
1982	Valley of Flowers National Park	Uttarakhand
1983	Mahatma Gandhi Marine National Park	Andaman & Nicobar Islands
1983	Namdapha National Park	Arunachal Pradesh

1983	Fossil National Park	Madhya Pradesh
1983	Sanjay Gandhi National Park	Maharashtra
1983	Rajaji National Park	Uttarakhand
1984	Great Himalayan National Park	Himachal Pradesh
1984	Silent Valley National Park	Kerala
1984	Sunderban National Park	West Bengal
1985	Balpakram National Park	Meghalaya
1986	Mouling National Park	Arunachal Pradesh
1986	Betla National Park	Jharkhand
1986	Nokrek Ridge National Park	Meghalaya
1986	Neora Valley National Park	West Bengal
1986	Singalila National Park	West Bengal
1987	Middle Button Island National Park	Andaman & Nicobar Islands
1987	Mount Harriet National Park	Andaman & Nicobar Islands
1987	North Button Island National Park	Andaman & Nicobar Islands
1987	Saddle Peak National Park	Andaman & Nicobar Islands
1987	South Button Island National Park	Andaman & Nicobar Islands
1987	Pin Valley National Park	Himachal Pradesh
1987	Anshi National Park	Karnataka
1987	Kudremukh National Park	Karnataka
1988	Nagarahole (Rajiv Gandhi) National	Karnataka

	Park	
1988	Bhitarkanika National Park	Odisha
1989	Sri Venkateswara National Park	Andhra Pradesh
1989	Valmiki National Park	Bihar
1989	Sultan National Park	Haryana
1989	Indira Gandhi (Annamalai) National Park	Tamil Nadu
1989	Gangotri National Park	Uttarakhand
1990	Manas National Park	Assam
1990	Mudumalai National Park	Tamil Nadu
1990	Mukurthi National Park	Tamil Nadu
1990	Govind National Park	Uttarakhand
1991	Murlen National Park	Mizoram
1992	Campbell Bay National Park	Andaman & Nicobar Islands
1992	Galathea Bay National Park	Andaman & Nicobar Islands
1992	Mollem National Park	Goa
1992	City Forest (Salim Ali) National Park	Jammu & Kashmir
1992	Phawngpui Blue Mountain National Park	Mizoram
1992	Desert National Park	Rajasthan
1992	Sariska National Park	Rajasthan
1992	Buxa National Park	West Bengal

1992	Gorumara National Park	West Bengal
1993	Intanki National Park	Nagaland
1994	Kasu Brahmananda Reddy National Park	Telangana
1994	Mahaveer Harina Vanasthali National Park	Telangana
1994	Mrugavani National Park	Telangana
1996	Rani Jhansi Marine National Park	Andaman & Nicobar Islands
1998	Nameri National Park	Assam
1999	Dibru-Saikhowa National Park	Assam
1999	Rajiv Gandhi Orang National Park	Assam
2003	Kalesar National Park	Haryana
2003	Anamudi Shola National Park	Kerala
2003	Mathikettan Shola National Park	Kerala
2003	Pampadum Shola National Park	Kerala
2004	Chandoli National Park	Maharashtra
2005	Rajiv Gandhi (Rameswaram) National Park	Andhra Pradesh
2006	Mukundra Hills National Park	Rajasthan
2007	Clouded Leopard National Park	Tripura
2007	Bison National Park	Tripura
2008	Papikonda National Park	Andhra Pradesh
2010	Inderkilla National Park	Himachal Pradesh

2010	Khirganga National Park	Himachal Pradesh
2010	Simbalbara National Park	Himachal Pradesh
2014	Jaldapara National Park	West Bengal

13.5. BIOSPHERE RESERVES

The purpose of Biosphere Reserves (BRs) are special areas is to protect biodiversity and promote sustainable development. They support the research and management of human-nature interactions by acting as "learning places for sustainable development. The United Nations Educational, Scientific, and Cultural Organisation (UNESCO) created." Biosphere Reserves International Day in 2022. It is observed on November 3, to emphasise the importance of biosphere reserves in preserving biodiversity and advancing sustainable development. It tries to increase understanding, exchange best practices, and recognise the World Network of Biosphere Reserves' (WNBR) successes. They serve as "learning places for sustainable development," helping study and manage interactions between people and nature. shoreline, aquatic, and land areas are all part of biosphere reserves. Each one encourages ideas that balance biodiversity protection with sustainable usage. World Network of Biosphere Reserves provides a worldwide platform for BRs sites that encourage balance between nature and communities, involved in information exchange and development. Launched in 1971, the MAB Programme is an intergovernmental effort that promotes sustainable development and protecting ecosystems by using research to enhance human-nature coexistence. India's Biosphere Reserves are Thirteen of India's eighteen Biosphere Reserves, which span around 91,425 square kilometres, are included in UNESCO's WNBR. They represent India's abundant biodiversity and community-focused conservation, and they are dispersed among mountains, forests, coastlines, and islands.

a) Key facts about focusing on their size, age, and distribution in India.

Important biosphere reserves in India,	**Place**	**Area/year**
The Great Rann of Kutch (Kachchh)	Gujarat The largest	12,454 square kilometres. biggest biosphere reserve in India
the Eastern Himalayas (Garo Hills region)	Nokrek, Meghalaya, The oldest and newest	820 square kilometres India's smallest biosphere reserve.
The Nilgiri Biosphere Reserve	Tamilnadu The oldest (first designated)	1986 under the Man and the Biosphere Programme.
The Panna Biosphere Reserve	Madhya Pradesh The newest among	in 2011 by the Ministry of Environment, Forest and Climate Change.gktoday

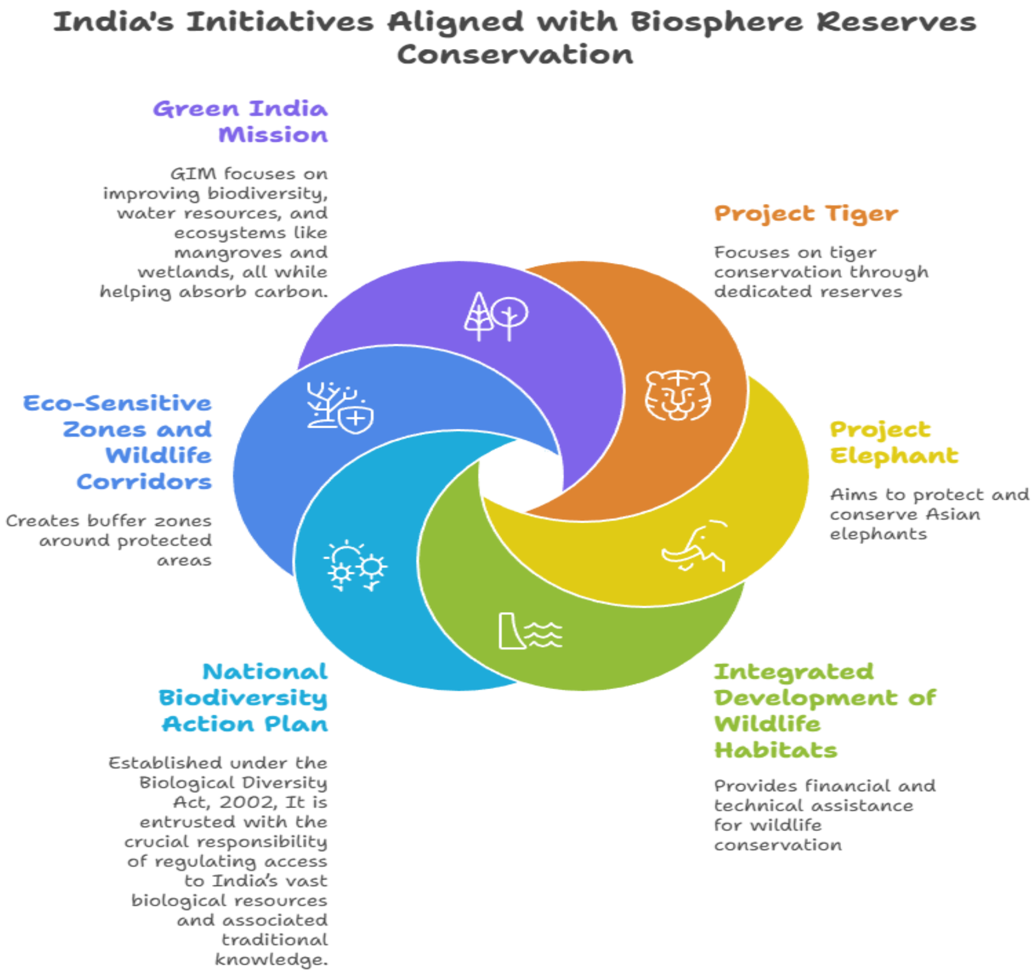
2b. States with Biosphere Reserves.

States	Biosphere Reserves
Madhya Pradesh	Pachmarhi, Achanakmar–Amarkantak (shared with Chhattisgarh), and Panna.
Tamil Nadu	Nilgiri (shared with Kerala and Karnataka), Gulf of Mannar, and Agasthyamalai (shared with Kerala)

Role of India in promoting Biosphere Reserves.

Regulatory Strategy:

The Ministry of Environment, Forests, and Climate Change's Biosphere Reserve Division carries out the Conservation of Natural Resources and Ecosystems (CNRE) Centrally Sponsored Scheme, which is supported financially by a special sub-scheme for Biosphere Reserves. It prioritises local populations through alternative livelihoods and eco-development, adopting a 60:40 Center–State model (90:10 for Northeastern and Himalayan states) and concentrating on buffer and transition zones to lessen strain on core areas. Combining National Initiatives like Project Tiger, Project Elephant, Green India Mission, Integrated Development of Wildlife Habitats (IDWH) Scheme, and National Biodiversity Action Plan (NBAP) for balanced, sustainable development are complemented by India's BRs, which preserve biodiversity and assist communities.



.Difficulties in Biosphere Reserve Management

A. Excessive Human Stress on Ecosystems
Ecosystems suffer damage by an excessive dependence on trees for grazing, 6fuel, and fodder. For instance, overgrazing in the Cold Desert BR (Himachal Pradesh) is destroying delicate alpine habitats.

Ecosystems have been destroyed by buildings, tourism, and agriculture, as seen in the Nilgiri BR, where impacts from development endanger important elephant travel routes.

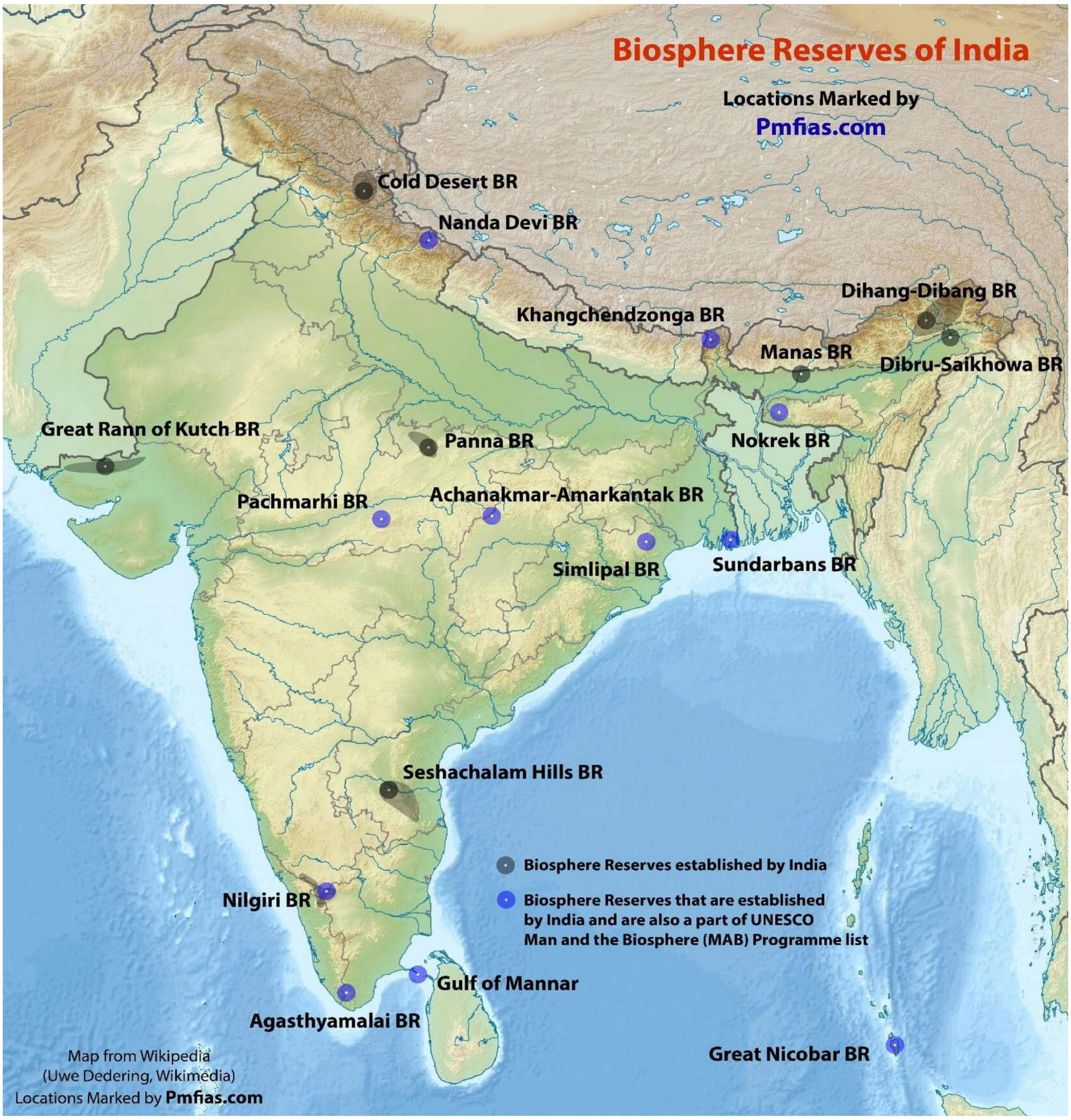
B. Poaching and Illegal Extraction:
As evidenced by reports of tiger and elephant poaching in Simlipal BR (Odisha), wildlife poaching, timber logging, and overharvesting of forest products continue to endanger biodiversity.

C. Impacts of Climate Change:
As shown in the Sundarbans BR, which is experiencing mangrove loss and coastline erosion, climate change is endangering ecosystems through sea level rise, saline intrusion, and harsh weather.

As of right now, India has **eighteen designated biosphere reserves**, thirteen of which are acknowledged by UNESCO's MAB.

S.No.	Year	Name	State	Area (km^2)
1	1986	Nilgiri Biosphere Reserve	TN (2537), Kerala (1455), Karnataka (1527)	5520
2	1988	Nanda Devi Biosphere Reserve	Uttarakhand	5860
4	1988	Nokrek Biosphere Reserve	Meghalaya	820
3	1989	Gulf of Mannar Biosphere Reserve	Tamil Nadu	10500
5	1989	Sundarbans Biosphere Reserve	West Bengal	9630
6	1989	Manas Biosphere Reserve	Assam	2837
7	1989	Great Nicobar Biosphere Reserve	Andaman and Nicobar Islands	885
8	1994	Simlipal Biosphere Reserve	Odisha	4374
9	1997	Dibru-Saikhowa Biosphere Reserve	Assam	765
10	1998	Dihang-Dibang Biosphere Reserve	Arunachal Pradesh	5112
11	1999	Pachmarhi Biosphere Reserve	Madhya Pradesh	4982
12	2000	Khangchendzonga Biosphere Reserve	Sikkim	2620
13	2001	Agasthyamalai Biosphere Reserve	Kerala, Tamil Nadu	3500
14	2005	Achanakmar-Amarkantak BR	Madhya Pradesh, Chhattisgarh	3835
15	2008	Great Rann of Kutch BR	Gujarat	12454
16	2009	Cold Desert Biosphere Reserve	Himachal Pradesh	7770
17	2010	Seshachalam Hills Biosphere Reserve	Andhra Pradesh	4755
18	2011	Panna Biosphere Reserve	Madhya Pradesh	543

Biosphere Reserves Established by India and Recognized by UNESCO's MAB



Biosphere Reserves Established by India and Recognized by UNESCO's MAB

D1. Nilgiri Biosphere Reserve

The purplish blue blooms of Neelakurinji, which bloom once every twelve years, are the source of the name Nilgiris (blue mountain). The national parks of Mudumalai, Mukurthi, Nagarhole, Bandipur, and Silent Valley, along with the wildlife sanctuaries of Aralam, Wayanad, and Sathyamangalam, comprise the Nilgiri Sub-Cluster (UNESCO World Heritage Site).

Vegetation includes semi-evergreen forests, wet deciduous forests, dry deciduous forests, thorn woods, montane sholas and grasslands at high elevations, and tropical evergreen forests on the western edge of the Western Ghats.

D2. The Nanda Devi Biosphere Reserve.

Nanda Devi National Park + Valley of Flowers National Park equals Nanda Devi Biosphere Reserve.Key Wildlife: Bharal or Blue Sheep (LC), Musk Deer (EN), Snow Leopards (VU), etc.

D3. The Biosphere Reserve of Nokrek

The highest peak in the Garo hills is Nokrek (1,412 m), which is deciduous, semi-evergreen, and evergreen.Important Wildlife: Giant Flying Squirrel (LC), Red Panda (EN), Hoolock Gibbons (EN).

D4. Gulf of Mannar Biosphere Reserve.

It is located on the Coromandel Coast area, between the southeast tip of India and the west coast of Sri Lanka. The Gulf of Mannar and Palk Bay, which is located between Sri Lanka and India to the north, are divided by the Ramsethu (Adam's Bridge) series of low islands and reefs, which includes Mannar Island.
The islands of the biosphere reserve include mangroves, salt marshes, coral reefs, seagrass beds, and estuaries. Major Wildlife: Olive Ridley turtles (VU), dugongs (VU), etc.

D5. The Biosphere Reserve of the Sundarbans.

Situated in the enormous Ganges Delta, it borders Bangladesh to the east and lies south of kolkata.The endangered Royal Bengal Tiger (EN) finds habitat there. Sundarbans National Park + Sajnekhali Wildlife Sanctuary + Lothian Wildlife Sanctuary + Haliday WLS = Sundarbans BR.

D6. The Biosphere Reserve of Manas

Manas National Park is Manas BR. It shares a border with Bhutan's Royal Manas National Park. Manas is well-known for its Wild Water Buffalo (EN) population. Assam Roofed Turtle (EN), Hispid Hare (EN), Golden Langur (EN), and Pygmy Hog (EN) are examples of rare and endemic fauna. The grassland biomes include elephants, Bengal florican (CR), rhinoceroses (reintroduced in 2007), pygmy hogs, and more.

D7. The Great Biosphere Reserve of Nicobar.

Campbell Bay National Park plus Galathea National Park is Great Nicobar BR.Tropical moist evergreen woods make up the vegetation.
Key Wildlife: Saltwater Crocodile (LC), Dugong (VU), etc.

D8. Reserve for the Similipal Biosphere

Mayurbhanj Elephant Reserve (Similipal TR + Hadgarh Wildlife Sanctuary + Kuldiha WLS) is part of it. Erenga, Kharias, Mankirdias, Ho, Gonda, and Munda are among the tribes. Royal Bengal Tigers, Wild Elephants (EN), Gaurs (VU-Indian Bison), and Chausingha (VU) are the main fauna.

D9. The Pachmarhi Biosphere Reserve

In the middle of the Satpura Range is Pachmarhi BR (Satpura National Park + Bori Wildlife Sanctuary10 + Pachmarhi WLS). The Dhoopgarh (1,352 m) is the tallest mountain.

The main tribes are the Gonds. Fauna: Indian Giant Flying Squirrels (LC), tigers, gaurs, etc.

D10. The Biosphere Reserve of Khangchendzonga

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The biosphere reserve is a hotspot for the conservation of internationally important biodiversity. Kanchenjunga (8,586 m), the third-highest mountain peak in the world, is part of it. At altitudes of 1,220 to 8,586 meters above the level of the sea, it is among the world's highest ecosystems. The KBR's central region, the Khangchendzonga NP, was designated as India's first "Mixed World Heritage Site." Key Wildlife: Great Tibetan Sheep (Argali – NT), Red Panda (EN), Snow Leopard VU, Musk Deer (EN), etc.

D11. The Biosphere Reserve of Dibru-Saikhowa, Poland

Dibru-Saikhowa National Park is equal to Dibru-Saikhowa BR.
Major Wildlife: Clouded Leopard (VU), Gangetic Dolphin (EN), Bengal Tiger, etc.

