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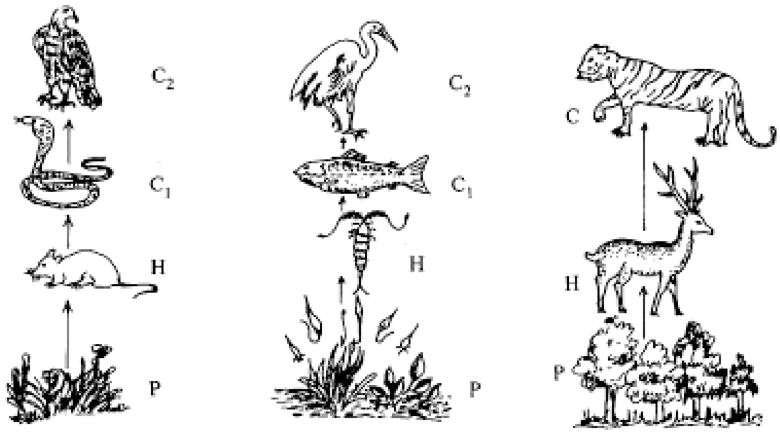
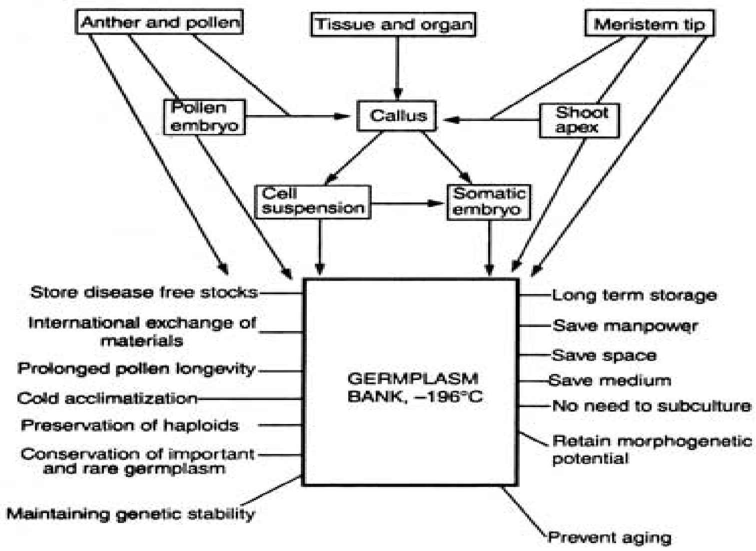
Vardhman Mahaveer Open University, Kota





Plant Ecology, Plant Resource Utilization and Biodiversity Conservation

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Vardhman Mahaveer Open University, Kota

Plant Ecology, Plant Resource Utilization and Biodiversity Conservation

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Editor

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Department of Botany
Govt. College, Kota

Writers:

- **Dr. Seema Bhaduriya** — 1,2,3,4
  Department of Botany
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- **Dr. Jay Singh** — 17,18, 19,20
  Department of Botany
  University of Rajasthan, Jaipur

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MBO-07

Vardhman Mahaveer Open University, Kota

Index

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Preface

The present book entitled **"Plant Ecology, Plant Resource Utilization and Biodiversity Conservation"** has been designed so as to cover the unit-wise syllabus of MBO-07 course for M.Sc. Botany (Final) students of Vardhman Mahaveer Open University, Kota. The basic principles and theory have been explained in simple, concise and lucid manner. Adequate examples, diagrammes, photographs and self-learning exercises have also been included to enable the students to grasp the subject easily. The unit writers have consulted various standard books on the subject and they are thankful to the authors of these reference books.

Unit - 1

Plant Ecology

Structure of the Unit:

1.0 Objectives

After studying this unit you be able to understanding the concept of ecology:

- Determination of the characters of the Autecology and Synecology.
- Concept of Population Ecology.
- Concept of Community Ecology.

1.1 Introduction

A community is a collection of populations of all the organisms which occur together in a given place and time. Community ecology is the study of the interactions between the organisms, and the interactions between the organisms and their environment. Communities can have emergent properties which arise from these interactions - properties which could not be predicted by studying the individual populations in isolation.

1.2 Plant Ecology

1.2.1 Basic Concepts of Ecology

Like other sciences ecology too has its own principles and basic concepts;

(1) All living organisms and their environment are mutually reactive, affecting each other in various ways. Animal population, flora, and vegetation are interdependent through the environment and are mutually reactive.

(2) Environment, which is actually a complex of several inter-related factors and is much dynamic (i.e. varying with time and space), works as a sieve selecting organisms for growth from so many forms, as its one or the other factor becomes critical at critical stages of the life cycle of the species.

(3) The species puts each effort to maintain its uniformity in structure, function, reproduction, growth and development by preservation of its genetic pool. However, species is also plastic and reacts to the varying environment to get it self adjusted structurally and physiologically in the changing environment. This is achieved by the degree of plasticity set by the genetic constitution of the species. The various forms of a species, in order to meet the challenge of changed environment, may arise by virtue of somatic plasticity, the ecads, or by the reorganisation of their genes during sexual reproduction, the ecotypes. Thus species may increase their capacity oftolerance towards changing environment developing **ecads** and **ecotypes.**

(4) It is not only the environment which influences the life of organisms, but organisms too modify their environment as a result of their growth, dispersal, reproduction, death, decay etc. Thus, the environment is caused to change due to organisms' activities. The dynamic environment and organisms make ways for the development of different kinds of organisms through a process known as **succession.** The process continues till the development of a community which is now more or less stable and is now able to keep itself adjusted in equilibrium with the environment. This final stage of community is called a **climax.**

(5) Clements and Shelford (1939), however, put forth a concept of biome wherein all plants and animals are related to each other by their co-action and reaction

on the environment. According to their view, under similar climatic conditions, there may simultaneously develop more than one community, some reaching to climax stage, others under different stages of succession. This complex of several communities in any area, represented by an assemblage of different kinds of plants, animals etc., sharing a common climate, is called a "biome".

In the above account, basic concepts of ecology have been explained mainly upon **structural** basis. However, with the introduction of ecosystem concept in ecology, **functional** aspects along with the structural ones are also to be strongly emphasized. Tansley (1935) thus emphasized the role of environment, with its various factors interacting with each other in his comprehensive term ecosystem which involves all the non-living and living factors working in a complex. With this new concept in modern ecology, following are the basic concepts:

(1) When both, biotic and abiotic components are considered, the basic **structural and functional** units of nature are ecosystems. Discrete biological units consist of populations and communities, including biomes. Each population occupies a specific niche, a unique functional position with respect to other organisms with which it interacts.

(2) There exist varying degrees of +, - or even neutral **interactions among organisms**, at both, inter- and intraspecific levels, which determine along with abiotic parameters, the degree of success a particular population has within a given habitat. Population ecologists study interactions at population as well as community levels. They study **competition,** usually between populations from the same trophic level (such as herbivores competing for the same grass i.e. population ecology involving individuals of same species), and **prey-predator** interactions between members of adjacent trophic levels (i.e. population ecology involving interactions between individuals of different species, at community level).

(3) Also, there is involved **energetics of ecosystem,** as energy is the driving force of this system. The radiant energy is trapped by the autotrophic organisms (producers) and is transferred as organic molecules to the heterotrophic organisms (consumers). This energy flow is uni-directional or non-cyclic.

(4) The chemical components of the ecosystem move in defined cycles called "**biogeochemical cycles".** Within the ecosphere, biological systems

frequently regulate the rate of movement of cycling of the chemicals. Role of water as the universal solvent for biological systems is much relevant here.

(5) Successful growth of the organism is governed by **limiting factors.** For success in growth and reproduction with a particular habitat, an organism requires various essential factors from its environment. The success of an organism is limited not only by deficiencies in substances or conditions but also by excesses. The minimal and maximal levels of tolerance for all ecological factors of a species vary seasonally, geographically and according to the age of the population.

(6) Under natural conditions, different kinds of population undergo succession. Ecosystems undergo an orderly process of change with time, passing from a less complex to a more complex state. This process involves not only changes in species composition but also changes in the physical environment of a community. The terminal or stabilised state is known as the **climax.**

According to Evans (1956), the ecosystem involves the circulation, transformation and accumulation of energy and matter through the medium of living things and their activities. Thus, the dynamic abiotic components of the environment and the assemblage of plants and animals there, as a result of interactions between themselves keep modifying and changing each other, and this leads to the development of ecosystem.

(7) Then come to the probabilities of **disruption** and exploitation of ecosphere. As a result of natural condition or activities of man, species diversity of an ecosystem is reduced. It leads to a set back to the state of development and reduction in the stability of the ecosystem. Man's exploitation of ecosystems is directed toward channeling productivity to his needs. **Applied ecology or human ecology** is the use of ecological concepts to describe human activities and the determination of ways in which people can best obtain their needs from ecosystems. Ecosystems which are substantially altered by **human** activities are called **managed;** whereas those free from such disturbances are referred to as **natural.**

1.2.2 Approaches to Ecology

Its Main Subdivisions and Developmental Facets

The definition of ecology makes it quite evident that fuller understanding of nature involves the study of plants, animals, and their environment. A perusal of the developmental history of ecology reveals that ecological studies made from time to time are based upon three principal aspects — taxonomic **affinities, habitat and levels of organisation. Accordingly,** these approaches could lead to the development of the following **main subdivisions** of ecology:

1. **Based on taxonomic affinities:** In early days of ecology, botanists and zoologists engaged themselves separately in the study of ecology of plants and animals respectively. This led to the development of such sub-divisions as (i) **Plant** ecology, and (ii) **Animal ecology.** In each, there may be taken specialized fields like ecology of pines, insect ecology, avian ecology, bacterial ecology and ecology of mosquitoes, turtles etc. However, modern ecologists feel that the principles in the study of plants and animals are not only much similar, but these two great groups of organisms are very much inseparably interrelated with each other. Thus, modern ecology prefers not to make much distinction between ecology of plants and animals. The term ecology indeed includes the interrelationships and interdependencies of all kinds of organisms with their environment.
2. **Based on habitat: Some** ecologists thought of the study of **habitats and their effects upon the organisms.** There are selected a number of different types of habitats such as freshwater, marine, estuarine, grasslands, forests, arid lands etc. These are then studied in detail for their possible relationship with the kinds of organisms present there. Such a habitat approach led to the development of third subdivision of ecology, known as (iii) **Habitat ecology.**
3. **Based on levels of organization:** With such an approach to the ecology of area, units of study are either **individual organisms or groups of organisms.** Accordingly the other two, fourth and fifth subdivisions of ecology are (iv) Autecology, and (v) **Synecology,**

1.3 Autecology

This is also known as "**ecology of individuals where we study the relation of individual species to its environment.**" Thus at a given time, emphasis is given on the requirements and reaction of an individual species together with the influence of environment upon it. With an autecological approach, individual species are the units of study. These are studied for details of their geographic distribution, morphology, taxonomic position and life-cycle etc., alongwith the various ecological factors which might influence different stages of their life cycles.