D12. Biosphere Reserve of Dihang-Dibang

This biosphere reserve contains all or a portion of the Mouling NP and the Dibang WLS. With an altitudinal range of 750 to 3000 meters at the highest point, Mouling Peak, the landscape is rough. Key Wildlife: Red Panda (EN), Takin (VU).

D13. The Biosphere Reserve of Agasthyamala

Shendurney Wildlife Sanctuary + Peppara Wildlife Sanctuary + Neyyar Wildlife Sanctuary + Kalakad Mundanthurai TR = Agasthyamala BRKani tribes from Kerala and Tamil Nadu live in the reserve. Nilgiri Tahr (EN) is the main fauna.

D14. The Biosphere Reserve of Achanakmar-Amarkantak .

It encompasses the states of Chhattisgarh and Madhya Pradesh. The reserve includes the Satpuras, eastern Vindhyas, and the Maikal highlands.

Major Wildlife: Indian Wild Dog (VU), Four-Horned Antelope (Chausingha (VU)), etc.
Dry and wet deciduous woods make up the vegetation.

D15. Kutch Biosphere Reserve's Great Rann

The Thar Desert has a salt marsh called the Great Rann of Kutch. Kachchh Desert Sanctuary (in Great Rann of Kutch) + Wild Ass Sanctuary (in Little Rann of Kutch), Narayan Sarovar Sanctuary + Kutch Bustard Sanctuary + Banni Grasslands Reserve = Great Rann of Kutch BR. Principal Wildlife: Indian Wild Ass (NT), Great Indian Bustard (CR), etc.

D16. Biosphere Reserve for the Cold Desert

Pin Valley National Park, Chandratal, Sarchu, and Kibber Wildlife Sanctuaries are among them. Snow Leopard (VU), Himalayan Ibex (Siberian Ibex – LC) are major fauna.

D17. Biosphere Reserve of Seshachalam Hills

South of the Panna River in southern Andhra Pradesh, Seshachalam Hills represent a part of the Eastern Ghats.These hills contain Sri Venkateshwara National Park and Tirupati, a significant Hindu pilgrimage centre. Major Flora: Red Sanders (NT) and other rare and unique plant species have significant economic value. The golden gecko (LC, endemic to the Tirumala Hills) is a major reptile.

D18. Reserve for Panna Biosphere

Panna TR = Panna Biosphere Reserve. Fauna: Sambar (VU), Chital (LC), Chinkara (LC), and Tiger (EN). Important Plants and Animals of India's Biosphere Reserves

.Salient Flora/Fauna of the Biosphere Reserves of India

Name	Key fauna
Nilgiri BR	Lion Tailed Macaque (EN), Nilgiri Tahr (EN), Malabar Giant Squirrel (LC), Nilgiri Langur (VU)
Nanda Devi BR	Snow Leopard (VU), Musk Deer (EN), Bharal Or Blue Sheep (LC)
Gulf of Mannar	Dugong (VU), Olive Ridley turtles (VU)
Nokrek	Red Panda (EN), Hoolock Gibbons (EN), Red Giant Flying Squirrel (LC)
Sundarbans	Royal Bengal Tiger (EN)
Manas	Assam Roofed Turtle (EN), Hispid Hare (EN), Golden Langur (EN), Pygmy Hog (EN), Wild Water Buffalo (EN), Bengal florican (CR)
Simlipal	Royal Bengal Tigers, Wild Elephants (EN), Gaurs (VU – Indian Bison), Chausingha (VU)
Dihang-Dibang	Takin (VU), Red Panda (EN)
Pachmarhi BR	Tiger, Gaur, Indian Giant Flying Squirrels (LC)
Achanakmar-Amarkantak BR	Four Horned Antelope (Chausingha (VU)), Indian Wild Dog (VU)
Great Rann of Kutch	Great Indian Bustard (CR), Indian Wild Ass (NT)
Cold Desert	Snow Leopard (VU), Himalayan Ibex (also referred to as Siberian Ibex – LC)
Khangchendzonga	Red Panda (EN), Snow Leopard (VU), Musk Deer (EN), Great Tibetan Sheep (Argali – NT)
Agasthyamalai BR	Nilgiri Tahr (EN)
Great Nicobar BR	Dugong (VU), Saltwater Crocodile (LC)
Dibru-Saikhowa	Bengal Tiger, Clouded Leopard (VU), Gangetic Dolphin (EN)
Seshachalam Hills	Red Sanders (NT), Golden Gecko (LC – Endemic To Tirumala Hills)
Panna	Tiger (EN), Chital (LC), Chinkara (LC), Sambar (VU)

13.6 MANGROVES AS PROTECTED AREA

Because mangroves are vital coastal ecosystems that sustain biodiversity, livelihoods, and climate resilience, they are frequently designated and maintained as protected areas. Mangroves consider to be a "protected area"and classified legally as wildlife sanctuaries, national parks, conservation reserves, community reserves, and marine protected areas, where industrial building, clearing, and reclamation are either banned or extremely limited. Land use, trash disposal, and other harmful activities in and around mangrove belts are further regulated by Coastal Regulation Zone (CRZ) regulations and specialist programs like the "Conservation and Management of Mangroves and Coral Reefs." Because of their extensive root systems, mangroves serve as natural bio guards that minimise coastal erosion and protect populations from storm surges, cyclones, and tsunamis. Losing them puts at risk biodiversity, food security, and climate change mitigation since they store significant amounts of "blue carbon," sustain fisheries nursery, and offer home for several vulnerable species. The examples of Mangrove protected areas include the biggest mangrove forests in the world, the Sundarbans (India–Bangladesh) contain national parks and key wildlife sanctuaries that are also recognised as UNESCO World Heritage Sites. The Godavari–Krishna delta mangroves in Andhra Pradesh, the Pichavaram and Muthupet mangroves in Tamil Nadu, the Andaman and Nicobar Islands' mangrove reserves, and the Bhitarkanika Wildlife Sanctuary and National Park in Odisha are some of the other significant mangrove protected areas in India.

13.7.3. Potential hazards to Mangroves:

A. Field Transformation:
The "State of the World's Mangroves 2024" study states that between 2000 and 2020, rice farming (43%), oil palm plantations, and aquaculture (6%) were the main causes of mangrove loss. Mangroves are severely degraded as a result of charcoal manufacturing and timberextraction.

B. Pollution:
Oil spills endanger ecosystem health and mangrove regeneration, especially in places like the Niger Delta.

C. Invasive Species:
By outcompeting native species, changing soil salinity, `decreasing freshwater availability, and impeding regeneration, the expansion of Prosopis juliflora, an aggressive invasive plant found in the mangroves of Tamil Nadu and Sri Lanka, disturbs mangrove ecosystems.

Major Threats to Mangroves

A. Land Conversion:
According to the "State of the World's Mangroves 2024" report, aquaculture (26%), along with oil palm plantations and rice cultivation (43%), has been a major driver of mangrove loss between 2000 and 2020.
Timber extraction and charcoal production lead to severe mangrove degradation.

B. Pollution:
Oil spills, particularly in areas like the Niger Delta, threaten mangrove regeneration and ecosystem health.

C. Invasive Species:
The spread of *Prosopis juliflora*, an aggressive invasive species found in the mangroves of Tamil Nadu and Sri Lanka, disrupts mangrove ecosystems by outcompeting native species, altering soil salinity, reducing freshwater availability, and hindering regeneration.

D. Strengthening Legal Framework:
Enforce stricter laws and regulatory measures to curb deforestation, pollution, and unsustainable coastal development.

E. Community Participation:
Engage local communities in conservation initiatives and provide sustainable livelihood opportunities linked to mangrove protection such as "adopt" mangrove areas, ensuring their maintenance, protection, and restoration.

F. Research & Technology Adoption:
Invest in research for phytoremediation, medicinal applications, and sustainable mangrove uses. Utilize drone monitoring and Artificial Intelligence (AI) for real-time surveillance and protection against illegal activities.

G. Bio-Restoration:
Implement bio-restoration techniques to rehabilitate degraded mangrove areas, ensuring species diversity to enhance resilience against climate change.

H. Sustainable Coastal Development:
Promote eco-friendly infrastructure, regulate aquaculture, and integrate mangrove conservation into urban planning.

I. International Collaboration:
Strengthen global cooperation through agreements like the Ramsar Convention and the Blue Carbon Initiative for effective mangrove conservation strategies.

A protected mangrove area

It is a mangrove ecosystem that is officially designated for conservation due to its ecological importance, such as the Sundarbans in India and Bangladesh, the Bhitarkanika Mangroves in Odisha, and the Pichavaram Mangroves in Tamil Nadu. These areas are safeguarded by government regulations like the Coastal Regulation Zone (CRZ) notification and various acts, which restrict activities like development and aquaculture to preserve biodiversity and 1

Key examples of protected mangrove areas

A. Sundarbans:
The world's biggest mangrove forest, shared by Bangladesh and India, is a UNESCO World Heritage Site that includes animal sanctuaries and protected places like Sundarbans National Park.

B. Mangroves in Bhitarkanika:
The second-largest mangrove forest in India is situated in Odisha and has been designated as a Ramsar Site.

C. Pichavaram Mangroves: This important mangrove region in Tamil Nadu has been named a Ramsar Site.
D. Godavari-Krishna Delta Mangroves: Another significant mangrove habitat in India is found in Andhra Pradesh.

Governmental and legal safeguards

1 (ESAs).

A. The fauna (Protection) Act of 1972: Gives these ecosystems' fauna and habitats more protection.

B. Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI): A government program to boost local livelihoods via conservation and expand mangrove cover along coasts.

C. Compensatory Replantation: If development projects impact mangroves, they must be replanted at a 3:1 ratio.

D. Joint Mangrove Management: In states like Gujarat, Tamil Nadu, Andhra Pradesh, and Odisha, local communities are involved in restoration project

Significance of protected mangroves

A. Biodiversity Hub: Provides critical habitats for a wide array of species including the Bengal tiger, estuarine crocodile, and various bird and marine life.

B. Coastal Protection: Acts as a natural barrier against storm surges, tsunamis, and coastal erosion by binding soil and absorbing wave energy.

C. Carbon Sequestration: Stores vast amounts of carbon, making them crucial in mitigating climate change.

D. Livelihood Support: Supports local communities through jobs in conservation, sustainable fishing, and tourism

Bhitarkanika Mangroves

They are an Indian protected area that was named a national park in 1998, a wildlife sanctuary in 1975, and a Ramsar site of international significance in 2002. This mangrove forest, which located in Odisha, is an important environment for biodiversity since it serves as a nursery for fish, a home for saltwater crocodiles, and a home for many bird species.

Additionally, it provides substantial coastal defence against tidal surges and storms.
Designations and protection

Wildlife Refuge: In 1975, a 672 square km region was designated as a wildlife refuge.
National Park: In 1998, the sanctuary's central region was designated as a national park.
Ramsar Site: It was acknowledged as a wetland of global significance when it was named a Ramsar site in 2002.

Gahmata Marine Sanctuary:

Founded in 1998, the 35 km of shoreline on its eastern side is a part of the Gahmata Marine Sa4nctuary.

Biodiversity and its significance

a) Biodiversity Hotspot: Of India's 58 known mangrove species, 55 are found in Bhitarkanika, which supports a wide range of plants and animals.

b) Crocodile abitat: he region is a significant breeding habitat for saltwater crocodiles and has the greatest number in all of India.

c) Avian Life: Many migratory and resident water birds use it as a key breeding and wintering area.

d) Fish Nursery: It serves as a crucial breeding ground for estuary and brackish water fish.

e) Coastal Protection: The mangrove forest acts as a natural barrier to keep people and the land safe from erosion, tidal surges, and storms.

13.6. SUMMARY

Wildlife sanctuaries are critical in preserving biodiversity, protecting endangered species, and maintaining ecological balance. Despite challenges like habitat loss, poaching, and climate change, these sanctuaries remain vital to conservation in India.

13.8. SELF ASSESSMENT

1. Describe India's Wildlife Sanctuary Classification.
2. Explain Flora and Fauna in Wildlife Sanctuaries in India
3. Explain the Value of Wildlife Sanctuaries for the Environment and Ecology.
4. Explain Environmental and Ecological Importance of Wildlife Sanctuaries
5. ExplainChallenges faced by Wildlife Sanctuaries in India
6. Write Future Prospects of wildlife sanctuaries
7. Explain Key Characteristics and Indian examples (IUCN Category II)
8. Write a List of National Parks in India.
9. Explain Key facts about focusing on their size, age, and distribution of Biosphere Reserves India.
10. Write Eighteen designated biosphere reserves.
11. Explain Salient Flora/Fauna of the Biosphere Reserves of India
12. Explain Potential hazards to Mangroves
13. Discuss Major Threats to Mangroves.
14. Explain Key examples of protected mangrove areas
15. Explain Governmental and legal safeguards of Mangrives as protected areas
16. Explain Significance of protected mangroves
17. Explain Bhitarkanika Mangroves
18. Write about Gahmata Marine Sanctuary

13.9 Suggested Reading

1. **Chauhan, S.S.** 2013. *Status of Biodiversity in India: Issues and Challenges.* Indian Journal of Plant Sciences 3(1) : 35-42.
2. **Wood,A.,Pamela,S.E.** and**Johanna,M**. 2000. *The root causes of biodiversity loss*. United Kingdom: Early-Scan Publications.
3. **Richard B. Primack**, 1993. *Essentials of Conservation Biology* (6^{th} Edition) Oxford University Press.
4. **Heywood, V.M.** and**Watson,R.T**. 1985. Global Biodiversity Assessment, Cambridge University Press, Cambridge.
5. **Swaminathan M.N. &Jam R.S.**, 1982. *Biodiversity: Implications for Global Security*, Macmillan

Dr Madhuri Vajha

Lesson- 14

STRATEGIES FOR *EX SITU* CONSERVATION: BOTANICAL GARDENS, SEED BANKS, FIELD BANKS, GENE BANKS

OBJECTIVE:

The purpose of this chapter is to thoroughly examine ex situ conservation, its definition, and a variety of techniques, such as cryopreservation, gene banks, botanical gardens, zoological parks, and seed banks.

STRUCTURE OF THE LESSON:

14.1. INTRODUCTION

Conservations of Biodiversity: Conservation is the protection, preservation, management, or restoration of wildlife and natural resources such as forests and water. Through the conservation of biodiversity and the survival of many species and habitats which are threatened due to human activities can be ensured. There is an urgent need, not only to manage and conserve the biotic wealth, but also restore the degraded ecosystems. Humans have been directly or indirectly dependent on biodiversity for sustenance to a considerable extent. However, increasing population pressure and developmental activities have led to large scale depletion of the natural resources. Conservation is the protection, preservation, management, or restoration of wildlife and natural resources such as forests and water. Through the conservation of biodiversity and the survival of many species and habitats which are threatened due to human activities can be ensured. There is an urgent need, not only to manage and conserve the biotic wealth, but also restore the degraded ecosystems. There are 2 types of Conservation:. In-situ conservation 2. Ex-situ conservation.

One of the main objectives of the Botanical Survey of India (BSI) is ex-situ conservation. It is essentially a "off site" conservation strategy that uses a couple of techniques to move a target species that is under threat from its natural habitat to a much safer location, such as a botanical garden, zoological garden, seed bank, gene bank, etc.

This method's major objective is to sufficiently support conservation efforts by ensuring the survival of endangered and disappearing taxa and species as well as the preservation of related genetic diversity. Since species under varying threat perceptions are kept in safe custody until the casual factors endangering their survival in the wild have returned to normal and reintroduction is possible, it further supports the idea of reintroducing species in their natural or original habitat.

The preamble of Article 9 of the Convention on Biological Diversity (CBD) emphasizes the necessity of creating Botanic Gardens as a supplementary strategy to in-situ conservation (conserving plant and animal species in their natural habitat) methods in order to protect endangered plant species and taxa in their native nations and to take the necessary steps to prevent their extinction.

As the guardian of the nation's floral wealth, BSI has established a number of well-networked major and minor Botanic Gardens spread across various geographical belts of the country specifically to conserve its vast, endemic, and threatened flora in order to adhere to CBD's directives. In fact, BSI started work in the same field long before CBD was established. To this end, some facilities store seeds, conserve pollen, store plant shoots at low temperatures (in vitro preservation), and use tissue culture techniques.

The "*ex situ* conservation" refers to the preservation of biological diversity elements outside of their natural habitats. This conserves genetic resources as well as wild and domesticated species using a range of techniques and tools. Reintroducing an animal or plant is a well-known example of this type of conservation effort. For instance, once-extinct Gangetic gharials have been reintroduced into the rivers of Madhya Pradesh, Uttar Pradesh, and Rajasthan. Ex situ conservation techniques, such as those used in zoos, botanical gardens, aquariums, seed banks, gene banks, tissue culture, and cryopreservation, conserve species outside of their natural environments. Through artificial plant propagation, long-term preservation of seeds and genetic material, and captive breeding programs, these methods protect genetic material and individual organisms. Zoological gardens: Oversee captive breeding programs for endangered species, emphasising genetic variety, and offer chances for public education and research. Aquariums: Support conservation efforts and raise public awareness by maintaining and breeding aquatic species. Artificial insemination and embryo transfer: methods to preserve genetic diversity in captive populations and improve breeding success.

14.2. E*X SITU* CONSERVATION OF PLANTS

a. Botanical gardens: Grow and record living plant collections for educational, conservation, and research purposes.
b. Seed banks: To preserve genetic variety and viability for extended periods of time, store seeds in regulated, low-temperature environments.
c. Gene banks: Conserve genetic resources for further studies and breeding initiatives, including DNA and embryos.
d. Tissue culture: A laboratory method for large-scale multiplication, particularly for plants that are challenging to multiply through conventional channels.
e. Cryopreservation: To avoid degradation and enable long-term storage, biological material such as tissues, cells, or embryos are preserved at extremely low temperatures (e.g., -196°Cnegative 196 increased to the limit with power cap C $-196°C$ in liquid nitrogen).

14.3. GUIDING PRINCIPLES

a. Habitat restoration: Individuals or items that help in return into rebuilt habitats are likely produced through ex situ activities.
b. Research and education: Every ex situ facility offers worthwhile chances for research and public education on conservation issues.
c. Record-keeping: For efficient administration, thorough documentation of genetic lineages and propagation success is essential.
d. An essential tactic for safeguarding endangered species and habitats is ex situ conservation. It gives endangered animals a lifeline and supports in-situ operations.

14.4. METHODS OF *EX SITU* CONSERVATION OF BIODIVERSITY

(i) Seed gene bank: These are cold storages where seeds are kept under controlled temperature and humidity for storage and this is easiest way to store the germ plasma of plants at low temperature. Seeds preserved under controlled conditions (minus temperature) remain viable for long durations of time.

(ii) Gene bank: Genetic variability also is preserved by gene bank under normal growing conditions. These are cold storages where germ plam are kept under controlled temperature and humidity for storage; this is an important way of preserving the genetic resources.

(iii) Cryopreservation: This is the newest application of technology for preservation of biotic parts. This type of conservation is done at very low temperature (196°C) in liquid nitrogen. The metabolic activities of the organisms are suspended under low temperature, which are later used for research purposes.

(iv) Tissue culture bank: Cryopreservation of disease free meristems is very helpful. Long term culture of excised roots and shoots are maintained. Meristem culture is very popular in plant propagation as it’s a virus and disease free method of multiplication.

(v) Long term captive breeding: The method involves capture, maintenance and captive breeding on long term basis of individuals of the endangered species which have lost their habitat permanently or certain highly unfavourable conditions are present in their habitat.

(vi) Botanical gardens: A botanical garden is a place where flowers, fruits and vegetables are grown. The botanical gardens provide beauty and calm environment. Most of them have started keeping exotic plants for educational and research purposes.

(vii) Animal Translocation: Release of animals in a new locality which come from anywhere else. Translocation is carried in following cases: Animal Translocation: Release of animals in a new locality which come from anywhere else. Translocation is carried in following cases:

1. When a species on which an animal is dependent becomes rare.
2. When a species is endemic or restricted to a particular area.
3. Due to habit destruction and unfavorable environment conditions.
4. Increase in population in an area.

14.5. Prominent techniques and methods of ex situ type of conservation Botanical Gardens

(i) Zoological Parks
(ii) Gene Banks
(iii) Seed Banks, and
(iv) Cryopreservation

14.5.1. Botanical Gardens:

Botanical gardens are establishments that maintain documented collections of living plants for scientific study, conservation, education, and display. Genetically representative permanent collections should be obtained for conservation, (re-)introduction, research, and education. Conservation is being realised through seeds, cuttings, and tissue or cell cultures.

14.5.2. Zoological parks

They are places where animals are kept in cages, shown to the public, and may even reproduce. There are regional programs for the conservation of endangered species all over the world, and cooperative breeding programs with international study books and coordinators that assess the roles of individual animals and institutions from a global or regional perspective are responsible for coordinating the breeding of endangered species. : In zoos wild animals are maintained in captivity and conservation of wild animals (rare, endangered species). The oldest zoo, the Schonbrumm zoo which exists today also, was established in VIENNA in 1759. In India, the 1st zoo came into existence at BARRACKPORE in 1800. In world there are about 800 zoos. Such zoos have about 3000 species of vertebrates. Some zoos have undertaken captive breeding programmes

14.5.3. Gene Banks

DNA, sperm, and embryos from endangered species are preserved in Gene Banks and can be utilised for study, breeding initiatives, and possible reintroductions in the future.

14.5.4.The Seed Banks

To maintain genetic variety, seed banks store seeds under certain conditions.
They are therefore a form of gene bank.
Compared to other ex situ conservation techniques, they have a number of advantages, including simplicity of storage, space economy, comparatively low manpower requirements, and the ability to retain large samples at a cost that is economically feasible.

There are several reasons to preserve seeds, including: Having the genes required by plant breeders to improve the nutritional quality, flavour, drought tolerance, disease esistance, and yield of plants used in agriculture (i.e., crops or domesticated species) to prevent rare or endangered plant species from losing their genetic variety in an attempt to preserve biodiversity ex situ. Organelles, cells, tissues, extracellular matrix, organs, or any other biological constructs vulnerable to damage from uncontrolled chemical kinetics are preserved through the process of cryopreservation, which involves cooling to extremely low temperatures (usually -80 °C using solid carbon dioxide or -196 °C using liquid nitrogen). Any chemical or enzymatic activity that may harm the biological substance in issue is effectively halted at low enough temperatures. It is a helpful technique for long-term germplasm preservation, particularly for plant species with limited desiccation tolerance that are challenging to preserve as seeds.

14.6. CRYOPRESERVATION

1. Cryopreservation is a process where organelles, cells, tissues, extracellular matrix, organs or any other biological constructs susceptible to damage caused by unregulated chemical kinetics are preserved by cooling to very low temperatures (typically -80 °C using solid carbon dioxide or -196 °C using liquid nitrogen).
2. At low enough temperatures, any enzymatic or chemical activity that might cause damage to the biological material in question is effectively stopped.
3. It is a useful method for long-term storage of germplasm, especially for plant species that are difficult to conserve as seeds due to low desiccation tolerance.
4. For aquatic species, it has limited application because female gametes and fertilised eggs usually cannot be frozen.
5. For livestock, it usually means the preservation of germplasm for the purpose of genetic conservation.
6. This distinction is more relevant for livestock than for other sectors because it is more widely applied for uses other than conservation.

14.8. USES OF CRYOPRESERVATION

Cryopreservation can be used for the following purposes:
1. Conservation of plant germplasm
   a. Vegetative propagated species (root and tubers, ornamental, fruit trees)
   b. Recalcitrant seed species (Howea, coconut, coffee)

2. Conservation of tissue with specific characteristics
   a. Medicinal and alcohol-producing cell lines
   b. Genetically transformed tissues
   c. Transformation/ Mutagenesis competent tissues (ECSs)

3. Eradication of viruses (Banana, Plum)

4. Conservation of plant pathogens (fungi, nematodes)

While ex situ conservation refers to the managed conservation of species outside of their natural habitats, in situ conservation refers to the protection of species within their natural ecosystems.

14.8. COMPARATIVE ANALYSIS *IN SITU* CONSERVATION AND *EX SITU* CONSERVATION

Final table of contents about in situ conservation and ex situ conservation

Aspect	***in situ* Conservation**	***ex situ* Conservation**
Definition	preservation of species and genetic diversity within their native environments	Conservation of species or genetic material in controlled or artificial environments away from their natural habitats
Location	Occurs in natural environments such rivers, coral reefs, fields, and woods.	Aappens in controlled or artificial settings, such as botanical gardens, aquariums, zoos, gene banks, and seed banks
Focus	preserving whole ecosystems, allowing for continuous evolution, and maintaining natural ecological processes	Safeguarding each species' genetic resources while they are being cared for by humans in order to ensure their survival and future usage.
Examples	holy groves, ecological reserves, national parks, and animal sanctuaries.	Zoos, botanical gardens, tissue culture storage facilities, collections of seeds, gene banks, and experimental breeding initiatives.
Benefits	preserves whole populations and environments while preserving natural behaviour, associations, and mechanisms of evolution	Allows for controlled breeding, research, education, and recovery of backup for endangered species.
Cost	Once established, protected areas are often fairly priced per species, however land and administration costs may be high.	Often more costly because of personnel, technology, infrastructure
Limitation	Large areas are required, land use issues must be resolved, and effective legal protection and management are essential.	Populations are susceptible to facility breakdowns and budget shortages, and species may not exhibit typical behaviours or growth
Purpose	long-term preservation of biodiversity by preserving healthy wild populations in their natural habitat	Restoration or reintroduction initiatives, as well as emergency or supporting conservation for extremely endangered species.

14.9. EX SITU CONSERVATION & IN SITU CONSERVATION: ADVANTAGES & DISADVANTAGES

Aspect	**In Situ Conservation**	**Ex Situ Conservation**
Persistent threats	Pollution, habitat loss, invasive species, and climate change are all common threats to natural habitats.	Certain species may not be able to adapt successfully to artificial environments since they reside outside of their native home..
Enduring dangers	Natural habitat threats, such as pollution, habitat loss, introduced species, and climate change, frequently survive.	High infrastructure and maintenance expenses necessitate ongoing financial and human assistance.
Population & Habitat	In addition to isolating populations, habitat loss can lower survival and gene flow.	High infrastructure and maintenance expenses need consistent financial and human assistance..
Genetic concerns	Small or isolated populations may already have less genetic diversity, that decreases adaptability.	If not properly maintained, confined populations may have little genetic variety and run the danger of inbreeding.
Management restricts	Requires vast regions, robust administration, and security forces, which may be less appropriate .	. After being brought back, domesticated animals may struggle to live and lose their natural habits.
Scope	when habitats are severely damaged or destroyed, requiring the use of other remedies.	Scale is limited; not practical for many species (particularly diverse or habitat-focused taxa).

14.10. ADVANTAGES OF EX-SITU PRESERVATION:

1. It is useful for declining population of species.
2. Endangered animals on the verge of extinction are successfully breeded.
3. Threatened species are breeded in captivity and then released in the natural habitats.
4. Ex-situ centres offer the possibilities of observing wild animals, which is otherwise not possible.
5. It is extremely useful for conducting research and scientific work on different species

14.11. DIFFERENCE BETWEEN "IN-SITU CONSERVATION" AND "EX-SITU CONSERVATION"

Some of the major Differences between In-situ and ex-situ Conservation are as follows:

In situ Conservation:
1. It is conservation of endangered species in their natural habitats.
2. The endangered species are protected from predators.
3. The depleting resources are augmented.
4. The population recovers in natural environment.

Ex situ Conservation:
1. It is conservation of endangered species outside their natural habitats.
2. The endangered species are protected from all adverse factors.
3. They are kept under human supervision and provided all the essentials.
4. Offspring produced in captive breeding are released in natural habitat for acclimatization.

14.12. BOTANIC GARDENS/ EX-SITU CONSERVATORIES UNDER THE CONTROL OF BOTANICAL SURVEY OF INDIA ARE AS FOLLOWS:

Sl. No.	Name of the Botanic Garden/ Ex-situ conservatory	Targeted groups	Total number of species conserved
1.	Acharya Jagadish Chandra Bose Indian Botanic Garden, Howrah – West Bengal. (The erstwhile Royal Botanic Garden, Calcutta and Indian Botanic Garden, Howrah.): Estd.1787, Area- 273 acres	A national repository of plants. Conserves important plant species of India and other countries. Represents a miniature of the world flora.	1400 species approx.
2.	Botanic Garden of Indian Republic (BGIR), Noida, Uttar Pradesh Estd: 2002, Area- 163.79 acres	An under construction garden, showcasing region's wide variety of native flora. Plants from 23 states of the country are conserved.	900 species
3.	Barapani Experimental Garden, Barapani & National Orchidarium, Shillong, Meghalaya Estd: 1966 Area: 25 acres	Orchids, Nepenthes, Insectivorous plants, Medicinal plants, Arboriculture species and other endemic threatened plants of North East India. Including well equipped tissue culture laboratory for micro propagation and storage of germ plasm.	750 species approx..
4.	Experimental Botanic Garden, Andaman & Nocobar Island, Dhanikari Area: 70 acres	Endemic and threatened plants of Andaman & Nicobar Islands	250 species approx...
5.	Experimental Botanic Garden, Arunachal Regional Centre, Sankie view Area: 110 acres	Endemic and threatened plants of Arunachal Pradesh	200 species approx.

6.	Experimental Botanic Garden & National Orchidarium, Yercaud, Tamilnadu under Southern Regional Centre, Coimbatore. Area; 40 acres	Endemic orchids of Western & Eastern Ghats, Endemic plants of Western Ghats and others. Tissue culture laboratory attached.	1200 species
7.	Experimental Botanic Garden, Western Regional Centre, Mundhwa,Pune Area: 38 acres	Endemic and threatened plants of Maharashtra, Goa and Karnataka etc.	500 species
8.	Experimental Botanic Garden, Sikkim & Himalayan, Regional Centre, Gangtok	Endemic and threatened plants of Sikkim, Himalaya and Orchids of Sikkim etc.	200 species
9.	Experimental Botanic Garden, Northen Regional Centre, Pauri Area; 35 acres	National Gymnosperm collection and other Endemic plants	750 species
10.	Experimental Botanic Garden, Northen Regional Centre, Khirsu Area: 18 acres	'Nature reserve' and other Endemic and threatened plants of the area	
11.	Experimental Botanic Garden, Northern Regional Centre, Dehradun Area; 5 Acres	Endemic and threatened plants of Uttarakhand and Uttar Pradesh.	350 species
12.	Experimental Botanic Garden, Arid Zone Regioal Centre, Jodhpur Area:12 acres	Endemic and Threatened plants of Arid regions of Rajasthan and Gujarat, Cactus collections.	185 species
13.	Experimental Botanic Garden, Central Circle, Allahabad, U.P. Area: 7 acres	Endemic and threatened plants of Uttarpradesh and Madhyapradesh etc.	600 species approx.

14.14 SUMMARY

Ex Situ Conservation is an essential component of global biodiversity preservation efforts. A balanced approach that integrates ex situ and in-situ conservation strategies is crucial for ensuring the long-term survival of species and the health of ecosystems. Understanding the role of ex situ method of conservation in the broader context of biodiversity management is important for effective policy-making and implementation. Another name for ex situ type conservation is off-site conservation. This term highlights the practice of conserving species outside their natural habitats, such as in zoos, botanical gardens, etc. This type of conservation is necessary for several reasons, including – Species Recovery, Research & Education, Protection of Species from Threats, etc.

14.14. SELF ASSESSMENT

1. What is another name for ex situ conservation? Why do we need ex-situ conservation?
2. List Botanic Gardens/ Ex-situ conservatories under the control of Botanical Survey of India
3. Differentiate "In-situ Conservation" and "Ex-situ Conservation" .

14.15. SUGGESTED READING

1. Richard B. Primack, 1993. *Essentials of Conservation Biology* (6th Edition) Oxford University Press.
2. Heywood, V.M. andWatson,R.T. 1985. Global Biodiversity Assessment, Cambridge University Press, Cambridge.
3. Swaminathan M.N. &Jam R.S., 1982. *Biodiversity: Implications for Global Security*, Macmillan.

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LESSON -15

IN VITRO PRESERVATION

OBJECTIVES:

Protecting genetic diversity for future use, enabling long-term storage in a small amount of space, maintaining pathogen-free material, supporting breeding for improved traits (like disease resistance), conserving recalcitrant seeds or vegetatively propagated plants, and lowering labour and cost by minimising subculturing through slow-growth or cryopreservation are the main goals of in vitro germplasm preservation

STRUCTURE OF THE LESSON:

15.6. SUGGESTED READING

15.1. INTRODUCTION TO GERMPLASM CONSERVATION

In general, germplasm refers to the genetic material (total gene content) that is passed down to the progeny through germ cells. The breeder uses germplasm as a raw material to create a variety of crops. Therefore, germplasm protection becomes important in all breeding programs. Ancient man developed the practice of preserving some seeds or vegetative propagules from one season to the next when he discovered the value of plants for food and shelter. To put it another way, this may be considered rudimentary yet traditional germplasm management and storage, which is quite beneficial in breeding programs. Preserving the genetic variety of a certain plant or genetic stock for use at any point in the future is the fundamental goal of germplasm conservation (or storage)In recent years, many new plant species with desired and improved characteristics have started replacing the primitive and conventionally used agricultural plants. It is important to conserve the endangered plants or else some of the valuable genetic traits present in the primitive plants may be lost. A global body namely International Board of Plant Genetic Resources (IBPGR) has been established for germplasm conservation. Its main objective is to provide necessary support for collection, conservation and utilization of plant genetic resources throughout the world. There are two approaches for germplasm conservation of plant genetic materials: 1. In-situ conservation 2. Ex-situ conservation 1. In-Situ Conservation:

15.3. In vitro techniques for germplasm conservation: The best techniques for conserving the germplasm of vegetatively propagated plants are those that use shoots, meristems, and embryos. This in vitro method can help maintain plants with resistant seeds and genetically modified elements.

a) Advantages

In vitro germplasm conservation has a number of benefits.

i. It is possible to preserve a lot of materials in a small area.

ii. The conserved germplasm can be kept in a pathogen-free environment.

iii. It can be shielded from the dangers of nature.

iv. A huge number of plants can be obtained anytime needed from the germplasm collection.

v.Because the germplasm is kept under aspectic circumstances, there are few barriers to their transportation across national and international borders.

15.2. THREE APPROACHES FOR THE IN VITRO CONSERVATION

15.2.1. Freeze-preservation, or cryopreservation

15.2.2. Cold storage

15.2.3. Low oxygen and low pressure storage

15.2.1.1.The process of cryopreservation

Cryopreservation literally translates to "preservation in the frozen state" (Greek: krayos-frost). The idea behind cryopreservation is to lower the temperature while using cryoprotectants to get plant cell and tissue cultures to a condition of zero metabolism or nondividing.

15.2.1.2 Temperature range at cryopreservation done

In general, cryopreservation refers to the storage of germplasm at extremely low temperatures:

(i) At -79°C, over solid carbon dioxide
(ii) Deep freezers with low temperatures (at -80°C)
(iii) Nitrogen in the vapour phase (at -150°C)
(iv) At -196°C in liquid nitrogen

Liquid nitrogen cryopreservation is the most widely employed of these.
The cells remain entirely dormant at the liquid nitrogen temperature (-196°C), allowing for long-term conservation.

In reality, a variety of plant species, including rice, wheat, peanuts, cassava, sugarcane, strawberries, and coconuts, have had their germplasm effectively preserved using cryopreservation. Cells, meristems, and embryos kept under cryopreservation can be used to regenerate a variety of plants.

15.2.1.3. Cryopreservation Mechanism:

The process of freeze preservation relies on the water inside the cells changing from a liquid to a solid. Compared to pure water, which has a freezing point of about 0°C, cell water requires a substantially lower temperature to freeze—up to -68°C—due to the presence of salts and organic compounds in the cells. The metabolic processes and biological deteriorations in the cells and tissues nearly stop when they are kept at low temperatures.

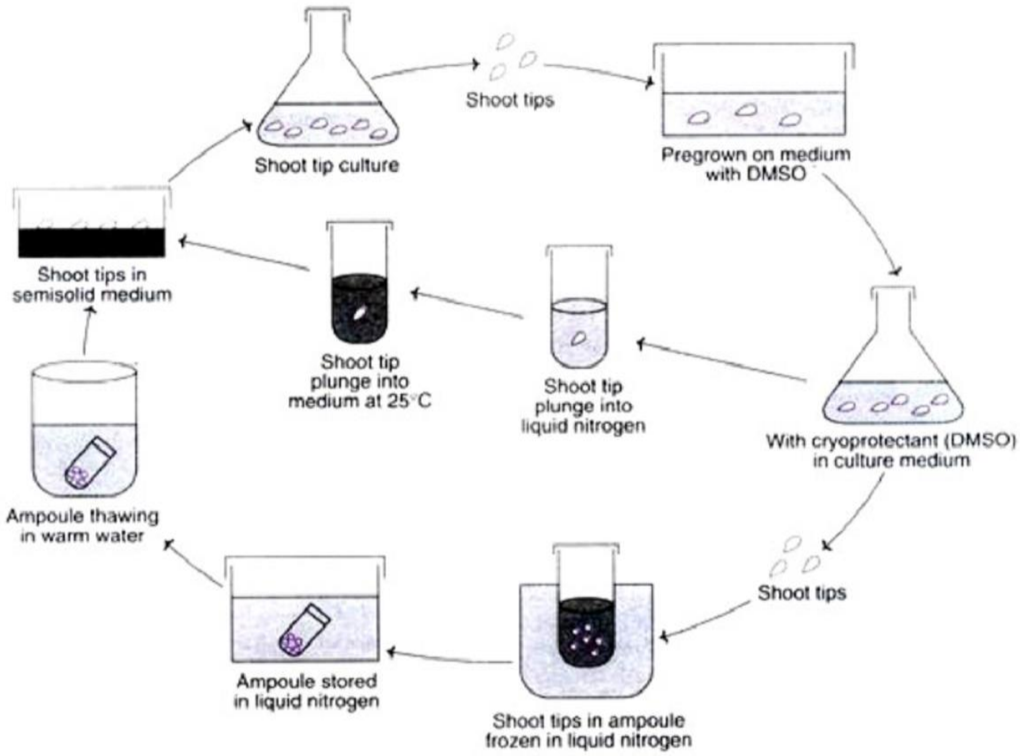
15.2.1.4. Limitations and Precautions for Effective Cryopreservation

It is crucial to have a solid theoretical and technical understanding of cryopreservation techniques and live plant cells. The following is a list of additional safety measures (the constraints that must be overcome) for effective cryopreservation:

(i) It is important to stop ice crystals from forming inside cells since they harm both the cell and its organelles.
(ii) Cells may be harmed by high intracellular solute concentrations.
(iii) During freezing, certain solutes from the cell may occasionally seep out.
(iv) Cryoprotectants have an impact on cell viability as well.
(v) The plant material's physiological state is also crucial.

15.2.1.5 Cryopreservation technique

1. The following steps are often involved in the cryopreservation of plant cell culture and subsequent plant regeneration:
2. The creation of tissue cultures that are sterile
3. Pretreatment and cryoprotectant addition
4. Freezing
5. Storage
6. Thawing
7. Re-culture
8. Survival/viability measurement
9. Regeneration of plants.



15.2.1.6. Key characteristics

Here is a quick description of the key characteristics of the aforementioned stages.

A. Sterile tissue culture development: The capacity of the explant to survive in cryopreservation is significantly influenced by the choice of plant species and tissues, particularly with regard to the morphological and physiological characteristics. Plant tissues such as meristems, embryos, endosperms, ovules, seeds, cultured plant cells, protoplasts, and calluses may all be cryopreserved. These include suspension cell cultures and meristematic cells in the late lag phase or log phase.

B. Cryoprotectants lower the freezing and super-cooling points of water. Consequently, the cryopreservation process slows down the creation of ice crystals. Dimethyl sulfoxide (DMSO), glycerol, ethylene, propylene, sucrose, mannose, glucose, proline, and acetamide are a few examples of cryoprotectants. The most popular ones are glycerol, sucrose, and DMSO. For more efficient cryopreservation without causing harm to cells or tissues, a combination of cryoprotectants is typically utilised rather than a single one.

C. Freezing The plant species has a major influence on how sensitive the cells are to low temperatures.
There are four basic kinds of freezing techniques used:

C1. The slow-freezing technique
The tissue or necessary plant material is transferred to liquid nitrogen after being gradually frozen at a cooling rate of 0.5–5°C/min from 0°C to -100°C. The slow-freezing technique has the benefit of allowing some water to escape the cells. Instead of intracellular freezing, this encourages the production of extracellular ice. This leads to a partial dehydration of the plant

cells, which improves their survival. Suspension cultures may be effectively cryopreserved using the slow-freezing method.

C2. Rapid freezing method: This straightforward procedure entails submerging the plant material-containing vial in liquid nitrogen.
The temperature drops from -300° to -1000°C/min during fast freezing. The freezing process happens so fast that tiny ice crystals grow inside the cells. Additionally, there is very little intracellular ice crystal formation. Shoot tips and somatic embryos are cryopreserved using the rapid freezing procedure.