Population ecology or **autoecology** is a sub-field of ecology that deals with the dynamics of species populations and explain that these populations interaction with the environment. It is the study of how the population sizes of species groups change over time and space.

The development of population ecology owes much to demography and actuarial life tables. Population ecology is important in conservation biology, especially in the development of population viability analysis (PVA) which makes it possible to predict the long-term probability of a species persisting in a given habitat patch. Although population ecology is a subfield of biology, it provides interesting problems for mathematicians and statisticians who work in population dynamics.

1.4 Synecology

The study of groups of organisms i.e. community is known as synecology. It is descriptive but also can be experimental with the aid of tools such as computer and radioactive tracers. It is subdivided into aquatic and terrestrial; Terrestrial includes Desert, Grassland, Forest and Aquatic includes Freshwater, Brackish and Marine water. Through the concept of Tansley (1935) the divergence between autecology and synecology were brought together. The concept states that "all organisms are interacting with one another and also with the abiotic elements of their environment in an interrelated system. This means that organisms and environment form a reciprocating system. There is a give and take between these two systems with the action or inaction of one system having impact on the other system. From this concept therefore emanates three main levels of integration in ecology: i. Individual ii. Population – Communnity iii. Ecosystem .These are referred to as the basic units of ecology especially the ecosystem.

Population: An aggregation of individuals of the same species in a continuous area which contain no potential breeding barrier.

Community: A group of interacting populations in a given habitat. Usually restricted to organisms of similar size and life habits e.g tree community, insect community, bird community, human community. BIOME: Several interacting communities

Ecosystem: abstraction of many separate ecosystems with similar characteristics.

Under natural conditions, however, organisms- plants, animals, microbes etc., live together as a natural group affecting each other's life in several ways. Thus, more complex situations exist where the units of study, instead of single organisms are groups of organisms known as a community. Such an approach where units of study are groups of organisms is called **synecological approach**. Depending upon the conditions as these exist, synecology may deal with-

1. **Population ecology:** A recently developed field, where the units of study are pure stands of individuals of a single species - population. As a result of aggregation of these individuals, it becomes desirable to study the interdependencies between them, and the populations are studied in terms of their size, growth rates etc., which are chiefly governed by the interactions of the members of population. Thus, population ecology is the study of such and other similar relationships of group of organisms. The main job of population ecologist is, "Why is this population of a particular density?" To answer this and other questions he studies competition, usually between population from the same trophic level (herbivores competing for same grass). Population ecology is also concerned with communities. A population ecologist also studies interactions between populations of different species in a community. For instance, study of prey-predator interactions between members of adjacent trophic levels of a community.
2. **Community ecology:** In contrast with population ecology, here the units of study are groups of individuals belonging to different species-plants as well as animals. The living (biotic) components of the community are studied mainly for the nature of interdependencies between individuals of different species. Major concerns of community ecologist are, "Why is this community of a particular diversity? Why does a particular community occur at a given location? How communities interact and how these change through time?"
3. **Biome ecology:** In nature, we generally find that there may exist a complex of more than one community, some in their climax stages and others in different stages of succession, and these all communities grow under more or less similar climatic conditions in **an area. Thus** in biomes, as units of study there **are studied interactions between different communities of** area.
4. **Ecosystem ecology:** This has been the most recent development in ecology. It is established that not only living (biotic) but also non-living (abiotic) components of the nature interact with each other. These interacting biotic and

abiotic components, then interact with each other to form an integrated system—ecosystem or **ecological complex or ecological system**. Thus it becomes the most complicated synecological approach to the ecology of an area, where the units are the whole system-living as well as non-living components. Here we mainly emphasize the similarities and differences in food relationships among living organisms and various forms of energy supporting their life. This has also been referred to as bioenergetic approach in modern ecology.

1.5 Population Ecology

Population Level of Integration in Ecology is known as Population. Population is the unit of analysis in Population ecology. A population consists of individuals of the same species that live, interact and migrate through the same niche and habitat. It is a aggregation of related individuals (same species) capable of interbreeding and living (occupying) a continuous area that contain no potential breeding barrier. The organisms are of the same kind they occupy a particular area the population is the structural component of an ecosystem which develops and maintains itself by reproduction i.e. it is a self regulating system. **The study dealing with structure and dynamics of individuals in a population and their interactions with environment is known as Population Ecology**. The basic characteristic of a population is its size or density (numbers per unit area or per unit volume) Read on: Malthusian growth Model, Simplified population models, Age structure/pyramid. These Introductory models serve as foundation upon which the discipline of population ecology is built in order to further understand demographic processes in real life study populations and conduct statistical tests. The field of population ecology often uses data on life history and matrix algebra to develop projection matrices on fecundity and survivorship and this information is used in managing wildlife stocks and setting harvest quotas. The population density is dependent on: Natality (birth), Mortality (deaths), Immigration and Emigration I

The foregoing unit provides a background of the various ecological factors as they might govern the distribution of organisms, and details of the requirements and reactions of an individual species (autecology). However, organisms in nature rarely grow as separated from each other. Invariably, organisms grow organised as populations, communities and ecosystems. We would consider the basic concepts applicable at each of these three levels of organization and we begin with population level. In this unit, we would consider properties of populations as though largely isolated from populations of other species.

Population ecology is the study of individuals of the same species where the processes as aggregation, interdependencies between individuals etc. and the various factors governing such processes are emphasised. This has been an important development in modern ecology. The foundations of population ecology were laid by animal ecologists in the first half of this century. It is only relatively recently that detailed studies of plant populations have been made. The increasing population of the world could attract the attention of not only of ecologists but also of behaviourial scientists and it led to the development of such new facets in ecology.Population ecology, thus has to play a vital role in a number of socio economic problems both at national as well as international levels.

A population is generally a group of individuals of a particular species occupying a particular area at a specific time. Some of the ecologists, however, recognise two types of population.

1. Monospecific population: It is the population of individuals of only one species.

2. Mixed or polyspecific population: It is the population of individuals of more than one species. However, in ecology polyspecific population is generally referred to as a **community,** and the term **population** is used for group of individuals of any kind of organism.

1.6 Community Ecology

In nature, different kinds of organisms grow in association with each other. A group of several species plants or animals living together with mutual tolerance and beneficial interactions in a natural area is known as a **community.** In a community, organisms share the same habitat growing in an uniform environment. **Community ecology is the study of the interactions between these organisms, and the interactions between the organisms and their environment.** A forest, grassland, a desert, or a pond is natural communities. By definition, a community must include only living entities of the area. If non-living (abiotic) factors together with the living (biotic) entities are also considered, then we would be dealing with an ecosystem rather than a community.

The concept of community is by no means so recent, and it may be traced back to the time of Theophrastus (370-250 B.C.) who had recognised the existence of plant communities or associations of species in different environmental areas. Many centuries later, Grisebach (1838) recognised the **plant formation** as an important unit of vegetation. Thereafter Edward Forbes (1844), while studying the molluscs of Aegean Sea, noticed for the first time that in different areas (i.e. at different depths), there might be distinguished different types of assemblages' of species. It was indeed in the later part of the 19th century that authentic studies on communities began, when Cari Mobius (1880) coined the term **biocoenosis** for the associations of organisms in an oyster-bed community. In 1902, Schroter and Kirchner introduced the term **synecology** referring to plant species on the ocean bottom as an association or community. Later developments in this particular field were the methods of studying such associations and their developmental trends in varying habitat conditions, etc. Further studies in community ecology led to the development of following **five lines** of traditional thoughts of classifications:

(1) In U.S.A., Cowles (1899) and Clements (1905) emphasized the process of succession.

(2) In Britain, Tansley (1904), also emphasized the idea of succession in **community** classifications.

(3) In North Europe, at Uppsala (Sweden), HuIt (1881) and Du Rietz (1930) emphasized phytosociological, whereas Raunkiaer (1934) physiognomic methods of community studies.

(4) In Southern Europe, Zurich-Montpellier school, led by Braun-Blanquet (1932), who also developed phyto-sociological studies.

(5) In addition to above, with a different view point, not very clear, there developed also a Russian school of thought.

A community has its own structure, developmental history and behaviour. All these characteristics are in correlation with the environmental factors (synecology), just as population of same species (population ecology) and individual species (autecology) are correlated.

1.7 Summary

A community is a collection of populations of all the organisms which occur together in a given place and time. Community ecology is the study of the interactions between these organisms, and the interactions between the organisms and their environment. Communities can have emergent properties which arise from these interactions - properties which could not be predicted by studying the individual populations in isolation.

Traditionally, the term ‘community’ has had restricted use to describe the activities of the populations only, whereas when these are combined with the physical environment (e.g. nutrient dynamics and energetics) the term ecosystem has been used.

The term ‘community’ is also commonly used to refer to a subset of populations within the whole community, for example plant communities, insect communities, arthropod communities, small mammal communities, etc.