C3. The procedure of stepwise freezing: This is a step-by-step process that combines the benefits of both slow and fast freezing techniques. The plant material is quickly chilled by submerging it in liquid nitrogen after being initially cooled to an intermediate temperature and kept there for around half an hour.
Suspension cultures, shoot apices, and buds have all been effectively cryopreserved using the stepwise freezing procedure.

C4. Dry freezing method: Unlike water-imbibing seeds, which are vulnerable to cryogenic injury, some workers have found that non-germinated dry seeds may withstand freezing at extremely low temperatures. Similarly, after cryopreservation, dehydrated cells are shown to have a higher survival rate.

C5. Storage: Just as crucial as freezing is keeping the frozen cultures at the proper temperature. For storage, frozen cells and tissues are typically stored between -70 and -196°C. However, ice crystals may form inside the cells at temperatures over -130°C, which lowers cell viability. The best temperature for storage in a liquid nitrogen refrigerator is either -196°C in the liquid phase or 150°C in the vapour phase. Stopping all cellular metabolic processes while preserving cell viability is the ultimate goal of storage. The optimal temperature for long-term liquid nitrogen storage is -196°C. The liquid nitrogen refrigerator needs a steady and consistent supply of liquid nitrogen. In certain samples, it is required to regularly assess the germplasm's vitality. The storage of germplasm must be properly documented.

D. Documentation

The following details must be included in the thorough documentation:

(i) The material's taxonomic categorisation
(ii) Culture history
(iii) Morphogenic potential
(iv) Genetic modifications carried out
(v) Somaclonal differences
(vi) The medium of culture
(vii) Kinetics of growth

E. Thawing

Typically, the frozen samples in ampoules are submerged in a bath of warm water (between 37 and 45°C) with vigorous whirling to thaw them. This method thaws quickly (between 500 and 750°C per minute), shielding the cells from the harmful effects of ice crystal formation. The ampoules are swiftly moved to a water bath that is between 20 and 25 degrees Celsius as the thawing process (ice melting fully) takes place.

This transfer is required because prolonged exposure to a heated (37–45°C) water bath damages the cells. The thawing procedure becomes less important for cryopreserved material (cells/tissues) if the water content has been lowered to an ideal level prior to freezing.

F. Re-culture: To get rid of cryoprotectants, thawed germplasm is often washed many times. Following normal protocols, this material is subsequently re-cultured in a new medium. Some employees would rather cultivate the thawed material straight away without cleaning. This is because it is thought that certain essential compounds produced from the cells during freezing support in vitro growth.

G. Tests for Viability

At any point during cryopreservation, as well as during thawing or re-culture, the viability and survival of the frozen cells can be assessed. The methods used to assess cryopreserved cell viability are same to those used for cell cultures. Common staining methods include fluorescein diacetate (FDA), Evan's blue, and triphenyl tetrazolium chloride (TTC). The capacity of cryopreserved cells to divide and proliferate in culture is the best way to gauge their vitality.

H. Viability test

The initiation of cryopreserved cells into cell division and regrowth in culture is the best way to assess their vitality. The following expression can be used to evaluate this.

*(Total number of Growing cells/ Total number of Thawing cell) X 100

I.Regrowth of plants: Regenerating the intended plant is the ultimate goal of cryopreserving germplasm. The cryopreserved cells and tissues must be properly nourished and nurtured for proper plant development and regeneration. In addition to maintaining suitable climatic conditions, effective plant regeneration frequently requires the addition of certain growth-promoting chemicals.

15.2.2.Cold Storage:

In essence, cold storage is the preservation of germplasm at low, non-freezing temperatures (1–9°C). In contrast to cryopreservation, which completely stops the growth of the plant material, cold storage slows it down. As a result, cold storage is thought of as a slow growth germplasm conservation technique. This method's main benefit is that the plant material (cells/tissues) is protected from freezing damage. Long-term cold storage produces germplasm with a high survival rate and is easy and affordable. This method has been effectively used to store several fruit tree species' in vitro generated shoots and plants, such as strawberry and grape plants. With a few drops of medium added every two to three months, virus-free strawberry plants may be kept at 10°C for around six years. Many grape plants have been kept in cold storage (at about 9°C) for more than 15 years by moving them to a new medium every year.

15.2.2.1. Low-Pressure and Low-Oxygen Storage:

Low-pressure storage (LPS) and low-oxygen storage (LOS) have been developed for germplasm conservation as alternatives to cryopreservation and cold storage. Tissue culture storage at low pressure, low oxygen, and normal atmospheric pressure is shown graphically.

15.2.2.2. Low-Pressure Storage (LPS):

In low-pressure storage, the atmospheric pressure surrounding the plant material is reduced. This results in a partial decrease of the pressure exerted by the gases around the germplasm. The lowered partial pressure reduces the in vitro growth of plants (of organized or unorganized tissues). Lowpressure storage systems are useful for short-term and long-term storage of plant materials. The short-term storage is particularly useful to increase the shelf life of many plant materials e.g. fruits, vegetables, cut flowers, plant cuttings. The germplasm grown in cultures can be stored for long term under low pressure. Besides germplasm preservation, LPS reduces the activity of pathogenic organisms and inhibits spore germination in the plant culture systems.

15.2.2.3. Low-Oxygen Storage (LOS):

By adding inert gases, especially nitrogen, the atmospheric pressure (260 mm Hg) is maintained while the oxygen content is lowered. Plant tissue development (organised or unorganised tissue) is inhibited when the partial pressure of oxygen falls below 50 mm Hg. This is because there is less CO_2 produced when there is less O_2 available. Consequently, there is a decrease in photosynthetic activity, which prevents the development and dimension of plant tissue.

LOS's limitations: After a certain size, the long-term preservation of plant materials by low-oxygen storage is likely to impede plant development.

15.3. CRYOPRESERVATION TECHNIQUES FOR PLANT GERMPLASM CONSERVATION

It is one of the most effective conservation techniques developed as a result of the urgent necessity to preserve all that is remaining. It's an essential tool for both proactively securing a large library of genetic features for the unpredictable agricultural and environmental demands of the future, as well as for saving species that are on the edge of extinction.

Fundamentally, plant cryopreservation is an advanced scientific technique that involves cooling and storing plant cells, tissues, or organs—collectively known as explants—at extremely low temperatures. This typically means submerging oneself in liquid nitrogen at a freezing -196°C or in its vapor phase at about -160°C. The final objective? In order to thaw and rebuild these plant elements into viable plants or functional tissues, even after possibly indefinite storage, life must be suspended by preventing all metabolic activity.

15.3.1. The objectives of this deep-freeze approach are manifold:

1. **Long-Term Safeguarding:**

It's especially important for plants that are difficult to preserve with conventional seed banks. This includes species whose seeds are "intermediate" (they can withstand some drying but not enough for long-term cold storage) or "recalcitrant" (they die if dried or frozen conventionally). Additionally, it is essential for crops that are mostly grown from cuttings or other vegetative parts, such as fruit trees and many staple foods like potatoes and cassava.

2. **Maintaining Genetic Purity:**

Cryopreservation significantly lowers the chance of genetic alterations, such as mutations or variations, that may arise when plants are kept in field collections or repeatedly re-cultured in laboratories as it effectively stops the biological clock.

3. **Providing a Secure Safety Net:**

A crucial backup is provided by cryopreserved collections. While lab-based slow-growth cultures require ongoing care and run the risk of contamination or unintentional loss, field gene banks are susceptible to pests, illnesses, and natural disasters. The only practical long-term solution for "exceptional species"—those that resist traditional seed banking—is cryopreservation. The biological mechanism stops working at these extremely low temperatures, making theoretically infinite storage possible without genetic drift. Cryopreservation is essential for the future security of the world's plant biodiversity since it can prolong genetic viability from a few years or decades to possibly thousands of years. A thorough understanding of how plant cells respond to extremely low temperatures and how water behaves physically during freezing and thawing is essential for successful plant cryopreservation.

4. **Cellular Pitfalls at Ultra-Low Temperatures**:

The Mechanisms of Cryoinjury : Water makes up a large portion of plant tissues by nature. Cooling them without taking precautions might cause serious harm, mainly because water turns into ice.

5. **Intracellular Ice Formation (IIF):**

The arch-nemesis is this. When temperatures drop, water inside cells can freeze and create sharp ice crystals that physically tear apart cellular structures, including the membranes surrounding the cell, its nucleus, and other organelles, causing contents to leak and vital compartments to be destroyed.

6. **Osmotic Stress and "Solution Effects":**

Ice frequently forms initially outside the cells during slower cooling. In the remaining unfrozen external solution, this concentrates the solutes (sugars, salts). Water is drawn out of the cells by the resulting osmotic imbalance. Although this dehydration can lower IIF, "solution effects injury"—damage from high solute levels, drastic pH changes, and the mechanical stress of shrinking—is caused by excessive shrinkage and exposure to these highly concentrated solutions (both outside and ultimately inside the cell).

7. **Chilling Injury:**

Low temperatures can harm certain plants, particularly tropical or subtropical ones, even if they are above the freezing point of water (0°C to 15°C). Without the usage of ice, this chilling injury may cause cell death by interfering with metabolism and membrane function.

8. **Recrystallization:**

Recrystallization can occur even if cells survive the original freezing if they are warmed too slowly or stored at temperatures that allow ice crystals to move. It is possible for smaller, less dangerous ice crystals to combine and develop into larger, more harmful ones.

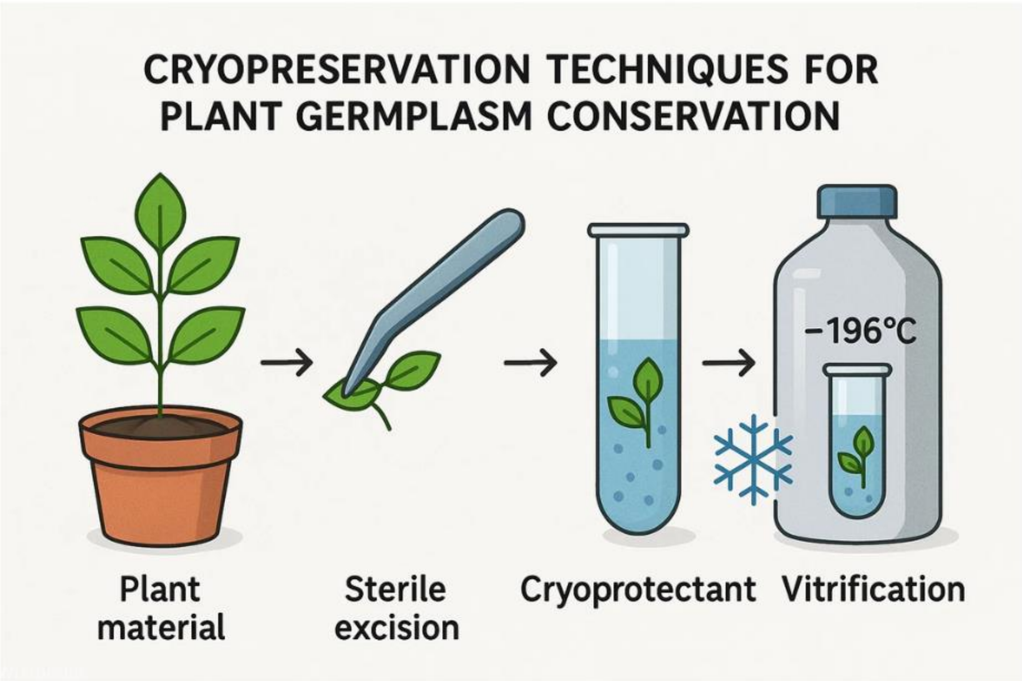
15.3.2. Vitrification

The "Glassy" Approach to Ice Damage Repair. The majority of contemporary cryopreservation techniques aim toward vitrification in order to avoid these ice-related damage. This is the process by which the cytoplasm, the cell's internal fluid, solidifies into a non-crystalline, amorphous, or "glassy" condition after very rapid cooling. The cytoplasm becomes extremely viscous in this glass-like condition, effectively halting molecular mobility and inhibiting the organization of water molecules into an organized ice crystal lattice.

Two crucial phases are usually involved in achieving vitrification:

1. First, the cell's solute content is greatly increased, making it more viscous; second, the cell is rapidly cooled.
2. This is accomplished by carefully dehydrating the body (physically or osmotically with cryoprotective chemicals) before undergoing an sudden drop in temperature.

Dehydrating just enough to avoid ice formation without causing irreparable osmotic damage or chemical toxicity from the protective chemicals is the most challenging aspect.



15.3.3. Cryoprotection: The Role of Cellular Antifreeze

a. Chemicals known as cryoprotective agents (CPAs) prevent biological samples from being harmed by freezing or thawing. They work by:
b. Reducing the quantity of ice that was created.
c. Boosting the concentration of intracellular solutes to encourage vitrification.
d. Stabilizing proteins and cell membranes.

15.3.4. Cryoprotective agents (CPAs) are broadly categorized as:

a. **Permeating CPAs:** Dimethyl sulfoxide (DMSO), ethylene glycol, and glycerol are examples of small compounds that can enter cells.
b. **Non-permeating CPAs :** Bigger molecules that mainly act osmotically from the outside include sugars (sucrose, glucose) and polymers (polyethylene glycol).

CPAs can be hazardous despite their advantages, particularly at large quantities. The varied reactions of various plant tissues and cell types make it difficult to optimize the type, concentration, exposure duration, and application temperature of CPAs in order to promote protection while avoiding injury.

15.3.5. Cryogenic Preservation: Surveying the Techniques

Cryopreservation techniques have changed significantly over time, shifting from intricate, equipment-intensive methods to more straightforward, adaptable vitrification procedures.

1. **Classical Controlled-Rate (Slow) Cooling:** An early technique based on dehydration caused by freezing. Before being quickly submerged in liquid nitrogen, samples treated with CPA are cooled gradually (e.g., 0.5–2°C/min) to an intermediate temperature (e.g., -30°C to -40°C), allowing water to escape the cells. Although it works well for cell suspensions, it frequently doesn't work as well for complicated tissues and requires costly programmable freezers.

2. **Vitrification-Based Strategies:** These utilize ultra-rapid cooling and maximize intracellular solute concentration in order to achieve a glassy state.

A. Direct Vitrification: After being osmotically dehydrated by highly concentrated "vitrification solutions" (such as PVS2 or PVS3, cocktails of CPAs), explants are submerged straight into liquid nitrogen. Pre-culture, loading with gentler CPAs, dehydration with the strong vitrification solution, quick cooling, quick warming, and cautious unloading are all part of this process.

B. Encapsulation-Dehydration: Alginate beads are used to enclose explants, such as shoot tips. After that, these beads are physically desiccated (for example, by utilizing sterile airflow), osmotically dehydrated in high-sucrose solution, and then quickly cooled in liquid nitrogen. Explants are shielded by the encapsulation, which also makes treatment easier.

C. Encapsulation-Vitrification: This hybrid technique involves rapidly cooling encapsulated explants after treating them with loading and vitrification solutions. This combines the effectiveness of vitrification solutions with the protection of encapsulation.

D. Droplet-Vitrification: A refinement in which explants treated with PVS2 are submerged in liquid nitrogen after being put in tiny droplets of fresh PVS2 solution on a carrier (such as aluminum foil). For many organisms, the little volume guarantees extremely rapid chilling and warming.

E. Cryo-plate Methods (V-cryoplate, D-cryoplate): Explants, often in minute alginate beads, are placed on specialized aluminum plates. These plates facilitate easy handling, standardized treatments, and very rapid heat exchange due to aluminum's high thermal conductivity. V-cryoplates involve PVS2 treatment on the plate, while D-cryoplates involve air desiccation after loading.

F. Other Notable Methods: Pregrowth-desiccation (culturing on CPA-supplemented media before to desiccation and freezing) and direct desiccation of naturally resistant explants (such as certain embryos and dormant buds) are also employed.

intracellular freezable water, taking various routes to accomplish this crucial dehydration while reducing related hazards.

15.3.6. The Diversity of Plant Materials

a. **Based on the biology of the species**, conservation objectives, and the viability of regeneration, a variety of plant materials can be cryopreserved.
b. **Shoot tips and Meristems:** The most frequently utilized to preserve clonal integrity in vegetatively propagated species. Genetic stability is provided by their tiny size and undifferentiated cells.
c. **Embryos (Zygotic and Somatic) and Embryonic Axes:** It is essential when direct plantlet regeneration is needed or for species with stubborn seeds. Somatic embryos are produced from in vitro cultures, while zygotic embryos/axes are removed from seeds.
d. **Seeds:** Cryopreservation can prolong the life of orthodox seeds, which are resistant to desiccation. Cryopreservation of removed embryos or axes is frequently the only choice for resistant or intermediate seeds.
e. **Pollen:** Supports breeding initiatives by preserving paternal genetic variability.
f. **Cell Cultures (Suspensions, Callus, Protoplasts):** Essential for maintaining research lines and biotech cultures.
g. **Dormant Buds:** Many woody temperate species can benefit from it, taking use of their innate resistance to cold.

15.3.6. The Diversity of Plant Materials

15.3.7. Germplasm Storage Applications:

Plant breeders and biotechnologists now benefit greatly from the preservation of germplasm. A brief description is given of a few of the uses.

1. **Stock culture maintenance**: Plant materials (cell/tissue cultures) of various species can be cryopreserved, kept for a number of years, and used as needed. In contrast, in vitro cell line maintenance requires periodic transfers and subculturing in order to prolong viability. Germplasm storage is therefore the best way to prevent subculturing and keep cells and tissues alive for many years.
2. For the long-term preservation of cell cultures that generate secondary metabolites (such as medications), cryopreservation is the best technique.
3. Plant materials devoid of disease (pathogens) can be frozen and multiplied as needed.
4. It is possible to keep recalcitrant seeds for a long time.
5. Preservation of gametoclonal and somaclonal differences across cultures.
6. Plant materials from endangered species can be conserved.
7. Conservation of pollen for enhancing longevity.
8. Rare germplasms developed through somatic hybridization and other genetic manipulations can be stored.
9. Cryopreservation is a good method for the selection of cold resistant mutant cell lines which could develop into frost resistant plants

15.3.8. Limitations of Germplasm Storage:

The major limitations of germplasm storage are the expensive equipment and the trained personnel. It may, however, be possible in the near future to develop low cost technology for cryopreservation of plant materials.

15.4. SUMMARY

Germplasm conservation includes the conservation of living genetic resources like pollens, seeds, or tissues of plant material for the purpose of plant breeding, and preservation in live conditions, and is useful for many research work. In-vitro conservation of germplasm is most widely used as it can store the genetic resources for long periods using approaches like cryopreservation, cold storage, or use of low temperature and low oxygen conditions.

In cryopreservation, very low temperatures or freezing point is used for conservation which is attained by the use of salt or cryoprotectants with the organic molecule. In this method, the cells or tissues are stopped at their non-dividing stage. Using cold storage and low pressures and low oxygen storage the growth of the germplasm is halted or reduced.

15.5. SELF ASSESSMENT:

1. Explain Invitro preservation.
2. Explain the role of Cryoprotectants.
3. Explain Cold Storage methods for invitro preservation..
4. Explain Vitrification
5. Describe Germplasm Storage Applications.

15.6. SUGGESTED READING

1. Plant Biotechnology by HC Chawala
2. Plant Tissue culture by Bhozvani

Dr Madhuri Vajha

LESSON- 16

AIR POLLUTION AND CLIMATE CHANGE; SUSTAINABLE DEVELOPMENT

OBJECTIVES:

1. The Sustainable Development Goals (SDGs) are primarily focused on eradicating poverty, safeguarding the environment, and ensuring peace and prosperity for all.
2. To evaluate how air pollution and climate change interact and to create integrated plans that lower emissions, enhance air quality, and aid in climate adaptation and mitigation.
3. Reduce emissions from industry, garbage burning, and agriculture to support sustainable production and consumption (SDG 12) and safeguard ecosystems and biodiversity (SDG

STRUCTURE OF THE LESSON:

16.1. INTRODUCTION

16.2. MAIN POLLUTANTS.

16.3. NATURAL AND MAN-MADE SOURCES POLLUTION.

16.4. NIEHS

16.5. AIR POLLUTION AND HEALTH EFFECTS CONTINUALLY ADVANCES.

16.6. AIR POLLUTION AFFECT .

16.7. CONTROL AND PREVENTION.

16.8. TOP CLIMATE IMPACTS ON AIR QUALITY.

16.9 CLIMATE CHANGE AND AIR POLLUTION - ECOSYSTEM-MEDIATED EFFECTS.

16.10. SUSTAINABLE DEVELOPMENT AND SDGS.

16.11. CO-BENEFIT SOLUTIONS.

16.12. SUMMARY

16.13. SELF ASESSMENT

16.14. SUGGESTED READING

16.1. INTRODUCTION TO AIR POLLUTION

The contamination of indoor or outdoor air by chemical, physical, or biological agents that alter the atmosphere's natural composition and endanger human health or the environment is known as air pollution. It is currently one of the main environmental risk factors for illness and early mortality in the world.

16.2. MAIN POLLUTANTS

When concentrations of gases, particles, or aerosols in the air are high enough to be harmful, air pollution results. Particulate matter ($PM_{2}.^{1}$ and PM_{2}^{1}), ozone, nitrogen dioxide, sulfur dioxide, and carbon monoxide are important pollutants of concern.

Pollutants are frequently categorized as either primary (directly released, such as sulfur dioxide from factories) or secondary (produced in the air, such as photochemical smog from NO_x and volatile organic compounds). Both interior and outdoor air pollution are significant, with domestic fuel combustion being a significant indoor source in many low- and middle-income nations.

Air pollution is a well-known environmental health risk. When exhaust billows across a busy highway, a plume rises from a smokestack, or brown haze settles over a city, we know what we're looking at. Even if you can't see certain air pollution, you can tell by its strong odor.

One well-known threat to environmental health is air pollution. When exhaust billows across a busy highway, a plume rises from a smokestack, or brown haze settles over a city, we know what we're looking at. Even if you can't see certain air pollution, you can tell by its strong odor. It is a major threat to global health and prosperity. Air pollution, in all forms, is responsible for more than 6.5 million deaths each year globally, a number that has increased over the past two decades.

16.3. NATURAL AND MAN-MADE SOURCES POLLUTION

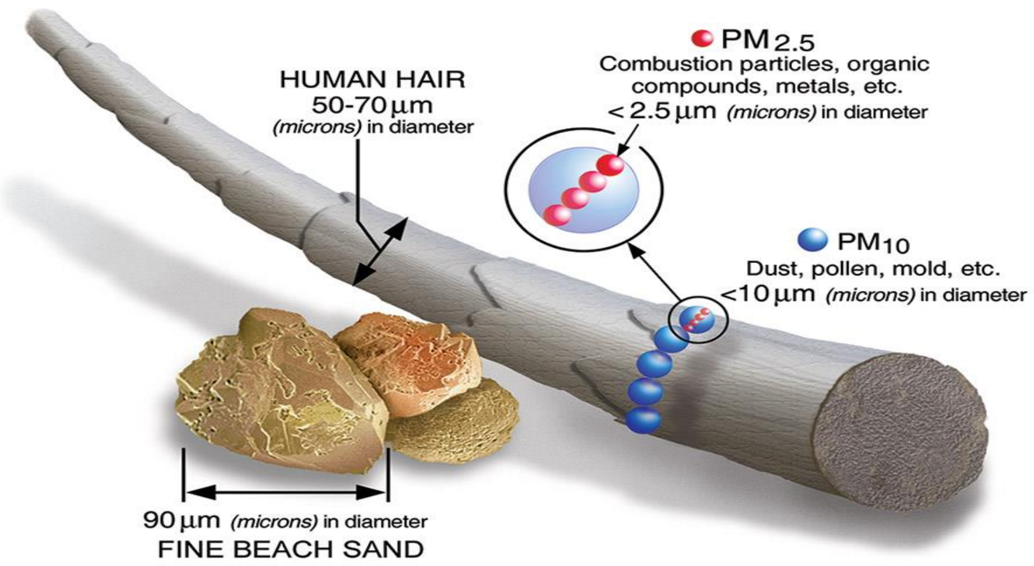
Air pollution is a mixture of dangerous materials from both natural and man-made sources.
The main sources of man-made air pollution include vehicle emissions, fuel oils and natural gas used to heat homes, by products of manufacturing and power generation, especially from coal-fueled power plants, and odors from chemical production.

Hazardous materials are released into the atmosphere by nature, including ash and gases from volcanic eruptions, smoke from wildfires that are frequently started by humans, and gasses like methane that are released from decomposing organic matter in soils.

The majority of the components of man-made air pollution, including ground-level ozone, different types of carbon, nitrogen oxides, sulfur oxides, volatile organic compounds, polycyclic aromatic hydrocarbons, and fine particulate matter, are found in traffic-related air pollution (TRAP), a mixture of gases and particles.

Ozone, an atmospheric gas, is often called smog when at ground level.It is created when pollutants emitted by cars, power plants, industrial boilers, refineries, and other sources chemically react in the presence of sunlight.

Noxious gases, which include carbon dioxide, carbon monoxide, nitrogen oxides (NOx), and sulfur oxides (SOx), are components of motor vehicle emissions and byproducts of industrial processes



Particulate matter (PM) is composed of chemicals such as sulfates, nitrates, carbon, or mineral dusts. Vehicle and industrial emissions from fossil fuel combustion, cigarette smoke, and burning organic matter, such as wildfires, all contain PM.

A subset of PM, fine particulate matter (PM 2.5) is 30 times thinner than a human hair. It can be inhaled deeply into lung tissue and contribute to serious health problems. PM 2.5 accounts for most health effects due to air pollution in the U.S. Small enough to enter the lungs and bloodstream, fine particulate air pollution (particles < 2.5 micrometres) from combustion (vehicles, power, burning) and natural sources is a major global health concern that necessitates indoor protection and awareness on days with high pollution.

Volatile organic compounds (VOC) vaporize at or near room temperature—hence, the designation volatile. They are called organic because they contain carbon. VOCs are given off by paints, cleaning supplies, pesticides, some furnishings, and even craft materials like glue. Gasoline and natural gas are major sources of VOCs, which are released during combustion.

Polycyclic aromatic hydrocarbons (PAH) are organic compounds containing carbon and hydrogen. Of more than 100 PAHs known to be widespread in the environment, 15 are listed in the Report on Carcinogens. In addition to combustion, many industrial processes, such as iron, steel, and rubber product manufacturing, as well as power generation, also produce PAHs as a by-product. PAHs are also found in particulate matter.

16.4. NIEHS

The National Institute of Environmental Health Sciences, or NIEHS, has been in operation for more than 50 years. It has been a pioneer in the study of air pollution and is a U.S. federal agency that conducts research on the impact of environmental factors on human health and well-being. Research on the effects of air pollution on health and the most vulnerable populations is still funded and carried out by the institute.

When the National Ambient Air Quality Standards were established in 1970, air pollution was regarded primarily as a threat to respiratory health. In 1993, NIEHS researchers published the landmark Six Cities Study, which established an association between fine particulate matter and mortality.

Air pollution exposure is associated with oxidative stress and inflammation in human cells, which may lay a foundation for chronic diseases and cancer. In 2013, the International Agency for Research on Cancer of the World Health Organization (WHO) classified air pollution as a human carcinogen.

Many studies have established that short-term exposure to higher levels of outdoor air pollution is associated with reduced lung function, asthma, cardiac problems, emergency department visits, and hospital admissions. Mortality rates related to air pollution are also a concern. Exposure to the air pollutant PM2.5 is associated with an increased risk of death.

A team of researchers, partially funded by NIEHS, found that deaths decreased after air pollution regulations were implemented and coal-powered plants were retired. The study data covered 21 years. More specifically, they found exposure to PM2.5 from coal was associated with a mortality risk that was twice as high as the risk from exposure to PM2.5 from all sources. PM2.5 from coal is high in sulfur dioxide, black carbon, and metals.

Public health concerns related to high air pollution exposures include cancer, cardiovascular disease, respiratory diseases, diabetes mellitus, obesity, and reproductive, neurological, and immune system disorders.

16.5. Air pollution and health effects continually advances.

Cancer

A large study of more than 57,000 women found living near major roadways may increase a woman’s risk for breast cancer.

Occupational exposure to benzene, an industrial chemical and component of gasoline, can cause leukemia and is associated with non-Hodgkin’s Lymphoma.

A long-term study, 2000-2016, found an association between lung cancer incidence and increased reliance on coal for energy generation.

Using a national dataset of older adults, researchers found that 10-year long exposures to PM2.5 and NO2 increased the risks of colorectal and prostate cancers.

Cardiovascular Disease

Fine particulate matter and nitrogen oxides are linked to impaired blood vessel function and increased cardiovascular disease risk, particularly in post-menopausal women and older Americans. Exposure to traffic-related air pollution (TRAP) can lower high-density lipoprotein levels and raises the risk of hypertensive disorders in pregnant women, contributing to pre-term birth and related health issues.

Respiratory Disease

Air pollution negatively impacts lung development and is associated with respiratory diseases like emphysema, asthma, and chronic obstructive pulmonary disease (COPD). Urbanization and outdoor air pollution contribute to increased asthma prevalence, particularly among children in low-income areas. Research from 2023 identified ozone and PM2.5 as linked to asthma-related airway changes in children. Additionally, a study involving 50,000 women found long-term exposure to PM2.5, PM10, and nitrogen dioxide associated with chronic bronchitis.

In 2020, a major public health challenge was confluence of the COVID-19 pandemic and wildfires across the western U.S. Building on a well-established connection between air pollution and respiratory-tract infections, a study linked exposure to wildfire smoke with more severe cases of COVID-19 and deaths.

16.6. AIR POLLUTION AFFECT

Air pollution impacts health universally, yet certain demographics face greater risks. Approximately 90% of urban dwellers globally are affected. NIEHS-funded studies reveal disparities in air pollution emissions related to race, ethnicity, and socioeconomic status. While emissions have decreased over recent decades, higher-income individuals enjoy more significant reductions in emissions across various sectors compared to those with lower incomes.

Long-term consequences of air pollution on children's respiratory health

One of the biggest studies on the long-term consequences of air pollution on children's respiratory health is the Children's Health Study at the University of Southern California, which is financed by the NIEHS. of the biggest studies on the long-term effects of air pollution on children' respiratory health is the University of Southern California's Children's Health Study, which is financed by the NIEHS. Among its conclusions:

Increased short-term respiratory infections caused by higher air pollution levels Asthma is more common in kids who participate in multiple outdoor activities and reside in areas with high ozone levels. Children who live close to busy roadways are more likely to get asthma. Adult bronchitis symptoms were more common in children who were exposed to high air pollution levels. Lung harm may result from residing in areas with greater pollution levels.

Other studies on women and children

Breathing PM 2.5, even at low levels, can affect the size of a developing child's brain and increase the likelihood of cognitive and emotional issues in adolescence. A large-scale study involving over 1 million birth records found that prenatal exposure to PM2.5 correlates with a higher risk of cerebral palsy, indicating the need for further research on environmental risk factors and prevention. Additionally, prenatal exposure to PAHs is linked to negative effects on brain development, including slower processing speed and symptoms of ADHD in urban youths.

Prenatal exposure to air pollution, particularly fine particulate matter (PM2.5), is linked to various adverse childhood outcomes, including ADHD-related problems and autism risk. Specifically, women exposed to high levels of PM2.5 during the third trimester have an increased likelihood of having children with autism and low birth weight. Additionally, such exposure can elevate the risk of high blood pressure in early life. A significant study involving over 300,000 women indicates that long-term exposure to air pollutants, notably ozone and PM2.5, is associated with an increased risk of postpartum depression.

The study with data on more than 5 million babies assessed associations between prenatal exposure to wildfire smoke and the risk of preterm birth. The researchers found that exposure to high levels of wildfire particulate matter during any period of pregnancy was associated with a greater chance of preterm birth.

Dementia in aged population:

Alzheimer's disease and related dementias pose a significant public health issue, particularly for aging populations. Research funded by NIEHS at the University of Washington established a connection between air pollution and increased dementia risk, providing strong evidence that fine particulate matter in the air contributes to this condition. In contrast, a 2022 study indicated that improved air quality is linked to a reduced dementia risk in older women, equivalent to a reduction of nearly 2.5 years in aged measurements. Furthermore, a large study analyzed various sources of PM2.5 emissions, finding associations with elevated dementia rates from agriculture, traffic, coal burning, and wildfires.

Air pollution was linked to a greater chance of developing several neurological disorders, including Parkinson's disease, Alzheimer's disease, and other dementias. Hospital admissions data from 63 million older adults in the U.S., obtained over 17 years (2000-2016), was analyzed along with estimated PM2.5 concentrations by zip code to conduct the study. Another study with data from 10-year long exposures also found a relationship between CO and PM2.5 and an increased chance of developing Parkinson's disease.

Osteoporosis affects women more than men. A large study associated high levels of air pollutants with bone damage, particularly in the lumbar spine, among postmenopausal women. This study expands previous findings linking air pollution and bone damage.

Nutrients may counter some harmful effects from air pollution. A 2020 study found omega-3 fatty acids, obtained by eating certain fish, may protect against PM2.5-associated brain shrinkage in older women.

Rural dwellers

NIEHS supported a translational research project on air pollution and asthma, highlighting that certain agricultural practices negatively impact children's respiratory health. The project implemented HEPA cleaners and a home education program to minimize pollutant exposure in homes. Research indicates exposure to smoke from agricultural burns, which clear post-harvest residues, can worsen respiratory health in children, a concern particularly evident in the Imperial Valley, California. Additionally, large-scale animal feeding operations may degrade air quality by emitting pollutants like ammonia gas, leading to acute lung function issues in affected children.

NIEHS and community involvement

NIEHS promotes community involvement in research and advocates for collaborative methods that enhance community capacity to tackle environmental health issues. Key approaches include community-engaged research and citizen science. NIEHS grant recipients have implemented strategies like using HEPA filtration, establishing land-use buffers and vegetation barriers, enhancing urban design with green spaces, and developing active travel routes to reduce TRAP exposure.

Air pollution and birth outcomes are linked, with efforts to reduce PM2.5 exposure potentially reducing low-birth weight and pre-term birth infants worldwide. Reducing pollution is particularly beneficial for children in low- and middle-income countries. Studies show that improving air quality may improve cognitive function and reduce dementia risk. Closed fossil-fuel power plants also reduce air pollution.

Sources of air pollution

Burning fossil fuels in factories, power plants, and automobiles releases particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and other pollutants. This is one of the main man-made sources. Other sources include biomass burning, open garbage burning, traffic and construction dust, and some industrial and agricultural processes.

Although artificial emissions predominate in many cities, natural sources including dust storms, wildfires, sea spray, and volcanic eruptions also have a role. Solid fuel stoves, kerosene lights, tobacco smoke, and certain building materials are examples of prevalent indoor sources.

According to WHO data, nearly all people on the planet (99%) breathe air that is more polluted and exceeds WHO guidelines, with low- and middle-income nations experiencing the largest exposures.

Air quality is closely linked to the earth's climate and ecosystems globally. Many of the drivers of air pollution (i.e. combustion of fossil fuels) are also sources of greenhouse gas emissions. Policies to reduce air pollution, therefore, offer a win-win strategy for both climate and health, lowering the burden of disease attributable to air pollution, as well as contributing to the near- and long-term mitigation of climate change.

Health impacts

Lung cancer, respiratory infections, chronic obstructive pulmonary disease, ischemic heart disease, and stroke are all made more likely by air pollution. Inflammation and long-term respiratory and cardiovascular harm can result from fine particulate matter's deep penetration into the lungs and bloodstream.

Air pollution is a major cause of non-communicable diseases, second only to tobacco, and is responsible for millions of premature deaths worldwide each year. Particularly at risk are low-income groups, older folks, children, and those with pre-existing medical conditions.

Environmental and climate effects

Air pollutants can damage crops, forests and freshwater systems, and contribute to acid rain and reduced visibility. Ozone at ground level harms plant growth, while particulate matter can deposit on leaves and soil, affecting ecosystems.

Many air pollutants or their precursors (for example, black carbon and ozone) also act as climate forcers, influencing global warming and regional weather patterns. Thus the same emissions often degrade air quality and drive climate change simultaneously.

16.7. CONTROL AND PREVENTION

Effective control starts with reducing emissions at source by shifting to cleaner fuels and technologies, improving energy efficiency and adopting less-polluting industrial processes. Examples include flue-gas desulfurization, catalytic converters, particulate filters, and replacing solid fuels with clean household energy.

At the individual and community level, using public transport, improving ventilation, avoiding open waste burning and supporting clean-air policies help reduce exposure and emissions. Strong air quality standards, monitoring networks and enforcement are essential to protect public health.

Overview

Clean air is essential for human health, vegetation, and the enjoyment of natural landscapes. Climate change will variably impact air quality across regions, worsening issues such as ground-level ozone and increasing allergen exposure, which can impair visibility and degrade indoor air quality. The extent of these impacts will depend on efforts to reduce air pollution through regulations, partnerships, and individual actions. Additionally, the relationship between climate change and air pollutants is bidirectional, as certain pollutants like ground-level ozone, which is also a greenhouse gas, can exacerbate climate change.

16.8. TOP CLIMATE IMPACTS ON AIR QUALITY

Climate change may affect air quality at both local and regional scales. Three key impacts are described in this section.

1. Outdoor and Indoor Air Pollution

In 2021, approximately 102 million Americans live in areas with poor air quality, exacerbated by climate-driven weather changes that increase ground-level ozone and particulate matter. These pollutants can lead to or worsen health issues, including respiratory and heart diseases. Climate change also negatively impacts indoor air quality, as outdoor pollutants may enter buildings and indoor pollutants like mold and dust mites may rise due to increased precipitation and storms. Such indoor pollutants are associated with serious health conditions, including asthma and cancer.

Air pollution may also damage crops, plants, and forests. For example, when plants absorb large amounts of ground-level ozone, they experience reduced photosy nthesis, slower growth, and higher sensitivity to diseases.

2. Wildfire Smoke

Wildfires are already more common and the wildfire season is longer due to climate change. Smoke from wildfires contaminates the air, making it difficult to see and interfering with outdoor activities. Additionally, it can spread to other areas hundreds of miles downwind.
Smoke from wildfires can exacerbate respiratory conditions like bronchitis, asthma, and chronic obstructive pulmonary disease (COPD). Premature births have also been connected to exposure to smoke from wildfires.

3. Airborne Allergens

Higher carbon dioxide concentrations, greater temperatures, longer and earlier springs and summers, and variations in precipitation are all predicted effects of climate change. People may be more exposed to pollen and other airborne allergens as a result of all these changes, which may increase the incidence of allergy-related diseases including hay fever and asthma.

4. Air Quality and the Economy

A strong economy is directly related to cleaner air. For instance, Americans' productivity and health are enhanced by clean air. Reductions in air pollution saved around 230,000 premature deaths, 200,000 heart attacks, 120,000 ER visits, and 17 million missed workdays in 2020 alone. Aiming for cleaner air also generates billions of dollars in revenue and exported goods and services for the US, as well as jobs and technological advancements.

5. Population Impacts

Many socially vulnerable groups, particularly Black and African Americans, face increased exposure to air pollution, leading to higher rates of childhood asthma. Chronic health issues are common in certain populations, including communities of color, low-income groups, Indigenous populations, and immigrants, who experience elevated rates of heart disease, asthma, and COPD. Additionally, outdoor workers such as farm workers and firefighters are particularly susceptible to air quality impacts from climate change. Furthermore, both rural and urban low-income populations often reside in older, poorly sealed buildings, increasing their exposure to allergens and pollutants, and making them more vulnerable to damage from extreme weather events.

6. Measures to reduce climate and air quality impacts

Go green. Switch to green power from renewable energy sources like solar, wind, and hydropower to reduce both air pollution and greenhouse gas emissions.

Reduce air pollution from vehicles. Walking, biking, and taking public transit among other actions can reduce emissions from transportation. These choices can also provide other benefits, such as safer streets.