A population refers to a group of individuals of one kind with no barriers to exchange of genetic material in a given area at a given time. For example, population of human beings in a city, or population of squirrels or of lions in a forest, or pine trees in a given land. The study dealing with structure and dynamics of individuals in a population and their interactions with environment is known as Population Ecology. It has almost the same meaning as that of conventional term Autecology, the study of ecology of individual species or its population, which is less in use now. Population ecology is a significant branch of ecology that plays an important role in protecting and managing populations, especially those of rare species, through various means including PVA Population Viability Analysis. PVA helps to determine whether a population would survive or face the risk of extinction (complete disappearance of a species from the biosphere) under a given set of environmental conditions. Further, each population has a minimum viable size - the size at which it can avoid the extinction due to various biotic and abiotic factors.

1.8 Glossary

- **Ecology** : The study of the interactions of organisms with their physical environment (abiotic) and with oneanother (biotic).
- **Population** : Any group of individuals, usually of a single species, occupying a given area at the same time;groups of organisms with homologue (same) alleles.

- **Predators** : separate more often by being active at different times of the day than do other kinds of animals. Examples: Hawks and owls, lions and leopards
- **Terrestrial poikilotherms** : (= ectotherms, e.g., lizards, snakes) relatively often partition food by being active at different times of the day. Example: Lizards (some active in cool part of day, others at hottest times)
- **Vertebrates segregate less by seasonal activity than do lower animals** Example: Mayflies and other stream in vertebrates will often emerge at different times of the year from the emergence times of their potential competitors.
- **Ecophysiology** : Branch of science that examines how the physiological functions of organisms influence the way they interact with the environment, both biotic and abiotic.
- **Behavioural ecology** : Branch of science that examines the roles of behaviour in enabling an animal to adapt to its environment. Population ecology studies the dynamics of populations of a single species.
- **Community ecology /synecology :** If focuses on the interactions between species within an ecological community.
- **Ecosystem ecology** : It explains the flows of energy and matter through the biotic and abiotic components of ecosystems.

1.9 Self-Learning Excercise

Section- A : (Very Short Answer Type Questions)

1. What is ecology? Define it.
2. What do you mean by population?
3. The most important component of the population is...................?
4. Who coined the term ecology?
5. How autecology is differ with synecology?
6. Name the types of ecology.
7. Define community?
8. Write the functional and structural unit of ecosystem.

9. Write about biotic factor of ecosystem.
10. What is biome ecology?

Section- B : (Short Answer Type Questions)

1. Write short note on concept of ecology.
2. Write role of biotic & abiotic factors in ecology?
3. Write ecology based on taxonomic affinities.
4. Write a note on poly-specific population.
5. Write the difference between population and community.
6. What do you understand by synecology?

Section- C : (Long Answer Type Questions)

1. "Basic concept of Ecology" explain it with experimental evidences.
2. Write notes on -
   a. Autecology b. Synecology
3. Explain population ecology in detail.
4. Describe the Approaches to Ecology in detail.

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Unit - 2

Habitat and Niche

Structure of the Unit:

2.0 Objectives

After studying the unit you will be understand -

- Concept and Habitat of Niche
- Importance of Niche
- Niche Width and Overlap
- Fundamental and realized Niche
- Resource Partitioning and Character Displacement

2.1 Introduction

Every organism has a place to live in nature, a functional role in that place, and a complex set of adaptations for reproducing its kind. On the surface, this observation might seem to be obvious, even trivial. However, in order to understand our biological world—the biosphere, how it operates and ultimately how to protect it—we need to understand at a deep level.

In this unit we will examine further some of the concepts that ecologists use to organize their thoughts about the ways in which organisms use their environment, relate to each other, and assemble into communities or ecosystems. The most fundamental and perhaps most difficult of these concepts is that of the **ecological niche**.

"A niche refers to the way in which an organism fits into an ecological community or ecosystem." Through the process of natural selection, a niche is the evolutionary result of a species' morphological (morphology refers to an organism's physical structure), physiological, and behavioural adaptations to its surroundings. **A habitat is** the actual location in the environment where an organism lives and consists of all the physical and biological resources available to a species. The collection of all the habitat areas of a species constitutes its **geographic range**.

2.2 History of the Niche Concept

Niche is known as "a place or position suitable or appropriate for a living thing." Biologists and naturalists have long considered each species to have a proper place in nature. Darwin was influenced by this idea, as evidenced by the quote at the beginning of this chapter, while developing his theory of natural selection. It is natural then that the first uses of the word niche in an ecological context had a very strong "place" association. Although not the first ecologist to use the word, Joseph Grinnell, in a series of papers published between 1917 and 1924, is generally credited with being the first to develop the ecological concept of the niche. Grinnell defined niche as the "ultimate distributional unit, occupied by just one species or sub-species." To be more specific, Grinnell was interested in determining which factors governed a species' potential geographical distribution and usually considered these to be physical or climatic factors, as opposed to relationships with other species such as competition or predation. For example, in a 1917 paper entitled "The niche-relationships of the California Thrasher," Grinnell considered the geographical range of thrashers, a common bird of the chaparral, to be limited by temperature since it avoided areas of extreme heat or cold. Thrashers, Grinnell maintained, were further restricted to chaparral areas because, being shy creatures, they needed dense hiding cover. These factors, because they explained the California thrasher's distribution, constituted the bird's niche. Grinnell's concept of the niche also included two important components: first, animals *evolved* to fill niches and, second, no two species could have exactly the same niche. These two concepts have turned out to be central to the subsequent development of niche theory.

At about the same time, one of the most important ecologists of the early part of this century, Charles Elton, was developing his own concept of niche. Elton's (1927) niche concept differed from that of Grinnell in several fundamental ways as evidenced by his definition of niche as an organism's "place in the biotic environment, its relations to food and enemies." When Elton uses the word "place" he really means the organism's role in its community—what it does, how it makes its living—as opposed to the geographical sense used by Grinnell. In practice, Elton tended to define niches based on an animal's size and feeding habits. For example, birds of similar size that catch insects on the wing were thought to have a similar niche; similarly, all large mammals that eat only grass were thought to have another. Elton's view of the niche concept was simply "to give more accurate and detailed definitions of the food habits of animals" than those afforded by words such as carnivore or herbivore.

A few years later the Russian scientist G. F. Gause (1934) combined Elton's view of the niche with the observation that very similar species cannot co-exist within a community. This is because resources such as food generally are in limited supply. Very similar organisms would have to compete with each other for the resource in question and inevitably one species would prove to be the superior competitor. Although Grinnell and even Darwin had stated much the same thing, Gause based his concept on mathematical reasoning by the Italian mathematician Vito Volterra. This idea, now often referred to as **"Gause's principle or the** competitive-exclusion principle" can be restated succinctly as "no two species in a community may possess the same niche," and has become a central tenet of modern niche theory.

In order to demonstrate this principle, Gause performed what are now considered to be classic experiments. Gause placed two species of *Paramecium*, a single-celled protozoan, into flasks containing a bacterial culture that served as food. Thus, in this artificial laboratory system both species of Paramecium were forced to have the same niche. Gause counted the numbers of Paramecium each day and found that after a few days one species always became extinct because it apparently was unable to compete with the other species for the single food resource. This process ofcompetitive exclusion has since been demonstrated many times in laboratory and field experiments with many species. However, extinction is not the only possible result of two species having the same niche. If two competing species can co-exist for a long period of time, then the possibility exists that they will evolve differences to minimize competition; that is, they can evolve different niches.

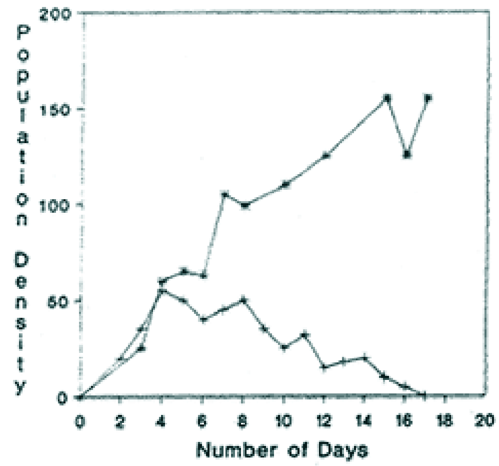

Fig.: 2.1 : Results of competition between two species of Paramecium with similar requirements.

Two niche concepts have been discussed so far. The first, propounded by Grinnell, is geographically oriented and we can term it a **place niche**. The second, championed by Elton and Gause, is defined on behavioral considerations and we might call this the **functional niche**. Ecologists were relatively satisfied by accepting these views of the niche until the late 1950s when the eminent limnologist and ecologist G. Evelyn Hutchinson devised a rigorous and quantitative concept of niche that, with slight modifications from his original concept, incorporated both place and functional elements and has remained the standard niche model for over thirty years. Prior to Hutchinson the niche was a rather nebulous concept defined only by words; that is, niches could not be measured. Hutchinson's new idea not only allowed a way to measure niches but also a way to compare niches of two or more species.

An animal that preys upon other animals will be limited in the range of prey sizes that it can kill. Certain prey will simply be too large to kill; others will be too small to bother with because the amount of energy needed to catch them is greater than the amount of energy to be gained by eating them.

2.3 Concept and Habitat of Niche

The Habitat

This is a related but distinct concept to Niche that describes the environment over which a species is known to occur and the type of community formed as a result. More specifically, habitat can be defined as regions in environmental space that are composed of multiple dimensions, each representing a biotic or abiotic environmental variable, that is, any component or characteristic of the environment related directly (forage biomass) and quality or indirectly (elelvation) to the use of a location by the animal eg. aquatic or terrestrial environment. Organisms are subject to environmental pressures but are also modifiers of their habitats by the regulatory feedback between them and their environment.

If we examine the geographic distribution of a widely-ranging species, we find that the distributional range consists of both occupied and unoccupied areas. Those areas actually occupied that meet the requirements for a species' survival and reproduction are its habitat. We mentioned earlier that the desert bighorn prefers desert mountain ranges—these mountain ranges, along with all the plants and other animals found there, constitute the bighorn's habitat.

Any place where organisms live is by definition a habitat. Your backyard, an empty plot, an agricultural field, a pristine mountain wilderness—all these are habitats for some group of organisms. Ecologists often find it useful to talk about kinds of habitats or to classify them into more or less general groupings. Habitats are typically classified on the basis of more or less obvious visual characteristics. Alpine meadows, conifer forests, marshes, lakes, desert scrub, and riparian zones along stream banks are all different habitats.

Sometimes habitat classifications have more to do with how the habitat functions than with its visual aspect. Although freshwater and saltwater marshes may appear similar superficially, each supports a different constellation of species. Along the

California coastline at the ocean's edge we can distinguish several zones that are functionally different. Above the high tide line, there is a splash zone that only the highest ocean waves can reach. Below this is the inter-tidal zone that is alternately exposed and submerged with the ebb and flow of the tide. Deeper still is the subtidal zone, which is always submerged. Although all of these zones may occur within a few meters of each other, they are fundamentally different habitats for the organisms that live there and they support distinct assemblages of species.

2.3.1 Habitat and Features

Habitats have many features or factors that are important to the organisms living there. Conveniently, we can divide habitat factors into two major groupings: physical factors *and* biotic-factors.

In terrestrial habitats some important physical factors are elevation, steepness, slope direction, soil type, and water availability. Elevation affects air temperature and rainfall—higher elevations are cooler and moister than lower ones. The steepness of a slope will affect the kind of soil that can form there and the amount of water that can soak into the ground after it rains. Slope aspect, the direction a slope faces is particularly important. In the northern hemisphere, south-facing slopes get more sun, are warmer and dryer, and thus support different vegetation than north-facing slopes. In aquatic habitats such characteristics as pH, salinity, dissolved oxygen concentration, temperature, and flow rate are important physical factors.

Biotic factors include all the other species that occur in the habitat. For an herbivore such as the desert bighorn sheep many of the grass, shrub, and herb species of the desert mountains constitutes its food source. Trees and shrubs form both hiding cover from predators and thermal the dead trees in which their holes are found but also the other birds (e.g., Pileated woodpeckers) that make the holes in the first place.

Finally, physical and biotic factors may interact to determine the quality of the habitat for a given organism. For example, the nutritional quality of plants available as food for herbivores, such as deer, is determined in large part by the quality of the soils present.

2.3.2 Habitats and their Conservation

Obviously a species cannot survive without its natural habitat, except perhaps in a zoo. It follows then that the fundamental unit in the conservation of biodiversity is not the species but the habitat.

An organism may have more than one habitat. During the summer many of our migratory waterfowl have breeding habitats in the arctic tundra, but in winter on the waterways and marshes of the southern United States. Mule deer of the Great Basin spend the summer in mountain forests, but winter snows drive them to lower elevation sagebrush zones where they can forage more easily. To ensure that there will always be migratory species such as these we need to protect not only the two habitats at the extremes of their seasonal movements but also the migration routes in between that serve as resting and feeding habitats. Habitats don't exist in isolation. Many habitats have inputs and outputs. We can take Mono Lake, for instance, a spectacular lake on the east side of the Sierra Nevada in California. Its water source is streams fed by winter rains and melting snow in the mountains. In its natural state, water leaves the lake only by evaporation. The balance between the inflowing streams and evaporation created a saline lake with many unique features, including a species of brine shrimp found only in Mono Lake. As a large, food-rich body of water in a desert area, the lake is a major fueling stop for migratory waterbirds and a major nesting area for other species, such as California gulls. When water from the lake's inflowing streams was diverted to quench the ever-growing thirst of southern California, the lake level dropped drastically. Islands in the lake became connected to the mainland, giving coyotes and other predators' access to an easy source of food: nesting California gulls. With adequate inflowing water, the islands were good nesting habitat; without the water they were unsuitable as nesting habitat. Without adequate inflowing water, the lake also would become too saline to be habitat for the Mono brine shrimp and to be a feeding habitat for migratory waterbirds. Recognition of this fundamental relationship between inflow and habitat for many species was the partial basis of a successful court action that reduced the diversion of water from the inflowing streams.

2.4 Niche Width and Overlap

Some plants and animals are more specialized than others and measures of niche breadth attempt to measure this quantitatively. Niche breadth has also been called niche width or niche size by ecologists. Niche breadth can be measured by observing the distribution of individual organisms within a set of resource states.

Levins (1968) proposed that niche breadth be estimated by measuring the uniformity of distribution of individuals among the resource states.

The concept of niche width or niche breadth refers essentially to the diversity of resource use shown by any one organism or group of organisms.

Those whose resources use is restricted to a small portion of the available resource spectrum are considered to have narrow niches, those which exploit a relatively diverse set of resources within the resource continuum are defined with broad niches.

They note that 'there are two situations in which one might wish to compare niche metrics: among species within communities, and between species of different communities. In both cases the paramount difficulty is standardization of the procedure so that measurements are comparable for different species and different communities.

Niche Overlap

One step to understanding community organization is to measure the overlap in resource use among the different species in a community guild. The most common resources measured in order to calculate overlap are food and space (or microhabitat). Several measures of niche overlap have been proposed and there is considerable controversy about which is best (Hurlbert 1978, Abrams 1980, Linton et al. 1981). The general problem of measuring niche overlap is very similar to the problem of measuring similarity.

In the same was that measures of niche breadth are all primarily derived from various indices of diversity, the various measures of niche overlap are usually based on some analysis of resource partitioning.

Each of these indices measures overlap along one resource dimension only. As noted above, multi-dimensional overlap may be derived as the arithmetic sum of separate overlaps if resource dimensions are inter-dependent, the product, if they are independent. Frequently, of course, it is very difficult to determine whether or not the separate dimensions are or are not dependent-or to what extent. Slobodkichoff and Schulz (1980) offer a valuable test for dependence and independence of resource dimensions used.

The different indices obviously each have difference strengths and weaknesses.

Although this has several disadvantages, it has the single advantage that it is sensitive to the number of individuals involved in each species Slobodkichoff and Schulz further note that the different measures embrace to different degrees, competitive events.

They stress a clear distinction between the concepts of resource use overlap and competitive pressure resulting from niche overlap, and note that the same distinction should be recognised in the different indices. They suggest that Pianka's (1973) overlap index represents resource use overlap (true niche overlap) while Levins' (1968) index (with its sensitivity to numbers of individuals) is more an index related to competitive pressure resulting from niche overlap.

2.5 Fundamental and Realized Niche

Such a niche, determined in the absence of relations with other species, is termed the **fundamental niche** and represents a species' potential to use available resources. Certain interactions between species can affect the breadth of a species' niche along one or several niche axes. For example, the risk of predation could shrink the breadth of a species' food niche axis if searching for certain kinds of food items increased the probability of being eaten. Competition for resources could also reduce the breadth of a species' niche along the resource axis in question. Thus the fundamental niche is the niche that exists in the absence of predators and competitors and is determined largely by the species morphological and physiological limitations. In the real world, a niche is limited in extent by the presence of interactions with other species and is termed the **realized niche**.

The realized niche of a species may vary from place to place because of the presence of different predators and competitors. In the Eel River of coastal California, for example, rainbow trout live primarily in riffles (shallow, fast-flowing areas) and feed on aquatic insects when predatory pikeminnows are present in the pools; in the absence of the predator, the realized niche of the trout expands to include the pools and more terrestrial insects that fall on the pool surface.

2.6 Character Displacement

Character displacement refers to the phenomenon where differences among similar species whose distributions overlap geographically are accentuated in regions where the species co-occur but are minimized or lost where the species' distributions do not overlap. This pattern results from evolutionary change driven by competition among species for a limited resource like food. The rationale for character displacement stems from the competitive exclusion principle, also called **Gause's Law,** which contends that to coexist in a stable environment two competing species must differ in their respective ecological niche; without differentiation, one species will eliminate or exclude the other through competition.

Character displacement was first explicitly explained by Brown and Wilson (1956): "Two closely related species have overlapping ranges. In the parts of the ranges where one species occurs alone, the populations of that species are similar to the other species and may even be very difficult to distinguish from it. In the area of overlap, where the two species occur together, the populations are more divergent and easily distinguished, i.e., they "displace" one another in one or more characters.

Character displacement is the term used to describe an evolutionary change that occurs when two similar **species** inhabit the same environment. Under such conditions, **natural selection** favours a divergence in the characters–morphology, ecology, behavior, or physiology of the organism. The idea was only formalized in the middle of the twentieth century by the American entomologists William L. Brown (1922-1997) and Edward O. Wilson (1929), who compared the characters of a number of species living together with characters in the same species living apart, or in allopatry. They found that sympatric species possessed many different characters although these same species were sometimes indistinguishable when living allopatrically. Brown and Wilson concluded that these situations resulted from **competition**: because the species were similar, they competed for the same resources and natural **selection** favored those species that competed less. Thus, the characters diverged.

2.7 Resource Partitioning

Differential resource selection is one of the principal factors, which permit species coexistence. In studies of niche partitioning, nest site location has received much less attention than food or habitat, perhaps because suitable nest sites are presumed to be readily available for most species. However, when a species has specific nesting requirements, suitable nesting locations may be difficult to obtain. This may bring about the overlap of nest sites and consequently, predation costs for breeders because of the attraction of the predators due to the increase in cumulative nest density. Factors commonly identified to explain aggregations are the spatial availability of food and defense against predators. Other studies suggest that ecto-parasitism and abiotic factors e.g. Precipitation affect habitat quality and become a dominant force influencing aggregation behavior in birds. Differential resource selection is one of the principal factors, which permit species co-existence. The response of wild populations to their resources is not always predictable because of the outcome of the number of interacting factors, which may go since a single until multiple factors. Food scarcity often leads to foraging in distant areas, which may result in formation of small colonies. Strong seasonal peaks in food resources may limit breeding to a single season of the year and cause synchronized breeding of the population. In these cases large colonies are formed and intense competition occurs for food. Competition might be lessened by a strategy of fine scale temporal and spatial segregation in the use of habitats among species with similar feeding habits.