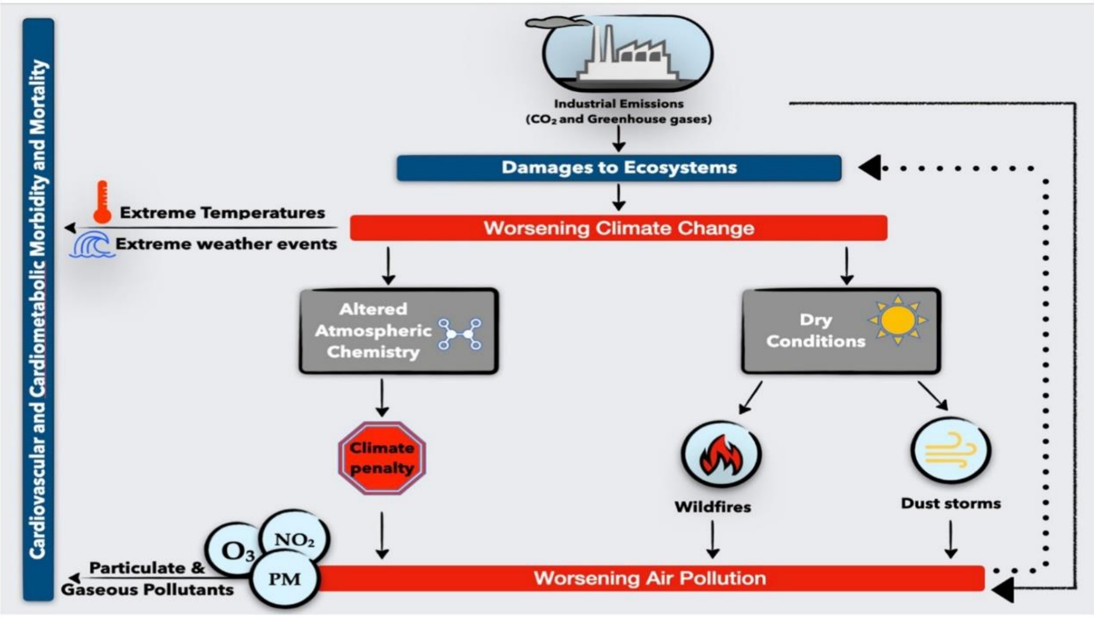
Improve air quality at ports. Communities situated near ports—which often include low-income and minority populations—are at a higher risk of air pollution exposure. Communities and stakeholders can work with EPA's Ports Initiative to improve environmental performance and advance clean technologies at ports. This effort helps people living near ports breathe cleaner air. Check out the *Community-Port Collaboration Toolkit* for ways communities can get involved.

Develop urban forests. Planting trees, especially in urban areas and along roads or highways, can help improve air quality. Trees also provide other benefits, such as reducing the impact of urban heat islands.

Prevent wildfires. Pay attention to weather and drought conditions. Avoid activities involving fire or sparks when it's dry, hot, and windy to help prevent wildfires.

Reduce your exposure. Use the Air Quality Index (AQI) to guide outdoor activities. When you see that the AQI is unhealthy, take simple steps to reduce your exposure like choosing less intense activities, take more breaks, and reschedule activities to a time when outdoor air quality is better.

Improve indoor air quality. Reduce or remove sources of indoor air pollutants whenever possible. For example, consider using portable air purifiers or high-efficiency filters in your heating, ventilation, and air conditioning systems.



16.9 Climate change and air pollution worsen each other, leading to several ecosystem-mediated effects.

Altered atmospheric chemistry and changing weather patterns contribute to the formation of air pollutants, a phenomenon termed the climate penalty. This leads to increased environmental exposures linked to negative cardiovascular health outcomes. Health professionals, especially cardiologists, must recognize the health risks posed by climate change and air pollution.

Climate change poses severe challenges to ecosystems and sustainable living due to environmental degradation and excessive consumption of resources. Anthropogenic greenhouse gas emissions trap heat, causing serious climate alterations. Schaeffer et al. describe a 'failed ecosystem' arising when repair mechanisms cannot counteract irreversible damages, leading to structural collapse. The IPCC report indicates that climate change is already impacting population health, creating complex interactions between climate and health. Notably, climate change exacerbates non-communicable diseases like cardiovascular disease (CVD), which is the leading global cause of death. This worsening occurs through both direct pathways, such as extreme heat and poor air quality, and indirect pathways, including pollutants and infrastructure damage from extreme weather.

Link between air pollution and climate change

Many air pollutants, including methane, black carbon, and ozone precursors, are both climate forcing agents that degrade air quality and contribute to global warming. Fossil fuel combustion emits greenhouse gases and other pollutants.

Climate change exacerbates air quality issues through phenomena like heatwaves and dust storms, increasing ozone and particulate matter levels. This feedback loop heightens the risk of cardiovascular and respiratory diseases, particularly in rapidly urbanizing areas, such as Indian cities.

Human and ecosystem impacts

Air pollution and climate change lead to increased premature deaths from heart and lung diseases, heat stress, and allergies. Short-lived climate pollutants like black carbon and ozone harm crops and ecosystems, reducing yields and weakening carbon sinks.

In countries such as India, air pollution causes significant premature deaths and threatens development, disproportionately affecting poorer communities and exacerbating social inequality, thus hindering sustainable development.

16.10. SUSTAINABLE DEVELOPMENT AND SDGS

Sustainable development is encapsulated by the 17 United Nations Sustainable Development Goals (SDGs), established in 2015 to eradicate poverty, safeguard the environment, and promote prosperity. Key goals linked to air pollution and climate include SDG 3 (Good Health and Well-being), SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities), and SDG 13 (Climate Action).

The SDGs advocate for economic growth that avoids environmental harm by promoting cleaner energy, sustainable transportation, and reduced industrial and household emissions, addressing health, equity, and environmental issues holistically.tainable development and SDGs.

16.11. CO-BENEFIT SOLUTIONS

Policies that reduce fossil fuel use and enhance energy efficiency yield co-benefits by lowering greenhouse gases and air pollutants. Initiatives such as renewable energy expansion, transport electrification, and improved industrial efficiency exemplify this, illustrated by India's LPG efforts for rural households. Targeted measures against short-lived climate pollutants like methane can mitigate immediate warming, prevent air pollution-related deaths, and safeguard crops. Thus, integrating air quality management with climate policy is crucial for achieving multiple Sustainable Development Goals equitably and efficiently.

16.12. SUMMARY

Air pollution, climate and sustainable development in India

Air pollution significantly affects cardiovascular health, with short-term exposure to fine particulate matter linked to increased risks of myocardial infarction, stroke, and mortality from cardiovascular diseases. The interplay between air pollution and climate change creates a cycle of harm, where fossil fuel emissions exacerbate climate issues and vice versa. Both challenges share origins and solutions, forming a central focus of the sustainable development agenda, which seeks to address current needs while safeguarding health and the environment for future generations.India is grappling with significant urban air pollution and rising greenhouse gas emissions from coal, transport, industry, and biomass burning. Despite this, emissions intensity has decreased since 2005, indicating potential for cleaner growth. Initiatives like the National Clean Air Programme, renewable energy expansion, electric mobility, and clean cooking schemes aim to improve air quality and enhance climate resilience, while aligning with Sustainable Development Goals (SDGs) to promote health, reduce inequality, and support long-term sustainable development.

16.13. SELF ASSESSMENT

1. Write an essay on Main pollutants.
2. Write an essay on Natural and man-made sources Pollution.
3. Explain activities of NIEHS
4. Air pollution and health effects continually advances.
5. Write an essay on Air pollution affect .
6. Control and prevention measures of pollution
7. Write an essay on Top Climate Impacts on Air Quality.
8. Discuss Climate change and air pollution - ecosystem-mediated effects.
9. Write about Sustainable development and SDGs

16.14. Suggested Reading

1. **Wilkinson, D.A**. 2007. *Fundamental Processes in Ecology: An Earth system Approach*. Oxford.
2. **Chapman, J.L.** and **Reiss, M.J.,** 2003. *Ecology: Principles and Applications*, (2nd Edition) Cambridge University Press, UK.
3. **Ambasht, R.S.** and **Ambasht, N.K**., 1999. *A Text Book of Ecology*, CBS Publishers and Distributers, New Delhi.

Dr Madhuri Vajha r

LESSON -17
PHYTOREMEDIATION

OBJECTIVES:

1. to assess the efficacy, benefits, and drawbacks of different phytoremediation methods
2. to provide a thorough explanation of the applications of plants and related bacteria to remediate environmental contaminants.

STRUCTURE OF THE LESSON:

17.1. INTRODUCTION

Phytoremediation is a plant-based technique that uses plants to eliminate, break down, or immobilize toxins from contaminated soil, water, and air. This economical and eco-friendly method makes use of some plants' inherent ability to absorb and break down toxins from the environment, including organic pollutants and heavy metals. Phytoextraction (plants absorb pollutants into their shoots), phytostabilization (plants immobilize pollutants in the soil), and phytodegradation (plants break down toxins) are important types.

17.1.1. PHYTOREMEDIATION- CONCEPT

Phytoremediation technologies use **living plants** to remove hazardous chemicals from soil, water, and air. It is defined as "the employment of green plants and associated microbes, as well as appropriate soil amendments and agronomic techniques, to either contain, remove, or render harmful environmental toxins harmless." Numerous plants have been shown to be capable of hyperaccumulate poisons at toxic waste sites, such as mustard, alpine pennycress, hemp, and pigweed. Phytoremediation has been effective in recovering abandoned metal mine workings, reducing ongoing coal mine discharges, and reducing contaminants in soils, water, and air at locations where polychlorinated biphenyls were deposited during manufacture. Phytoremediation operations have reduced metals, pesticides, solvents, explosives, and crude oil and its derivatives worldwide.

17.2. PROCEDURE

1. Absorption and metabolism: Contaminants from the soil are absorbed by plants, which can either retain them in their tissues or convert them into harmless chemicals.

Contaminants are mostly absorbed by plants through their roots, where they are transported inside and either stored or chemically changed into less dangerous forms.

2. Absorption of contaminants by plants

Through passive diffusion through membranes or active transporters that often transport nutrients like nitrate, phosphate, sulfate, or metal cations, roots absorb dissolved contaminants (metals, organic pollutants, microplastics) from soil solution.

After penetration, pollutants are carried to stems, leaves, flowers, and occasionally seeds via the xylem, where they may build up along the transpiration stream.

3. Storage and sequestration in tissues

Numerous inorganic pollutants, including Cd, Pb, and As, are immobilized by attaching to cell wall constituents, chelators (such phytochelatins), or being retained inside vacuoles in root or shoot cells, which lessens their interaction with delicate metabolic processes.

By concentrating metals to extremely high levels in their shoots (a process known as phytoextraction), hyperaccumulator plants make it possible to harvest and remove the pollutants from the site later.

4. Metabolic breakdown into harmless compounds

Many organic pollutants undergo "phytodegradation" (phytotransformation), in which xenobiotics undergo phase I reactions (oxidation, reduction, hydrolysis) and phase II conjugations (e.g., with sugars, amino acids, or glutathione) to form metabolites that are less toxic and more soluble in water.

These metabolites are frequently stored in vacuoles or integrated into the components of cell walls. In certain instances, they are further converted into volatile or totally mineralized compounds (such as the conversion of certain organics to CO2CO2 and water), which effectively detoxifies them.

5. **Role of rhizosphere and associated microbes**

In order to support plant metabolism, the rhizosphere microbiome, which is activated by root exudates, can break down or change pollutants either before or after plant uptake (rhizodegradation/phytostimulation).

The speciation, mobility, and bioavailability of contaminants can be altered by mycorrhizal fungi and bacteria, which can affect the amount absorbed and whether it is transferred to shoots or immobilized in roots.

6. Factors affecting absorption and metabolism
The availability of contaminants and, thus, the effectiveness of plant uptake are substantially regulated by soil pH, salinity, organic matter, moisture, and competing ions.

The selection of species for phytoremediation procedures is based on factors such as plant species, genotype, root architecture, transporter expression, and stress responses that determine whether pollutants are mostly stored, translocated, or metabolically destroyed.

2. Plant selection: Certain plants, referred to as hyperaccumulators, are chosen because they can withstand and accumulate large concentrations of particular pollutants without suffering any negative effects.

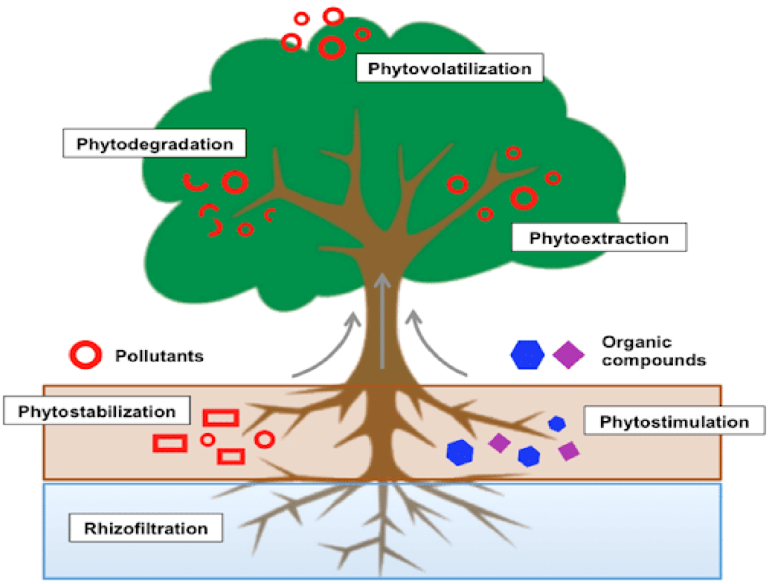
3. Rhizosphere activity: Microorganisms that aid in the breakdown of contaminants in the plant's root zone (rhizosphere) may also be involved in this process.

17.3. ADVANTAGES AND LIMITATIONS

Advantages: Compared to conventional methods like excavation, it is a less disruptive, economical, and environmentally friendly approach.

Limitations: Plant growth factors, like soil type and climate, affect the method's efficiency, and it can be slow.

17.4. TYPES OF PHYTOREMEDIATION



Phytoextraction, phytodegradation, rhizofiltration, phytovolatilization, and phytostabilization are the primary forms of phytoremediation. Different processes are used by each type to eliminate or stabilize pollutants.

a) **Phyto extraction:** Pollutants are absorbed and accumulated by plants in their leaves and shoots, which can then be collected and disposed of.

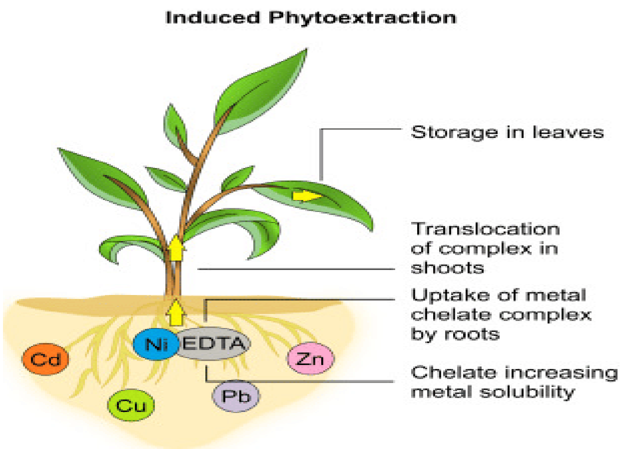
b) **Phyto stabilization:** By attaching pollutants to the soil and decreasing their mobility and bioavailability, plants can render them immobile.
c) **Phyto degradation/Phytotransformation:** Through their metabolic mechanisms, plants degrade organic pollutants.
d) **Phytofiltration:** Pollutants are filtered from contaminated water using the roots of plants.
e) **Phytovolatilization :** It is the process by which pollutants are absorbed by plants, converted to a gaseous state, and then released into the atmosphere.
f) **Phytostimulation:** In order to degrade pollutants, plant roots encourage microbial activity in the soil.

17. 4. PHYTOREMEDIATION- TYPES

17.4.1. Phytoextraction / Phytoaccumulation

a) The process by which plants store contaminants in their roots, shoots, or leaves above ground is known as phytoextraction or phytoaccumulation.
b) Elements from the soil or water are absorbed by the roots and concentrated in the biomass of the plant above ground.
c) Organisms with a high capacity for absorbing contaminants are known as hyperaccumulators.
d) Over the last twenty years or so, phytoextraction has been increasingly popular worldwide. Phytoextraction is frequently used to extract heavy metals and other inorganics.
e) Compared to the original contaminated soil or silt, contaminants are frequently concentrated in a much smaller amount of plant matter at the time of disposal.

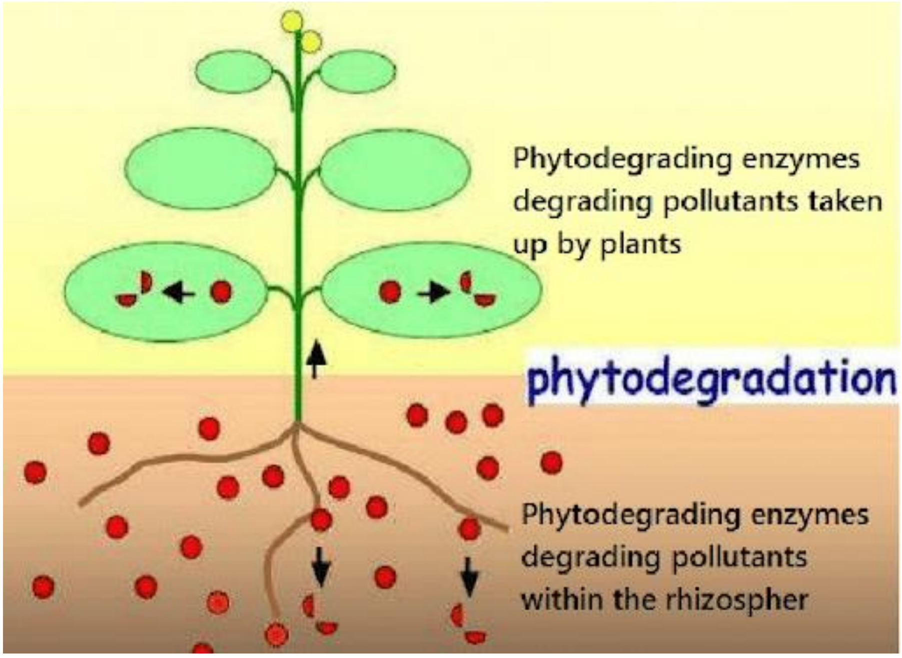
To achieve a significant cleanup, the growth/harvest cycle typically needs to be repeated over multiple crops because a lower level of pollution stays in the soil after harvest. The process results in the remediation of the soil.



17.4.2. Phyto transformation/ Phytodegradation

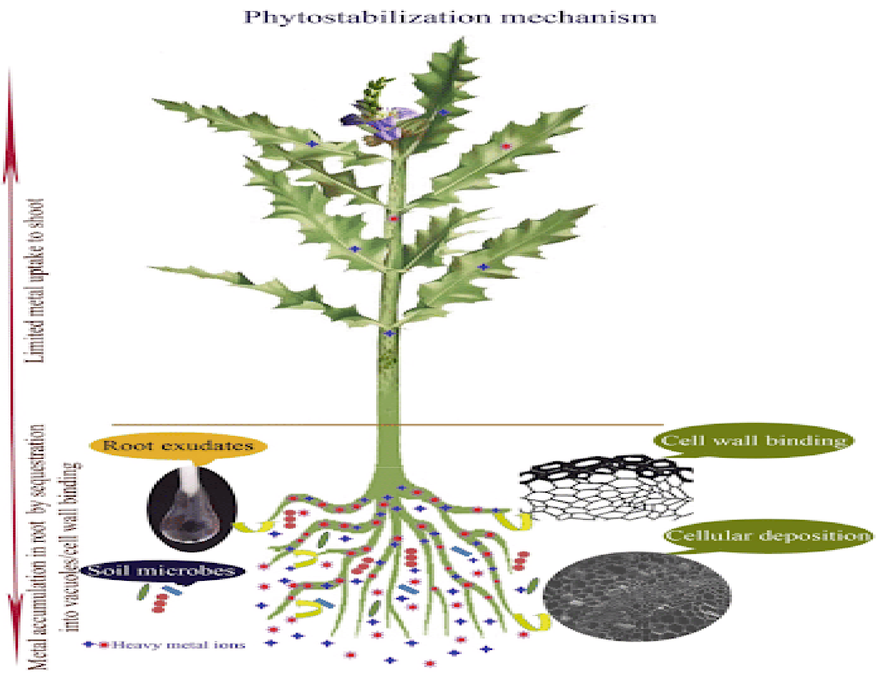
a) The conversion of organic contaminants from soil, sediments, or water into a more stable, less dangerous, and less mobile form is called phytotransformation, sometimes referred to as phytodegradation.
b) After the organic chemicals are broken down by the enzymes secreted by the plant roots, the plant absorbs them and expels them through transpiration.

c) Among the organic contaminants that this approach works well that include herbicides, trichloroethylene, and methyl tert-butyl ether.
d) Phytotransformation, a direct consequence of plant metabolism, is the chemical alteration of environmental chemicals that often leads to their inactivation, destruction (phytodegradation), or immobilization (phytostabilization).
e) The metabolism of some plants, including cannas, makes organic contaminants like pesticides, explosives, solvents, industrial chemicals, and other xenobiotic compounds non-toxic.
f) In other situations, microorganisms that live near plant roots may metabolize these chemicals in soil or water.