2.8 Summary

In this chapter we have discussed in detail some of the concepts that ecologists use to study biodiversity. These concepts are geographic range, habitat, and ecological niche. It should be obvious by now that these are not mutually exclusive topics. Elements of habitat and niche are considered into the determination of geographic ranges. It can also be difficult to say exactly where habitat leaves off and niche begins. Nonetheless, an understanding of these three concepts can help us to effectively plan conservation measures and to appreciate the wonderful complexity of our biosphere.

Niche: The most widely accepted definition was one by Hutchinson (1957) ‘The Niche is the set of biotic and abiotic conditions in which a species is able to persist and maintain stable population sizes.' Two issues are recognizable from this definition (a) functional role of an organism (b) its position in time and space. The ecological niche is a central concept in the ecology of organisms and is subdivided into fundamental and realised niches.

Fundamental niche is the set of environmental conditions under which a species is able to persist. Realised niche is the set of environmental plus ecological conditions under which a species persists. To determine an organisms niche in the community the following must be know: i. Nutrition and source of energy ii. Rate of metabolism and growth iii. Effect on other organism.

2.9 Glossary

- **Habitat and Niche:** The tendency for co-existing species which occupy a similar position along one niche dimension, e.g. altitude, to differ along another, e.g. diet.
- **Fundamental Niche:** The potential range of all environmental conditions under which an organism can thrive.
- **Realized Niche:** The part of the fundamental niche that a species actually occupies in nature due to inter or intra-specific competition.
- **Niche:** The role played by (occupation or profession) and the address of a particular species in its ecosystem.

2.10 Self-Learning Exercise

Section- A : (Very Short Answer Type Questions)

1. Define niche.
2. Define character displacement.
3. What is habitat?
4. What is overlapping?
5. Name the important types of habitat?
6. What is habitat conservation?
7. How fundamental niche and realized niche can be differentiated to each other?

Section- B : (Short Answer Type Questions)

1. Write short note on characters of habitat.
2. Write two importance of habitat conservation.
3. What is niche overlap?
4. Write the difference between Niche Width and Overlap?
5. What do you understand by fundamental niche?

Section- C : (Long Answer Type Questions)

1. Write an essay on concept and habitat of niche.
2. Write notes on -
    a. Realized niche
    b. Fundamental niche
3. Describe various types of niche in detail with the help of examples.
4. Write about character displacement in detail.
5. Define niche, habitat and conservation of niche in detail.

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Unit - 3

Ecosystem Organization

Structure of the Unit:

3.0 Objectives

After studying this unit, you will be able to:

- Recognize the two major components of ecosystem Biotic & Abiotic Components
- Explain energy flow through food chain
- Differentiate between the various trophic levels- producers, consumers and decomposers
- Construct a food chain and represents–terrestrial and aquatic ecosystem

3.1 Introduction

The earth is perhaps the only planet in the solar system that supports life. The portion of the earth which sustains life is called **biosphere**. Biosphere is very huge and can not be studied as a single entity. It is divided into many distinct functional units called **ecosystem.** In this unit you will study about the structure and functions of ecosystem.

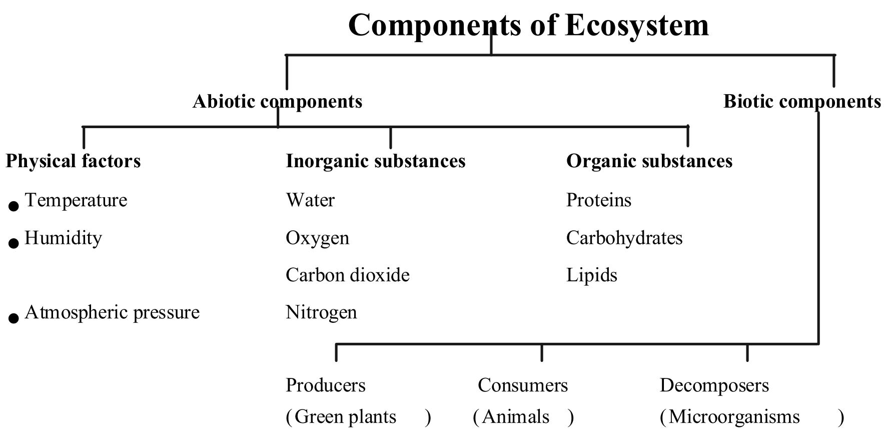
3.2 Ecosystem Structure

The term 'ecosystem' was coined by A.G. Tansley in 1935. An ecosystem is a functional unit of nature encompassing complex interaction between its biotic (living) and abiotic (non-living) components. For example- a pond is a good example of ecosystem.

3.2.1 Components of an ecosystem

Components of ecosystem: They are broadly grouped into:-

(a) Abiotic and (b) Biotic components



(a) Abiotic components (Nonliving): The abiotic component can be grouped into following three categories:-

- **(i) Physical factors:** Sun light, temperature, rainfall, humidity and pressure. They sustain and limit the growth of organisms in an ecosystem.
- **(ii) Inorganic substances:** Carbon dioxide, nitrogen, oxygen, phosphorus, sulphur, water, rock, soil and other minerals.
- **(iii) Organic compounds:** Carbohydrates, proteins, lipids and humic substances. They are the building blocks of living systems and therefore, make a link between the biotic and abiotic components.

(b) Biotic components (Living)

- **(i) Producers**: The green plants manufacture food for the entire ecosystem through the process of photosynthesis. Green plants are called **autotrophs,** as they absorb water and nutrients from the soil, carbon dioxide from the air, and capture solar energy for this process.
- **(ii) Consumers:** They are called heterotrophs and they consume food synthesized by the autotrophs. Based on food preferences they can be grouped into three broad categories. **Herbivores** (e.g. cow, deer and rabbit etc.) feed directly on plants, **carnivores** are animals which eat other animals (eg. lion, cat, dog etc.) and **omnivores** organisms feeding upon both plants and animals e.g. human, pigs and sparrow.
- **(iii) Decomposers:** They are also called **saprotrophs.** These are mostly bacteria and fungi that feed on dead decomposed and the dead organic matter of plants and animals by secreting enzymes outside their body on the decaying matter. They play a very important role in recycling of nutrients. They are also called **detrivoresor detritus feeders**.

(a) Abiotic components

- **(i) Light**: Solar radiation provides energy that controls the entire system.Penetration of light depends on transparency of water, amount of dissolved or suspended particles in water and the number of plankton. On the basis of extent of penetration of light a pond can be divided into **euphotic** (eu=true, photic=light), **mesophotic** and **aphotic** zones. Plenty of light is available to plants and animals in euphotic zone. No light is available in the aphotic zone.

(ii) Inorganic substances: These are water, carbon, nitrogen, phosphorus, calcium and a few other elements like sulphur depending on the location of the pond. The inorganic substances like O_2 and CO_2 are in dissolved state in water. All plants and animals depend on water for their food and exchange of gases- nitrogen, phosphorus, sulphur and other inorganic salts are held in reserve in bottom sediment and inside the living organisms. A very small fraction may be in the dissolved state.

(iii) Organic compounds: The commonly found organic matters in the pond are amino acids and humic acids and the breakdown products of dead animals and plants. They are partly dissolved in water and partly suspended in water.

(b) Biotic components

(i) **Producers or autotrophs:** synthesize food for all the heterotrophs of the pond. They can be categorized into two groups:-

(a) Floating micro-organisms and plants

(b) Rooted plants

(a) Floating micro-organisms (green) and plants are called **phyto-plankton** (“phyto”- plants, “plankton” –floating). They are microscopic organisms. Sometimes they are so abundant in pond that they make it look green in colour e.g. *Spirogyra, Ulothrix, Cladophora,* Diatoms*, Volvox.*

(b) **Rooted plants:** These are arranged in concentric zones from periphery to the deeper layers. Three distinct zones of aquatic plants can be seen with increasing deapth of water in the following order:

i) Zone of emergent vegetation: . eg. *Typha*, *Bulrushes* and *Sagittaria*

ii)Zone of rooted vegetation with floating leaves . eg. *Nymphaea*

iii) Zone of submergent vegetation: eg. All pond weeds like *Hydrilla* , *Rupia*, musk grass etc.

(ii) Consumers/Heterotrophs are animals which feed directly or indirectly on autotrophs eg. Tadpole, snails, sunfish, bass etc.

Pond animals can be classified into the following groups

(a) **Zooplanktons** are floating animals. Cyclops, Cypris

(b) **Nektons** are the animals that can swim and navigate at will. Eg. fishes

(c) **Benthic animals** are the bottom dwellers: beetle, mites, mollusks and some crustaceans.

(iii)Decomposers: They are distributed through out the entire in the whole pond but in the sediment most abundant. There are bacteria and fungi. (*Rhizopus, Penicillium, Curvularia ,Cladosporium)* found at the bottom of the pond

3.3 Organization

In addition to above, each community has its own trophic structure or organisms grouped based on feeding habits. Trophic structure of a pond consists of a variety of organisms as producers - which can prepare their own food through photosynthesis, consumers- heterotrophs which can not prepare their own food but are dependent on producers for nutrition directly or indirectly and decomposers, which decompose the dead and decaying matter and in this way release nutrients. Rooted or free-floating green plants (macrophytes), free-floating minute organisms (phytoplanktons – green algae and diatoms) constitute producers or autotrophs of a pond community. The consumers may be primary herbivores that directly feed on green plants or algae, secondary carnivores, that feed on herbivores or tertiary feeding on other carnivores. Zooplankton or floating minute animals like rotifers, crustaceans and protozoans, which feed on phytoplanktons, constitute herbivores in the pond community. In addition, there are several animal species associated with the green plants and feed on them. Some herbivores are also present at the bottom of the pond and feed on dead decaying plant parts. These may be beetles, mollusks or even crustaceans. Some birds and domesticated animals such as cow, goat and buffaloes also feed on green plants found in the pond especially on the margins in the littoral zone. Fishes constitute the secondary consumer of the pond feeding largely on herbivores. Some insects are also included in this category. In the pond, some larger fish or the game fish that feed on smaller fish constitute tertiary consumers. Besides there are varieties of decomposers (microconsumers – since they take a fraction of food) in the pond and these decompose complex, dead and decaying matter into simpler forms like nutrients, which are absorbed by the plants for their growth and development.

3.3.1 Trophic Structure

Trophic structure of a forest community also has a same pattern but with different species composition. In a forest, the autotrophs or the producers are the trees, which are also the dominant species. Additionally, the forests also have shrubs, herbs and grasses that are autotrophic and form a distinct understorey, but their role is lesser than that of trees. The type of the trees in the forests varies from place to place depending upon environmental conditions.

For example, a typical tropical moist deciduous forest is composed of tree species like teak (*Tectona grandis*), sal (*Shorea robusta*) or Queen's myrtle (*Lagerstoemia parviflora*); whereas a temperate deciduous forest has trees like oak (*Quercus*), maple (*Acer* sp.), birch (*Betula* sp.) and spruce (*Picea* sp.). The primary consumers in the forests include ants, beetles, leafhoppers, spider and bugs that feed on tree leaves. Besides, there are larger animals like elephants, nilgai, squirrels, rabbits, flying foxes and birds, which feed on shoots or fruits of the trees. Birds, snakes, lizards and foxes constitute secondary consumers whereas lions and tigers constitute tertiary consumers. The decomposers include several types of fungi, bacteria and actinomycetes.

Food chains and energy flow are the functional properties of ecosystems which make them dynamic. The biotic and abiotic components of an ecosystem are linked through them.

3.3.2 Food Chain

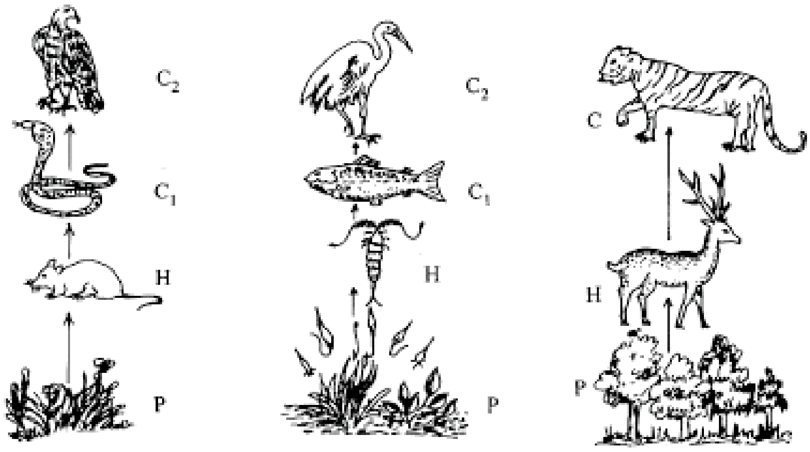
Transfer of food energy from green plants (producers) through a series of organisms with repeated eating and being eaten is called a **food chain**. e.g.

Grasses → Grasshopper → Frog → Snake → Hawk/Eagle

Each step in the food chain is called **trophic level**. In the above example grasses are 1st, and eagle represents the 5th trophic level.

During this process of transfer of energy, some energy is lost into the system as heat energy and is not available to the next trophic level. Therefore, the numbers of steps are limited in a chain to 4 or 5. Following trophic levels can be identified in a food chain.

(1) **Autotrophs:** They are the producers of food for all other organisms of the ecosystem. They are largely green plants and convert inorganic material in the presence of solar energy by the process of photosynthesis into the chemical energy (food). The total rate at which the radiant energy is stored by the process of photosynthesis in the green plants is called **Gross Primary Production** (GPP). This is also known as total photosynthesis or total assimilation. From the gross primary productivity a part is utilized by the plants for its own metabolism. The remaining amount is stored by the plant as **Net Primary Production** (NPP) which is available to consumers.



P = Producer, H = Herbivore, C = Carnivore,

C_1 = First level carnivore, C_2 = Top Carnivore

Fig. 3.1*:* Some examples of food chain

(2) **Herbivores:** The animals which eat the plants directly are called primary consumers or herbivores e.g. insects, birds, rodents and ruminants.

(3) **Carnivores:** They are secondary consumers if they feed on herbivores and tertiary consumers if they use carnivores as their food. e.g. frog, dog, cat and tiger.

(4) **Omnivores:** Animals that eat both plant and animals e.g. pig, bear and man

(5) **Decomposers:** They take care of the dead remains of organisms at each trophic level and help in recycling of the nutrients e.g. bacteria and fungi.

There are two types of food chains:

(i) **Grazing food chains:** which starts from the green plants that make food for herbivores and herbivores in turn for the carnivores.

(ii) **Detritus food chains:** start from the dead organic matter to the detrivore organisms which in turn make food for protozoan to carnivores etc.

In an ecosystem the two chains are interconnected and make y-shaped food chain. These two types of food chains are:-

Producers → Herbivores → Carnivores

Producers → Detritus Feeders → Carnivores

3.3.3 Food web

Trophic levels in an ecosystem are not linear rather they are interconnected and make a food web. Thus **food web is a network interconnected food chains existing in an ecosystem**. One animal may be a member of several different food chains. Food webs are more realistic models of energy flow through an ecosystem.

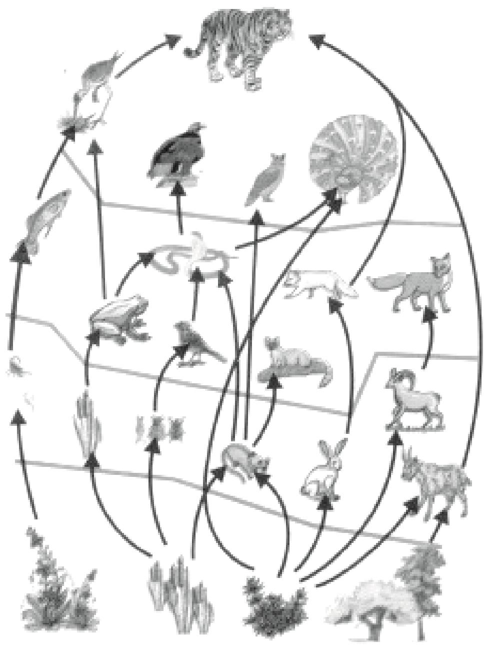


Fig. 3.2: Simple Food Web

The flow of energy in an ecosystem is always linear or one way. The quantity of energy flowing through the successive trophic levels decreases as shown by the reduced sizes of boxes in fig. 3.3. At every step in a food chain or web, the energy received by the organism NU is used to sustain itself and the left over is passed on to the next trophic level.

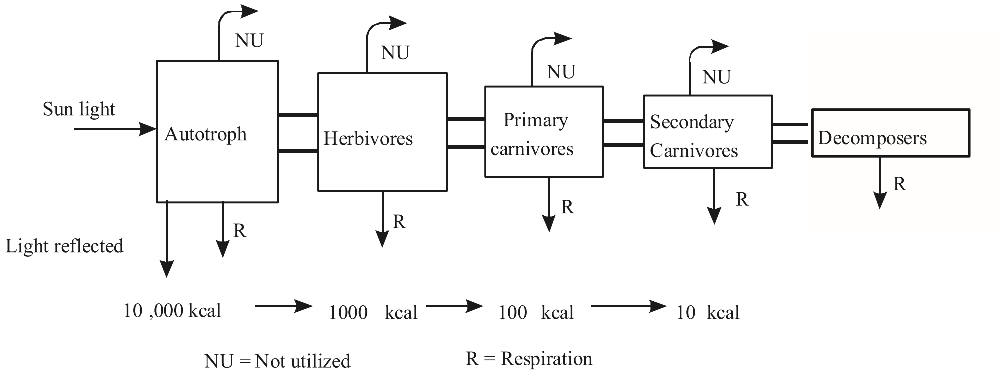


Fig. 3.3: Model of Energy Flow through an Ecosystem

Boxes indicate the standing crop biomass and pipes indicate the energy flowing.

(NU = Not utilized, R = Respiration)

3.4 Energy Dynamics

3.4.1 Ecological pyramid

Ecological pyramids are the graphic representations of trophic levels in an ecosystem. They are pyramidal in shape and they are of three types: The producers make the base of the pyramid and the subsequent tiers of the pyramid represent herbivore, carnivore and top carnivore levels.

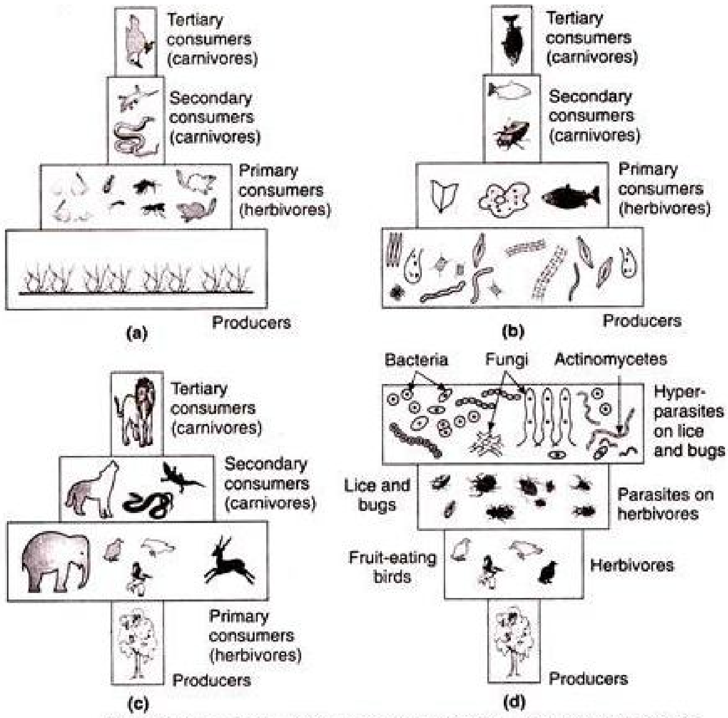
(1) **Pyramid of number:** This represents the number of organisms at each trophic level. For example in grassland the number of grasses is more than the number of herbivores that feed on them and the number of herbivores is more than the number of carnivores.