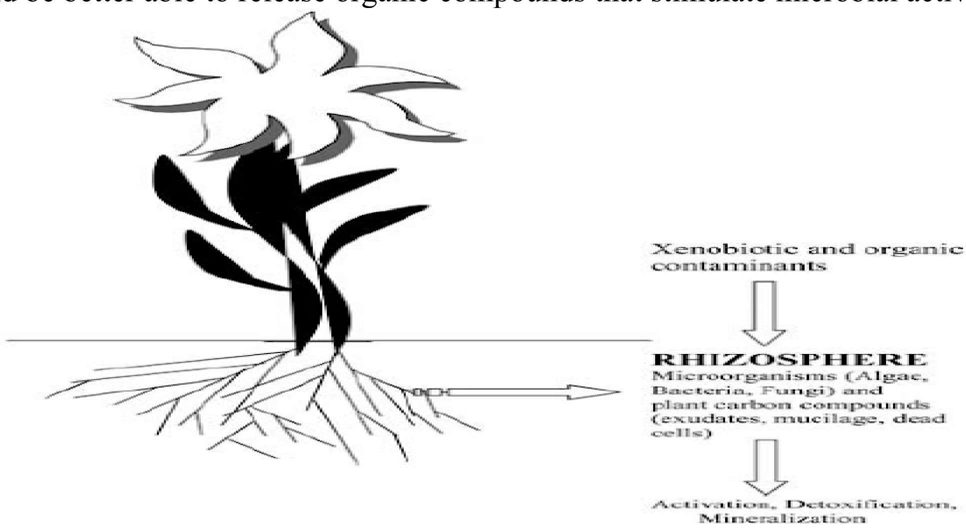
17.4.3. Phyto stabilization

a) Phytostabilization is the process by which plants restrict the migration and mobility of polluted soil.
b) Leachable elements generate an unstable mass of plant from which poisons cannot re-enter the environment because they are adsorbed and bonded into the structure of the plant.
c) The plant immobilizes pollutants by binding them to soil particles, reducing their availability for plant or human absorption. Unlike phytoextraction, phytostabilization focuses on sequestering pollutants in the soil close to the roots rather than in plant tissues. Exposure decreases as pollutant bioavailability decreases.
d) Additionally, plants have the ability to expel a substance that initiates a chemical reaction that transforms heavy metal pollution into a less dangerous form.
e) Stabilization lowers the bioavailability of the pollutant and decreases erosion, runoff, and leaching.
f) One example of phytostabilization in action is the application of a vegetative cap to confine and stabilize mining tailings.



17.4.4. Rhizo degradation/ Phytostimulation

a) Rhizodegradation, sometimes referred to as phytostimulation, is the process by which pollutants are broken down by rhizosphere activity.
b) This action is caused by the presence of proteins and enzymes made by plants or soil organisms like bacteria, yeast, and fungi.
c) These microorganisms have the ability to break down hazardous pollutants like fuels and solvents into safe and harmless byproducts.
d) Natural carbon-containing substances like sugar, alcohols, and acid are released by plants, giving bacteria more nourishment and boosting their activity.
e) Better plant-microbe interactions in transgenic plants may lead to production. The plant would be better able to release organic compounds that stimulate microbial activity.



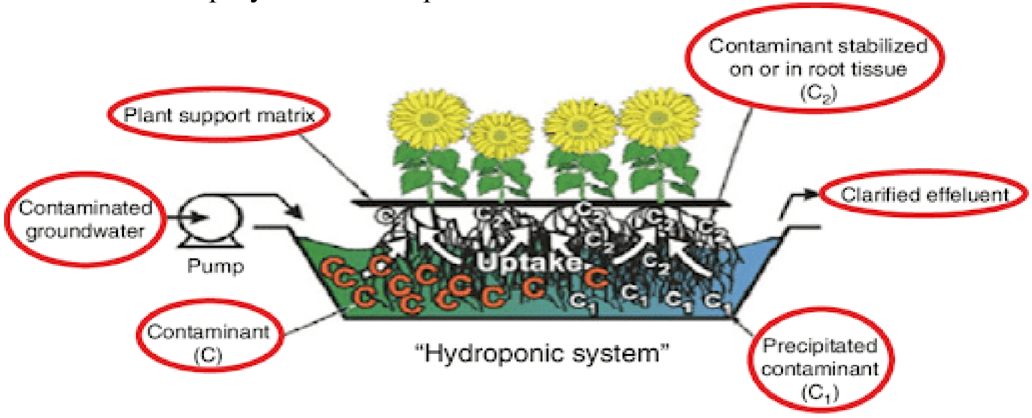
17.4.5.Rhizo filtration

a) Rhizofiltration is a technique that filters water through a mass of roots to remove excess nutrients and dangerous substances.

b) The roots either absorb or transfer pollutants.

c) By either planting directly in the contaminated region or removing the contaminated water and sending it to these plants off-site, this method is commonly employed to clean up contaminated groundwater.

d) In both cases, plants are often grown under controlled conditions in a greenhouse. This method is employed to lessen pollution in estuaries and wetlands.



17.4.6. Mycoremediation

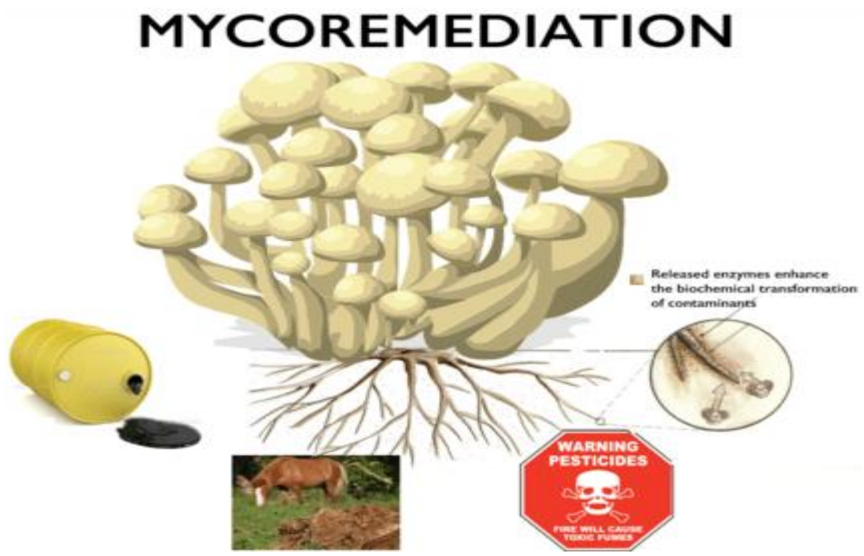
a) A form of bioremediation called mycoremediation uses fungi to clean up a location.

b) It has been demonstrated that using fungi to remove a variety of toxins from contaminated environments or wastewater is both economical and environmentally beneficial.

c) Heavy metals, organic pollutants, textile dyes, leather tanning chemicals and wastewater, petroleum fuels, polycyclic aromatic hydrocarbons, pharmaceuticals and personal care products, pesticides, and herbicides are among the contaminants found in terrestrial, freshwater, and marine habitats.

d) Enzymes and edible or medicinal mushrooms are examples of remediation process byproducts that can be important resources in and of themselves, increasing the remediation process's profitability.

e) Certain fungi are useful in the biodegradation of contaminants in extremely cold or radioactive environments where standard cleanup methods are either too costly or impractical to use because of the extreme circumstances.



17.6. SUMMARY

A plant-based technique for extracting and eliminating elemental contaminants from the environment or reducing their bioavailability in soil is called phytoremediation. Even at low quantities, plants can take up ionic materials from the soil through their root systems. By extending their root systems into the soil matrix, plants create a rhizosphere ecosystem that restores damaged soil, regulates soil fertility, and gathers heavy metals and modifies their bioavailability.

17.7. SELF ASSESSMENT

1. Explain Phytoremediation- Concept
2. Explain Procedure, Advantages and limitations for Phytoremediation

3. Describe iypes of phytoremediation

17.8. SUGGESTED READING

1. **Odum, E.P**. and **Gary W. Barrett**, 2011. *Fundamentals of Ecology* (5th Edition), Saunders ISBN.
2. **Russel, P.J**., **Wolfe,S.L.,Hertz, P. E., Starr, C.** and **Mc Million B.**, 2008. *Ecology*, Cengage Learning India PvtLtd.,New Delhi.
3. **Wilkinson, D.A**. 2007. *Fundamental Processes in Ecology: An Earth system Approach*. Oxford.
4. **Chapman, J.L.** and **Reiss, M.J.,** 2003. *Ecology: Principles and Applications*, (2nd Edition) Cambridge University Press, UK.

Dr .C.V.S.Bhaskar

LESSON- 18

APPLICATION OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM(GIS) IN \ BIODIVERSITY STUDIES.

OBJECTIVES:

It covers the needs and issues related to land resources. It will list the various fields in which geospatial technology might be useful. It will examine and talk about the several ways that GIS and remote sensing are used in land management. By the completion of this lesson, the student will understand the significance, the technique, and how RS/GIS technology may simplify land resource management.

STRUCTURE OF THE LESSON:

18.1. Introduction

18.2. Importance of land resources

18.3. Historical Perspective

18.4. Definition and scope

18.5. Types of Remote Sensing

18.6. Methods in Remote Sensing

18.7. Application of Geospatial Technology in Biodiversity Studies

18.8. Advantage over conventional methods

18.9. Relevance of RS and GIS in Wildlife and Biodiversity Management

18.10. Summary

18.11. Self Assessment

18.12. Suggested reading

18.1. INTRODUCTION:

Due to intense pressure from agriculture and population growth, land is a limited resource. For the purpose of choosing, planning, and implementing land use plans to satisfy the growing demands for fundamental human needs and welfare, information on land use, land cover, and opportunities for their best use is crucial. Monitoring the dynamics of land usage brought on by shifting demands from an expanding population is made easier with the help of data on land distribution and features. To enable development without the risk of land degradation, which would jeopardize the sustainable production of food and other agricultural goods, nations, village communities, and individual land users must choose the best options for land use. In order to produce information products in the form of maps as well as tabular and textual reports for land use decisions in a flexible, versatile, and integrated manner. Land

Information Systems (LIS) have emerged as a potent tool for managing and analyzing the vast amounts of basic data and information, statistical, spatial, and temporal.

18.2. IMPORTANCE OF LAND RESOURCES:

All of the natural environmental resources found on the surface of the earth, such as soil, topography, water, climate, and weather, are referred to as land. The ability of the land resources to supply food, fuel, lumber, fiber, and other raw materials, as well as numerous other plant and animal products, shelter, and recreation, is essential to human wellbeing and socioeconomic progress. Rational resource use and management at all levels (global, regional, sub-national, and local) has become crucial due to the pervasive pressures on land and the need to strike a balance between the exploitation and protection of natural resources. The current and future needs for produce and goods from the available land resources must be examined by international and regional organizations as well as individual nations. They must also consider how to meet these needs while taking into account the opportunities and limitations of a sustainable production from these resources. Sustainable development and land resource management are related.

18.3. HISTORICAL PERSPECTIVE:

However, the first photograph of nature was taken by Nicephore Niepce in 1827, which marks the beginning of the history of remote sensing. Since then, technology has advanced through the deployment of captive balloons in 1858, pigeons in 1903, low-altitude aircraft during World War I, and high-altitude aircraft in the 1950s to capture aerial photos. When the first meteorological satellite, Television Infrared Observation Satellites (TIROS-1), was launched in 1960, the era of satellite remote sensing officially began. Over the past 50 years, there has been a significant increase in the use of geospatial technology in India.

Since then, the use of this technology has advanced significantly. With the founding of the Indian Photo Interpretation Institute (renamed the Indian Institute of Remote Sensing in 1983) under the Survey of India in 1966 to provide training in aerial remote sensing techniques, further progress in the use of aerial photographs in India gained momentum. On March 17, 1988, the first Indian Remote Sensing satellite (IRS-1A) was launched. The Indian remote sensing satellite system currently operates the largest constellation of remote sensing satellites in the world, offering leadership and continuity in earth observations. Currently, over a dozen satellites are in orbit, generating petabytes of operational earth observation infrastructure.

There are 10 Remote Sensing satellites in operation viz. CARTOSAT (**Cartography and Satellite**) 1 & 2, CARTOSAT-2B, IRS-1C, IRS-1D, IRS-P3, Oceansat-1, Oceansat-2, Resourcesat-1 and Technology Experiment Satellite, (TES). The late 70s and early 80s was the period of emergence of Remote Sensing applications as a powerful tool for land resources survey and management. of data every day.

18.4. DEFINITION AND SCOPE:

The term "remote sensing" first emerged in the 1950s and refers to "*the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under* *investigation*". The era of satellite remote sensing began with the launching of Landsat-1 in July 1972 by the National Aeronautics and Space Administration (NASA), United States.

Its foundation is the utilization of picture data obtained by various sensors, including radar, scanners, and aerial cameras. In order to get relevant information about specific characteristics on Earth, satellite remote sensing is employed to evaluate images or numerical values collected from a distance. Any of a number of physical energy distributions may be employed by the instruments used for this purpose. For instance, sonars operate on the principle of acoustic wave distribution, while optical devices like multi-spectral scanners and photographic cameras use electromagnetic energy distribution. The term "remote sensing" refers to any method of analyzing and utilizing data from satellites, including Meteosat, the Advanced Very High Resolution Radiometer (AVHRR) of the National Oceanic and Atmospheric Administration (NOAA), Landsat (French: Satellite Pour l'Observation de la Terre), SPOT, Earth Resources Satellite (ERS), Satellite Access Request (SAR), and aerial photographs. Mapping and tracking the earth's resources is the primary goal of remote sensing.

The Geographical Information System (GIS) is computerized software that stores, retrieves, manipulates, analyzes and displays geographically referenced data sets, which can be used for different applications. Here the word '*Geographic*' deals with spatial objects or features which can be referenced or related to a specific location on the earth surface. The object may be physical/natural or may be cultural man made. Likewise the word '*Information*' deals with the large quantity of data about a particular object on the earth surface. The data include a set of qualitative and quantitative aspects which the real world objects acquire.

The term '*System*' is used to represent systems approach where the environment consists of a large number of objects / features on the earth's surface and their complex characteristics are broken down into their component parts for easy understanding and handling.

GIS data are represented and stored in the form of vector or raster.
In a vector data structure, geospatial data are represented as points, lines or polygons. For examples, fire rings or campsites would be stored as points, trails or streams as lines and forests or recreation opportunity classes as polygons.

In contrast, a raster data structure represents geospatial data in a regular grid of cells and the attribute applies to the entire cell. Raster data provide continuous coverage of an area. For example, Digital Elevation Model showing slope, aspect and elevation in a grid for an area is a raster data structure.

Attribute data can be handled in rational database software comprised of records and fields. GIS, therefore, can offer the unique ability to link such spatial and attribute data and tries to manipulate and analyze the relationships among them.

There are **three crucial steps** in using GIS to implement georeferenced data.
These include **data entry and preparation, analysis, and presentation**. Large volumes of non-spatial (tabular data) and spatial (maps) data can be stored in GIS. It could be applied to inventory and land resource management. Synoptic assessments of Earth are made easier by the gathering of remotely sensed data. These days, computers are typically used to store and process the data. Earth Resource Data Analysis System (ERDAS) Imagine, Environmental

Systems Research Institute (ESRI), MapInfo, and ER Mapper are the most widely used programs in remote sensing.

18.5. ACTIVE AND PASSIVE REMOTE SENSING

Sensors are tools used in remote sensing that are capable of measuring and recording electromagnetic energy. With their own energy source, active sensors like radar and lasers can measure the quantity of energy reflected from the surface by emitting a controlled beam of energy. These sensors can identify the position, height, speed, and direction of an object under inquiry by measuring the time interval between the emission and return. Regardless of the energy available from outside sources, active sensors can function day or night since they can produce their own controlled signals. Conversely, passive sensors are limited to using energy from natural sources. As a result, most passive sensors use the sun as a source of energy and can only work during daytime. However, passive sensors that measure the longer wavelengths related to the earth's temperature does not depend on the external source of illumination and can be operated at any time.

18.6. METHODS IN REMOTE SENSING

Remote sensing image data: Data can be used from different satellites such as Land Remote-Sensing Satellite (LANDSAT) (spatial resolution 30m), LISS III (spatial resolution 23.5m) and Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) data (spatial resolution 15m). These images provided suitable cloud-free spatial coverage with relatively high spatial and spectral resolutions.

Geometric correction:
To analyze the land use and land cover conditions of a specific geographic place, multispectral remote sensing data must be accurately registered. The distortions and degradations resulting from fluctuations in altitude, sensor platform velocity, scan speed, sweep of the sensor's field of view, earth curvature, and relief displacement are corrected geometrically in remote sensing data. Polyconic projections with Root Mean Square Error (RMS) are used to georeference the images, and LANDSAT-7 ETM+ data is reprojected into polyconic projections.

Ground reference data: In image analysis, ground reference data is crucial for identifying information classes, interpreting choices, and evaluating the accuracy of the outcomes. At this point, extensive reference information and a deep understanding of the region are necessary.

Classification scheme: Classification schemes offer structures for classifying and arranging data that can be taken from images. Classes that are significant to the study and observable from the available data are included in an appropriate classification scheme. Shape, size, pattern, tone, texture, shadows, position, association, and resolution are some of the interpretation keys that are used to work out picture enhancement, contrast stretching, and false color composites

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interpretation keys that are used to work out picture enhancement, contrast stretching, and false color composites.

Image Classification Techniques*:* The overall objective of the image classification procedure is to automatically categorize all pixels in an image into land cover classes or themes. Classes have to be distinguished in an image and classification needs to have different spectral characteristics. This can be analyzed by comparing spectral reflectance curves. Image classification gives results to a certain level of reliability. The principle of image classification is that a pixel is assigned to a class based on its feature vector by comparing it to predefined clusters in the feature space. Doing so for all image pixels result in a classified image.

a. Unsupervised Classification: The unsupervised classification approach is an automated classification method that creates a thematic raster layer from a remotely sensed image by letting the software identifies statistical patterns in the data without using any ground truth data.

b. Supervised Classification: Here the image analyst supervises the pixel categorization process by specifying, to the computer algorithm, numerical descriptions of various land cover types present in the image. Training samples that describe the typical spectral pattern of land cover classes are defined. Pixels in the image are compared numerically to the training samples and are labeled to land cover classes that have similar characteristics.

c. Fuzzy supervised classification approach: This approach allows for multiple and partial class memberships at the level of individual pixels and accommodate fuzziness in all three stages of a supervised classification of remotely sensed imagery. This approach considers that each pixel might belong to several different classes without definite boundaries

iv. Accuracy assessment: The degree of "correctness" of a map or classification is commonly expressed using the term "accuracy" in thematic mapping from remotely sensed data. If a thematic map created using a categorization offers an objective depiction of the land cover of the area it depicts, it might be deemed accurate. Therefore, classification accuracy is often understood to be the extent to which the resulting picture categorization adheres to the "truth" or agrees with reality. The accuracy evaluation requires a collection of reference pixels that represent geographic points on the categorized image.

Randomly selected reference pixels lessen or eliminate the possibility of bias. A random stratified sampling method was used to prepare the ground reference data. This sampling method allocates the sample size for each land use based on its spatial extent.

18.7. APPLICATION OF GEOSPATIAL TECHNOLOGY IN BIODIVERSITY STUDIES

18.7.1. Learning Objectives

The purpose of this module is to familiarize the reader with the biodiversity and the application of remote sensing (RS) and geographical information system (GIS) in conservation of biological diversity.

18.7.2.Introduction

Biological diversity or biodiversity has been defined by Convention on Biological Diversity (CBD) as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part". This includes the diversity within species, between species and of ecosystems. Biodiversity can also be defined as the natural variety and variability within and among living organisms and the ecological complexes in which they occur naturally, as well as the ways of interaction among organisms and with that of physical environment. It is a multidimensional concept that includes different components (e.g. the genetic, population, species and community levels), and each of them has structural, functional and compositional attributes (e.g. size of population, species composition and distribution of alleles).

Due to the complex nature of biodiversity, it becomes very difficult to express and assess the biodiversity. It must be related to not only the variability of life forms, but also with the ecological complexes of which they are recognized as important components. Conservation has become an essential mean of interacting with the rapid degradation and conversion of ecosystem, which lead to serious impacts on biodiversity. As rates of habitat loss and species destruction continue to mount, the need for conserving biodiversity has become increasingly vital during the last decade. In order to design significant conservation strategies, comprehensive information on the species distribution, as well as the information regarding changes in distribution with time, is required.