In some instances the pyramid of number may be inverted, i.e herbivores are more than primary producers as you may observe that many caterpillars and insects feed on a single tree.

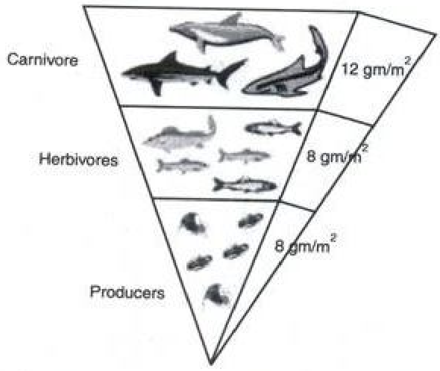
(2) **Pyramid of biomass:** This represents the total standing crop biomass at each trophic level. **Standing crop biomass** is the amount of the living matter at any given time. It is expressed as gm/unit area or kilo cal/unit area. In most of the terrestrial ecosystems, the pyramid of biomass is upright. However, in case of aquatic ecosystems the pyramid of biomass may be inverted e.g. in a pond phytoplankton are the main producers, they have very short life cycles and a rapid turn over rate (i.e. they are rapidly replaced by new plants). Therefore,

their total biomass at any given time is less than the biomass of herbivores supported by them.

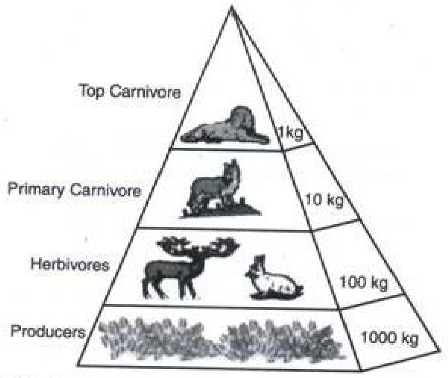
(3) **Pyramid of energy:** This pyramid represents the total amount of energy at each trophic level. Energy is expressed in terms of rate such as kcal/unit area /unit time or cal/unit area/unit time.e.g. in a lake autotroph energy is 20810 kcal/m/year. Energy pyramids are never inverted.



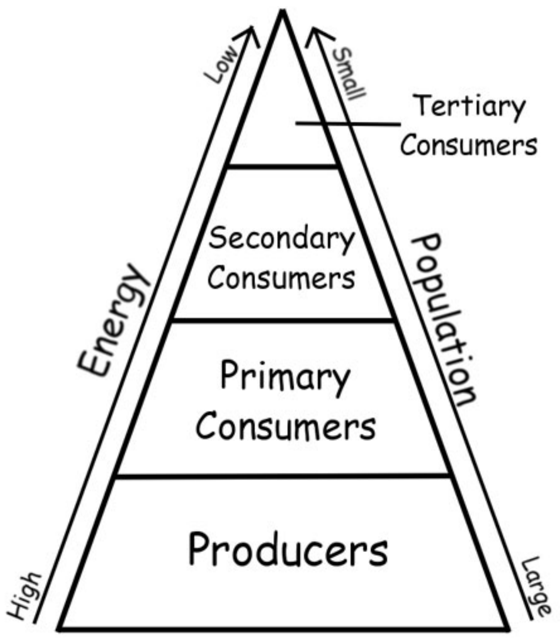
Pyramid of numbers (a) Grassland ecosystem, (b) Pond ecosystem, (c) Forest ecosystem and (d) Parasitic food chain.



Inverted Pyramid of Biomass in Aquatic Ecosystem



Upright Pyramid of Biomass for Grassland Ecosystem



Pyramid of Energy

Fig. 3.5: Ecological Pyramids

P = Producer; C_1= herbivore; C_1= Carnivore ; C_2= Top carnivore

There are two types of systems that are of ecological interest - open and cybernetic

Open System

Open systems depend on an outside environment to provide inputs and accept outputs. The ecosystem, too, is an example of an open system; it receives energy from an outside source. It acts upon it, and transmits it to the outside. Like, the sun fixes and utilizes it and ultimately dissipates heat to space. If the sun's energy were to be cut off, the ecosystem (and life on earth) would cease to function. An open system can consist of a number of components or parts, called subsystems: and each subsystem can consist of a number of elements.

Cybernetic System

A cybernetic system, which can also be an open system, has some sort of feedback system to make it self- regulating. It maintains itself to function by some forms of information feedback into the system in such a manner the cybernetic system has an ideal state.

Most living systems possess cybernetic systems that can function at various levels, from the cell to the community, but always functioning through organisms; the difference being that in living systems the set point is not fixed.

Rather, organisms have a limited range of tolerances, called homeostatic plateaus, within which conditions must be maintained. If environmental conditions exceed the operating limits of tile system, it goes out of control. Instead of negative feedback governing the system positive feedback takes over. Positive feedback is a continual movement away a system's set point or homeostatic plateau that ultimately can destroy the system, A feedback loop can be defined as the relationship in which a change in some original state of being 'feedback" onto that original state to alter the rate or direction of further change

Cybernetic systems produce stable systems. A stable system is one that responds to summit by developing forces to restore it to its original condition. In natural ecosystems this stability may mean that the system can survive many changes but still preserve a similar structure. Stability also means persistence, i.e., the system remains much the way it was.

In natural ecosystems the operation of feedback mechanisms in the regulation of population size in a hypothetical population of animals has positive feedback leading to self sustained change and negative feedback leading to self regulated homeostasis.

The result is a self-sustaining population increase, driven by the offspring feeding back into the breeding population in the same way, if more breeders die than are replaced each year (which happens in some populations), this loss will be reflected in a smaller breeding population and will result in sustaining decline in population number by the same type of the positive- feedback loop.

In the negative feedback-loop, the population is controlled by external factors, such as food supply. If the population increase in size, there will not be sufficient food to go around, and more individuals than usual will die from starvation; conversely, if the population decrease in size, there will be more than enough food to go around, and the animals will be well- nourished, leading to a smaller than normal die off.

In either case, the equilibrium population size is regained most interactions between different species of organisms, and many interactions between a given species and its physical environment, depend on either positive or negative feedback. All organisms in an ecosystem are part of several different feedback loops at any point in time. Some of these relationships are negative, while others are positive.

3.4.1 Homeostasis

Natural ecosystems possess self-regulating mechanisms that maintain their balance. **The tendency of ecosystems to resist change and remain in a state of equilibrium is called Homeostasis** (*homeo*=same and *stasis*=standing). Such a mechanism requires 'feedback' processes and many such process exist in the natural world.

A common way of thinking is that if ecosystems are self maintaining, then why not throw all wastes into nature and let nature take care of it? But it has been realized and experienced that whether it is an ecosystem, a community or even an organism, every system has its tolerance limits. Stresses beyond the tolerance limits of these systems can be fatal for the biosphere and hence for us.

Ecosystems provide a number of goods such as food, timber, medicines, genetic resources, etc. Ecosystems also serve a number of functions— ecological, economic, recreational/aesthetic, as well as educational. Major ecological functions of ecosystems include: meeting the habitat (shelter), food, water, air as well as breeding demands of not just humans but also of the various other organisms; providing ecological services—clean air, water, waste absorption—to the organisms living in it; regulating climate, flood control, coastline stabilization, carbon appropriation, waste treatment, biodiversity conservation, soil generation, disease regulation, and the provision of aesthetic and cultural benefits.

3.4.3 Liebig’s Law of the Minimum

In 1840, a German chemist **Jus us von Liebig** published a book, **OrganicChemistry and its Application to Agriculture and Physiology.** Liebig described in his bookthe effect of various factors of the growth of plants. He concluded his findings in this simple statement: **"Growth of a plant is dependent on the amount of food stuff which is present to it in minimum."** This has come to be known as **Liebig's law of the minimum.** He said that each plant requires certain kinds and quantities of nutrient or food material. If one of these food materials is absent, the plant dies and if it is present in minimal quantity, the growth of the plant will be minimum.

The Liebig law was originally related with chemical material required by plants in their natural environment. Later his hypothesis was expanded in order to include animals and all of the abiotic factors. A number of environmental factors like temperature, atmospheric gases, humidity, amount of light and many other similar abiotic factors can act as limiting factors with respect to the organism.

Liebig began experimental work on the topic of **limiting factors** that their significance on plant growth became evident. He was able to show that only one of the factors necessary for growth need be absent, or be present in very small amounts, to cause plant growth and development to be constricted. For plants, the basic nutrients necessary for growth can be subdivided into two categories, the abundant substances called the **macronutrients** which are:

(i) Nitrogen, Phosphorus, Potassium

(ii) Calcium, Magnesium, Sulphur

and the substances which are present in very small amounts called **trace elements** or **micronutrients:**

(i) Iron, Manganese, Boron

(ii) Chlorine, Copper, Zinc

(iii) Molybdenum, Vanadium

Liebig's experiments showed that only rarely did the macro nutrients become limiting factors and instead it was the micro nutrients that were the problem. These are present in such small amounts that they are measured in units of **parts per million (p.p.m.)**. Trace element deficiency in soils is now known to be responsible for poor yields from cereal crops, for tomatoes that fail to ripen, for apples that remain small and sour on the tree.

From this work, Leibig produced his Law of the Minimum which states that growth of a plant is dependent on the amount of foodstuff which is presented to it in minimum quantity.