In terms of conservation strategies, an understanding of the distribution patterns of biodiversity is essential. Because of manmade reasons and increasing climate change, biodiversity conservation is an essential concern. Numerous rich biodiversity zones have been deteriorating at a startling rate and are in grave danger. At the local, regional, and national levels, it is crucial to protect these zones and their habitats. Comprehensive data on the temporal distribution of species are necessary to establish conservation plans for the purpose of biodiversity conservation. The Convention on Biological Diversity (CBD) has made biodiversity conservation a top concern. It manifests itself at the genetic, species, and landscape levels.

Although biodiversity is generally considered at the species level, the comprehension at the landscape level has been given priority worldwide as the interaction with the habitat part is very well understood in the latter.

Land use and land cover (LULC) changes, climate change, sustainable development, and other global environmental challenges are closely linked to biological diversity. Due to rapid and widespread industrialization, urbanization, and other activities, humans have had a significant impact on ecosystems more quickly over the past few decades. The survival of biodiversity and their natural habitat was thus seriously threatened by such operations. Lack of ethics, awareness, and understanding of biodiversity, particularly among populations that have intimate relationships to the ecosystem, exacerbates this loss. Inventories to ascertain the existence, location, and dynamics of biodiversity are among the biological diversity problems.

Therefore, it becomes very important to link biodiversity and human interaction with respect to use of natural resources in order to sustain and preserve the biodiversity.

18.7.3. Geospatial Technologies

18.7.3.1 Remote Sensing (RS) literally means acquiring information about an object, area or phenomenon without coming in direct contact with it.

Remote Sensing includes all methods of obtaining pictures or other forms of electromagnetic records of Earth’s surface from a distance, and the treatment and processing of the picture data.

According to the United Nations (95th Plenary meeting, 3rd December, 1986), remote sensing (RS) means sensing of earth’s surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects, for the purpose of land use, natural resource management and the protection of the environment.

18.7.3.2 Geographical Information System (GIS) is a computer based information system which integrates a variety of qualities and characteristics to geographical location and helps in planning and decision making. In GIS system the map information supplemented with additional information, can be displayed and referenced using computers. It can provide spatial information with appropriate conventional statistics.

Burrough (1986) defined GIS as a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purpose.

18.8 Role of remote sensing (RS) and geographical information system (GIS) in Biodiversity

Advancements in satellite remote sensing technology have facilitated collaboration between remote sensing and biodiversity communities, enhancing information sharing on species distribution. This interdisciplinary cooperation aids in monitoring changes in species distribution and habitat loss, providing high temporal resolution data. The scientific community aims to assess and predict ecosystem responses to global climate change and its implications for humans.

The management and conservation of wildlife and biodiversity depend on reliable data regarding species distribution, abundance, habitats, and threats. Various organizations and countries are prioritizing the information ‘super highway’ to address biodiversity information needs identified by protected area managers, decision makers, and researchers. The Fourth World Parks Congress highlighted the necessity for improved information to support decision-making in protected areas. Furthermore, biodiversity databases must be geographically based to predict potential new populations of endangered species and specify hotspots.

Therefore, **Remote Sensing (RS) and Geographic information system (GIS)** a modern day geo-spatial technology, helps in data (information) collection for biodiversity conservation management and planning.

The traditional methods of biodiversity data collection are expensive and time-consuming. In contrast, remote sensing (RS) and Geographic Information Systems (GIS) offer efficient and cost-effective alternatives for gathering and managing natural resource information. These technologies provide systematic insights over regular intervals, yielding crucial data on soil, temperature, rainfall, topography, and other factors affecting species distribution. The relationship between RS/GIS data and species patterns can help predict species distribution in various areas. Past studies have recognized the potential synergies between remote sensing and conservation biology to enhance biodiversity monitoring and conservation efforts.

GIS is a tool for monitoring biodiversity, accommodating diverse spatial and attribute data. It enables targeted surveys and monitoring through information on species and habitat distribution across dates, allowing for the tracking of changes. Recent advancements have revolutionized information availability and the tools for managing it, transforming wildlife management to be more current and location-oriented.

There are two types of remote sensing approaches: direct and indirect. Direct remote sensing involves the observation of organisms or communities using satellite sensors, such as high spatial resolution and hyper-spectral sensors. Indirect remote sensing relies on environmental parameters derived from remotely sensed data, such as habitat parameters and species composition, as proxies for estimating species ranges and richness.

Remote sensing (RS) offers consistent, wide-scale data collection and monitoring of environmental changes across local to global levels, without the need for labor-intensive ground observations. It is instrumental in tracking biodiversity and ecosystem health by providing regular images for monitoring terrestrial, marine, and freshwater ecosystems. RS aids in assessing changes in ecosystem extent and contributes to species distribution estimates, integrating data with models to evaluate overall biodiversity dynamics.

Wildlife and Biodiversity Management emphasizes the need for updated spatial information for effective decision-making and plan implementation. This data, provided by Remote Sensing (RS), must be integrated with traditional databases. The IUCN (1996) highlights that the primary goal of wildlife conservation is to preserve plant and animal diversity, genetic traits, and ecological functions. RS techniques are essential in wildlife and biodiversity management due to their unique characteristics, including synoptic views and repetitive coverage. In forest management, RS contributes significantly to revising working plans, wildlife management, fire control, soil and water conservation, land utilization studies, grazing management, and mapping for afforestation programs.

18.8.1 Forest Management

18.8.1.1. Forestry Conversion Studies*:* The fast conversion of forest lands due to urbanization and population growth is seriously harming the biodiversity of the forest. One of the most important issues in forest management is the distribution and evolution of forest cover. In order to help policy makers make decisions that could guarantee and preserve the rich biodiversity of forest resources, it is also necessary to create methodologies for assessing and evaluating the size of forest resources and their changes. Due to its substantial influence on climate change, tracking changes in the forest cover has become a crucial undertaking. When combined with a ground survey, the RS method and GIS can reliably provide information on the geographical distribution of forests and their changes.

18.8.1.2 .Forest Fire Damage*:* One of the natural or man-made disasters that harms ecosystems and forest biodiversity globally is fire, which eventually has a negative impact on soil, trees, and people. Forest fire reduces soil nutrients and leaves the soil exposed, increasing soil and water erosion. As a result, having accurate and timely information about the total area burned, terrain, forest type, etc., is crucial. Effective fire management is extremely challenging in the absence of knowledge on the behavior and distribution of forest fires. When identifying burned forest and creating a spatial model to predict and evaluate the forest fire and its aftereffects, RS and GIS can be quite helpful.

18.8.1.3. Wildlife Management: Wildlife distribution and protection are the prime focus area of wildlife management. So far as the management is concerned the geospatial technology is very effective in analyzing, managing and visualizing wildlife data. GIS enables analysis and mapping of distribution of wildlife, their movements and pattern of habitat use, which can provide precious information for the development of wildlife management strategies. In recent times, the rapid technological improvements in GIS, as well as in remote sensing techniques have significantly increased their accessibility and efficacy in ecological management and research.

18.8.1.4. Grassland Management: Grasslands are the most diverse terrestrial ecosystem on Earth and are important sources of animal nutrition. Ground-based sensor technologies, such as the Global Positioning System (GPS), have been acknowledged as useful instruments for managing grasslands and herds. The availability of space-borne remote sensing data makes it feasible to evaluate and track grassland ecosystems using information about biomass, productivity level, quality, phenological stage, species composition and change, biophysical parameters, and management characteristics (e.g., degradation, grazing intensity).

18.8.1.5. Agricultural biodiversity: Agricultural biodiversity is a broad term that consists of all components of biodiversity related to food and agriculture, and all components of biodiversity that constitute the agricultural ecosystems, which are essential to sustain crucial functions of the agro-ecosystem, its structure and processes. The term Agro-bioinformatics is application of Informatics for management, presentation, discovery, exploration and analysis of Agriculture and related issues. Agro-bioinformatics is a type of electronic documentation of biographical, taxonomical and ecological aspects related to agriculture. It may consider a multidimensional database in which information stored in digital form, using RS and GIS. Furthermore spatial analysis significantly helps to understand agriculture biodiversity constraints.

It has been successfully demonstrated that combining multi-spectral and multi-temporal remote sensing data with local expertise and simulation models is a useful method for identifying and tracking a variety of features relevant to agriculture. Precision agriculture is necessary due to the spatial variability of crops. Geospatial technology (remotely sensed photos of the crops and GIS modeling method) makes it possible to identify such spatial variations. RS and other geospatial approaches can be used to evaluate the geographical variability in crop output.

Recent aerial imagery extensively aids crop yield prediction pre-harvest. Key to natural resource management, it involves vegetation analysis and change detection. Effective monitoring utilizes spectral bands—visible red, green, blue, and near-infrared (NIR)—to assess crop health, cover, soil moisture, yield, and nitrogen stress. Various spectral indices estimate crop distribution and yield, including: (a) normalized difference vegetation index (NDVI), (b) green vegetation index (GVI), (c) soil adjusted vegetation index (SAVI), and (d) perpendicular vegetation index (PVI), all leveraging red and NIR bands.

Summary:

Geographical Information Systems (GIS) software serves various applications in conservation and biodiversity research, primarily through map creation to analyze biodiversity at different spatial scales. The essential components of GIS include Hardware, Software, Data, People, and Methods/Procedures, which collaboratively manage geospatial

information for decision-making. The study highlights the significance of remote sensing alongside GIS in biodiversity assessments and applications in managing forests, wildlife, grasslands, and agricultural diversity. GIS data is categorized into two main types: vector data and raster data, each with distinct formats.
Each data type has its unique geographical characteristics, as well as its own advantages a. d disadvantages, which make it suitable for specific real world applications for GIS in construction.

The five steps in the analysis process are:

1. Frame the question
2 Explore and prepare data.
3. Choose analysis methods and tools.
4.Perform the analysis.
5.Examine and refine results.

Popular GIS software includes industry leader ArcGIS, the leading free option QGIS, and other tools like Google Earth Pro, Mapbox, Maptitude, Global Mapper, and cloud platforms such as Felt and Carto, catering to desktop, web, and mobile needs for mapping, analysis, and data visualization. These programs handle everything from basic mapping to complex spatial analysis, data management, and creating interactive web maps.

18.9. RELEVANCE OF RS AND GIS IN WILDLIFE AND BIODIVERSITY MANAGEMENT

Wildlife and Biodiversity management require a reliable and relevant data on the distribution of species, abundance, their habitats, as well as threats. Therefore, RS (Remote Sensing) and GIS (Geographic information system) Assists in data collection and to analyse the abundance of wildlife as well as provide suitable data for conservation management and planning. This paper reviews the relevance of RS and GIS in wildlife and biodiversity Management.
What is GIS (Geographic Information System)?

In the 21st century, rapid advancements in computer information systems aid in data acquisition related to cultural and physical environments for research and practical problem-solving. Both analogue and digital electronic devices facilitate asset recording and swift logical or arithmetic operations. Information systems are continuously evolving, enabling the manipulation, creation, storage, and application of spatial data at a much faster pace than traditional methods. These systems comprise tools and data to manage information about real-world events.

Our perception of the world is shaped through selection, generalization, and synthesis, leading to representations and information that reflect phenomena. A database serves as a comprehensive collection of various observations that depict the world at a specific time. It distinguishes between information, data, and knowledge, with information being essential for progression from data to knowledge.

The information that has many forms and origins, might be any one of the subsequent:

1. Real i.e. the landscape conditions, etc.

2. Captured, for example trace digital data of an area through RS (remote sensing) satellites or the Aerial photographs.
3. Interpreted, for example land use from the data of RS, profundity of perfect data.
4. Organized or structured i.e. tables concerning the conditions of an individual watershed.

18.9.1. Development of GIS

Geographic Information Management Technology integrates various domains such as Computer Science, Cartography, and Telecommunication, with applications in engineering and natural resource management. Often referred to as Geographic Information Systems (GIS), it is recognized as a robust toolset for handling spatial data and is sometimes called Spatial Information Systems due to its focus on positional data, not limited to geographical contexts.

For any of the application, a GIS can give answer of five standard questions:

1. Location: What subsists at a scrupulous location?
2. Condition: Spot locations where convinced conditions are exist.
3. Trends: What has been changed ever since?
4. Patterns: What spatial patterns are exist?
5. Representation: What if?

18.9.2. Relevance of RS and GIS in Wildlife and Biodiversity Management

Wildlife conservation aims to preserve plant and animal diversity through genetic and ecological functions while also valuing aesthetics, according to the IUCN (1996). National parks and reserves have been the primary conservation strategy for over a century; however, they face management challenges due to incomplete ecosystems, leading to declines in biodiversity. A new initiative focuses on promoting biological diversity outside traditional protected areas, as habitat loss and species decline from human activities rise. The use of RS and GIS technologies enhances the management of natural resources, providing valuable geographic data for resource planning. However, existing resource management is often sectoral and fails to address spatial needs because of outdated information, resulting in ineffective plans and resource inequities at various levels.

Wildlife and Biodiversity Management has emphasized the need of having updated spatial information for

a) decision making, and
b) implementation of plans.

Remote sensing has a definite role in providing updated spatial information. But, the information derived from remote sensing data will have to be merged into the conventional database as and when necessary. Geographic Information System can provide spatial information with relevant conventional statistics when data is made computer readable. It can help in changing the very approach of wildlife management based more on current information and location oriented.

Factors, which are to be given fresh look at the conventional information system in the forest department, are:

1. Operational deficiencies in the existing system due to various strains on it resulting lack of uniformity, standardization, and timeliness the information generated being not in a readily usable form
2. Change in the perspective of the forest department role from mere maintenance and preservation of the jungle to planned development and change in areas of nature conservation and ecology.
3. The requirement that have arisen subsequently to cater to planning, fundamental and other agencies calling for economic assessment, evaluation of the contribution of forestry to an economy and other benefits.

18.9.3. Current status of information about forest resources :

Currently, information about the forest resources is obtained by forest administrations at various levels by manual methods with little mechanical aids such as calculating machines etc.

This information is stored in Operation Records, History sheets, Control forms, or periodic returns and reports, with some states also using personal computers for this purpose. Data is collected at the forest range/division level by forest range officers, while higher-level decisions are made by conservators of forests. However, inconsistent storage procedures hinder data recovery, complicating management conclusions. Information needs vary across administrative levels; nationally, data on forested and non-forested areas is typically extensive, whereas state levels require specific details on forest types, both qualitative and quantitative.

At the forest division level, detailed quantitative data on aspects like height, density, fire management, growing stock, and wildlife management is essential. At the forest range level, required information includes fire line status, wildlife occurrences, fire incidents, soil conservation efforts, and plantation areas. This data can be collected through a Management Information System (MIS) to create a computerized database for state forest departments, aiding in management decisions. A host computer will be necessary to develop a geographic database for effective forest resource planning and management.
The following process could achieve this:
Data collection and generation of the resource base.
Data digitalization and processing
Data analysis/modelling/output generation.
Data input in GIS is in the form of map.
Hence primary ground information is to be convert into map format. Forest resources data layers as required in Information System concept could be digitize for making them computer readable. However, there could be even possibility of linking tabular data, point information with maps, etc. for further modelling & analysis. The models for prescribing various forest administration decisions based on available forest resource database can be use for efficient planning and management.

18.9.4. Role of remote sensing in wildlife and biodiversity management

Remote sensing techniques, including satellite imagery and aerial photo interpretation, are essential for wildlife and biodiversity management due to their synoptic view, repetitive coverage, and uniformity. They contribute significantly to forest management by aiding in the revision of working plans, wildlife and logging planning, fire control, land utilization studies, and social forestry mapping. Remote sensing data enhances biodiversity management by updating management, stock, and working plan maps effectively, providing vital information about vegetation types and forest cover changes at various scales. Its relevance in biodiversity and wildlife management is substantial.

The application of RS & GIS has been demonstrating in many institutions through some Case studies. Some application spots are following:

1. Revision and updating of stock maps
2. Preparation of working plan
   a) Fire risk Zonation
   b) Planning response routes
   c) Wildlife habitat analyses
   d) Protected area management
   e) Wasteland development planning
   f) Site suitability analysis for Afforestation
   g) Identification of JFM (Joint Forest Management)
   h) Areas and participatory forest
   i) Fire line and Management
   j) Soil and water conservation

18.9.5.GIS does not hoard a map in several straight logic, nor does it contain an individual view or image of any geographic area. As an alternative, the GIS supplies the data as of which we are able to illustrate the required view to ensemble a exacting rationale known as Geographic data.

18.9.6. TYPES OF GIS DATA:
Geographical data consists primarily two types of data i.e. Spatial as well as Non-Spatial or Attribute.

18.9.6.1 Representation of spatial information

Spatial data is the data which has geographic locations and physical dimensions on the earth's surface. Some examples are a state boundary, a river, a state capital, a lake, etc. Geographical features can be represent on a map by the point, line & polygon.

Point feature- A discrete location depicted by a singular symbol or label. A single x, y co-ordinates e.g. oil well could be represented by a point entity consisting of x, y coordinates.

Line feature- Represents a linear mark. A set of ordered x, y coordinates e.g. a road could be represented by a series of x, y coordinates.

Polygon feature- An area feature where boundary encloses a homogenous area e.g. a floodplain could be represent by a vicinity entity covering a set of x, y coordinates plus the label „flood plain.

1. The labels might be the real names as shown here, or they might be unusual symbols

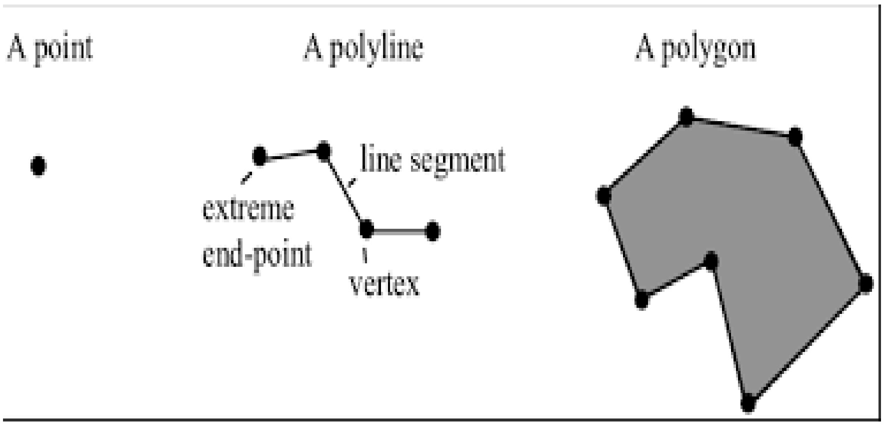

Fig: Types of geographical features on a map

18.9.6.2. Representation of non-spatial information

Non-Spatial data include information about the features. For example, the name of roads, schools, forests, etc., population or census data for the region concerned, etc. Non-Spatial data is that qualifies the spatial data. It describes some aspects of the spatial data, not specified by its geometry alone.

18.9. 7. Data Models

Alteration of actual world geographical disparity into distinct objects can be done via data models. It symbolizes the relation between the domain of geographic data of real world and depiction of these features by computer. Data models considered here are for demonstrating the twisting information. Data models can be of two types:

Raster & Vector.
Raster type of version of the geographical data, a collection of cells, positioned by synchronize is used, every cell is separately deal with the assessment of a trait. Every cell includes a particular value, and each position communicates with a cell. One collection of cell and related value is a LAYER. Raster Models are straightforward with which spatial scrutiny is faster and easier. Raster Data Models necessitate a huge amount of information to be accumulated, robustness of data is inadequate by the size of cell & productivity is less attractive.

Vector Data Model utilizes line sectors or points signify by its overt x, y synchronizes to spot locations. Distinct objects are shaped by linking line segments. Vector Data Models need less outputs appreciable, and storage space. Inference of perimeter/area is precise, and suppression is convenient and faster. Spatial analysis is really difficult with reverence to inscription software program

18.10. SUMMARY

The use of RS and GIS in biodiversity mapping and natural resource management is extensive, yet in developing countries, it faces challenges due to inadequate data, software, hardware, and expertise. Future research should aim for realistic and dynamic wildlife management, accounting for non-linear responses and stochastic events, while providing testable predictions. GIS plays a crucial role in environmental decision-making, comprising software, hardware, human resources, and data.

18.11. SELF ASSESSMENT

1. Write different types of Remote Sensing
2. Explain methods in Remote Sensing
3. Explaina application of Geospatial Technology in Biodiversity Studies
4. Explain Advantage over conventional methods of GIS
5. Explain Relevance of RS and GIS in Wildlife and Biodiversity management

18.12. SUGGESTED READING

1. Remote sensing, GIS and GPS by komal
2. Remote Sensing and GIS

Dr .C.V.S.Bhaskar