More recently, it has been shown that the opposite of the Law of the Minimum can also operate. A super-abundance of an element can sometimes compensate for the deficiency of another, for example a zinc deficiency in the soil can be compensated for if a plant grows in full sunlight and not in the shade. This compensation effect is called **factor interaction.**

Liebig made great contributions to the science of plant nutrition and soil fertility. As a result of millenia of practical experience of farmers manuring fields to improve fertility, many early chemists thought that the "principle ofvegetation", the essential nutrients needed for plant growth, were **organic** in nature rather than mineral. Liebig essentially debunked the humus theory and made a scientific case for plant requirements for mineral elements from the soil, carbon from CO_2 in the air, and H and O_2 from water. Liebig thought that plants derived most of their nitrogen content from the air as well, which is somewhat correct for legumes, but not true for other plants. Liebig developed the first mineral fertilizers applied to replentish nutrients removed from soils by crops and clearly saw mineral fertilizers as part of sustainable agricultural practices.

F. F. Blackmann, a British physiologist, incorporated the law of limiting factors. He while studying the factors affecting the rate of photosynthesis discovered that rate of photosynthesis is governed by the level of the factor that is operating at a limiting intensity.

The Liebig's law of minimum should be restricted to chemical materials such as oxygen, phosphorus etc., necessary for physiological growth and reproduction while other factors and the limiting effect of the maximum are included in the law of tolerance.

Usually, Leibig's law is combined with the **Law of Limiting Factors** developed by an American scientist called Blackman who studied the relationship of photosynthesis with a variety of environmental factors during the early years of this century. He discovered that the rate of photosynthesis was governed by the level of the factor that is operating at a limiting intensity.

Numerous modifications to the **Liebig-Blackman law** have been postulated, and in particular the role of a time factor on the relationship is usually added.

While we have thus concentrated on minimal amounts of a substance acting as a limit on growth, then so it is possible to have too much of a commodity. Too much calcium in the soils (such as occurs over chalky parent materials) can prevent a large group of plants known as the acidophiles or the acid tolerant plants from occurring. In coastal areas along the western side of Britain, the occurrence of strong westerly winds transfers large quantities of sea salt (mainly sodium chlorate but also potassium) for some 5km inland. The sea salt nuclei become trapped on leaf surfaces and after a strong spring gale, many newly formed buds and twigs of vegetation can become scorched by the salt. Growth becomes stunted as a consequence.

3.4.4 Natural and Artificial

Ecosystems are classified as follows:

(i) Natural ecosystems (ii) Man made ecosystems

(i) Natural ecosystems

(a) Totally dependent on solar radiation e.g. forests, grasslands, oceans, lakes, rivers and deserts. They provide food, fuel, fodder and medicines.

(b) Ecosystems dependent on solar radiation and energy subsidies (alternative sources) such as wind, rain and tides. e.g tropical rain forests, tidal estuaries and coral reefs.

(ii) Man made ecosystems

(a) Dependent on solar energy-e.g. Agricultural fields and aquaculture ponds.

(b) Dependent on fossil fuel e.g. urban and industrial ecosystems.

3.5 Functions of Ecosystem

It is clear from the trophic structure of an ecosystem that the amount of energy decreases at each subsequent trophic level. This is due to two reasons:

1. At each trophic a part of the available energy is lost in respiration or used up in metabolism.
2. A part of energy is lost at each transformation, i.e. when it moves from lower to higer trophic level as heat.

It is the ratio between the amount of energy acquired from the lower trophic level and the amount of energy transferred from higher trophic level is called **ecological efficiency**. Lindman in 1942 defined these ecological efficiencies for the 1st time and proposed 10% rule e.g. if autotrophs produce 100 cal, herbivores will be able to store 10 cal. and carnivores 1cal. However, there may be slight variations in different ecosystems and ecological efficiencies may range from 5 to 35%. Ecological efficiency (also called Lindman's efficiency) can be represented as

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

Ecosystems are complex dynamic system. They perform certain functions. These are:

(i) Energy flow through food chain

(ii) Nutrient cycling (biogeochemical cycles)

(iii) Ecological succession or ecosystem development

(iv) Homeostasis (or cybernetic) or feedback control mechanisms

Ponds, lakes, meadows, marshlands, grasslands, deserts and forests are examples of natural ecosystem. Many of you have seen an aquarium; a garden or a lawn etc. in your neighbourhood. These are man made ecosystem.

3.5.1 Production in Ecosystems

Productivity or Production refers to the rate of generation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface (or volume) per unit time, for instance grams per square metre per day. The mass unit may relate to dry matter or to the mass of carbon generated. It is a measurement of the rates of conversion of energy and nutrients into growth. There two major types: primary productivity (productivity of autotrophs) and secondary productivity (productivity of heterotrophs) food webs and trophic levelS: These are two widely employed conceptual models/maps used to explain the linkages among species in relation to production in the ecosystem and transfer of energy. They are used to illustrate pathways of energy flow in an ecological community, usually starting with solar energy being used by plants during photosynthesis. Food webs can be more complicated depending on which ecological dimension is being mapped such as species composition (types), species richness (number), biomass (dry weight of plants and animals), productivity (rates of conversion of energy and nutrients into growth) and stability (food webs over time). Trophic dynamics: When the relative abundance or biomass of each functional feeding group is stacked into their respective trophic (feeding) levels, they naturally sort into a pyramid of numbers. One of the several patterns that are repeated amongst the planet's ecosystems is the emergent pyramidal arrangement or trophic levels with amounts of energy transfer decreasing as species become further removed from the source of production. The size of each level in the pyramid generally represents biomass which can be measured as the dry weight of an organism. Autotrophs may have the highest global proportion of biomass, closely rivalled or surpassed by microbes. Functional trophic groups sort out hierarchically into pyramid trophic levels because it requires adaptations to become a photosynthesizer or a predator; few organisms have the adaptations needed to combine both abilities. Each trophic level contains unrelated species that grouped together because they share common ecological functions.

3.5.2 LitterFall and Decomposition

Primary Production in Terrestrial Ecosystems

Average net primary production in terms of dry weight for terrestrial ecosystems is presented. It is clear that more than 60% of terrestrial primary production occurs in the tropics. Thus tropical ecosystems generally have greater production than comparable ones at higher altitudes. However, there is much variation within the substantial overlap between categories. For example, primary production in tropical forests ranges from approx. 1000-3000 $g/m^2/yr$, temperate forests 600-2500 $g/m^2/yr$ and boreal forests 400-2000 $g/m^2/yr$. Some tropical forests are less productive than some of their temperate or local counterparts. Similar variations in plant production of savannas and grasslands are also found.

The highest rate of primary production occurs in tropical rain forests, and yet the average for these ecosystems, 2300 $g/m^2/yr$, represents conversion of less than 0.00 1% of the total solar radiation reaching $1m^2$ of the planet.

It shows energy losses in primary production between solar radiation and net primary production. These are comparisons for tropical and temperate intensive agriculture. Losses are due to**:**

(1) Geometry and rotation of the earth and transmission through the atmosphere.

(2) Energy not absorbed by chlorophyll.

(3) Rate of carbon dioxide diffusions and photo-chemical efficiency.

(4) Plant respiration.

Thus tropical forests, particularly tropical rain forests have maximum primary production among terrestrial ecosystems of the world. But these too have a very poor efficiency of conversion of less than 0.001% of the total solar radiation reaching $1m^2$ of the earth. Following are the possible reasons for this poor efficiency of net primary production:

1. **Energy losses between the outer atmosphere and plant canopy.** Only 15% and 8% of the solar radiation reaching the earth remains in tropical and temperate regions respectively.
2. **Interception of light by plants**. Annual average leaf area indices (leaf area index is the area of leaf (m^2) arranged vertically above each square meter of ground; a useful measure of canopy density) are at their highest in evergreen forests (10 or more) and their lowest in arid deserts (0.5 or less). In seasonal environments as Indian grassland this index value was 0.5 in dry season when the plants had died back and 5.0 in the wet season when they were actively growing.

No overall estimate can be given for **interception efficiency.** It can be defined as the fraction of incident light intercepted. On an estimated basis, values of annual average of interception efficiency are 20% for tropical intensive agriculture, 5% for tropical subsistence agriculture, and 33% for temperate intensive agriculture. This greater value for temperate one leads to tropical production being only slightly greater than the temperate estimate in summary values given above.

1. **Plant biochemistry:** On an average, only about 30% of gross primary production is available as net primary production in tropical rain forests compared with 40% in temperate forests. This difference is partly due to fast respiration at higher temperatures than is photosynthesis. Respiration is also greater in plant communities with a high ratio of standing crop to production. In forests the photosynthetic leaves support a large nonphotosynthetic biomass

of wood while in herbaceous vegetation most of the above ground tissues are photosynthetic.

3.5.3 Nutrient Regeneration

Decomposition rate largely determines the rate of nutrient cycling.

- The rates at which nutrients cycle in different ecosystems are extremely variable as a result of variable rates of decomposition.
- Decomposition takes an average of four to six years in temperate forests, while in a tropical rain forest, most organic material decomposes in a few months to a few years.
- The difference is largely the result of warmer temperatures and more abundant precipitation in tropical rain forests.
- Like net primary production, the rate of decomposition increases with actual transpiration.
- In tropical rain forests, relatively little organic material accumulates as leaf litter on the forest floor.
- 75% of the nutrients in the ecosystem are present in the woody trunks of trees.
- 10% of the nutrients are concentrated in the soil.
- In temperate forests, where decomposition is slower, the soil may contain 50% of the organic material.
- In aquatic ecosystems, decomposition in anaerobic mud of bottom sediments can take 50 years or more.
- However, algae and aquatic plants usually assimilate nutrients directly from the water.
- Aquatic sediments may constitute a nutrient sink.
- Nutrient cycling is strongly regulated by vegetation.
- Long-term ecological research (LTER) monitors the dynamics of ecosystems over long periods of time.
- The Hubbard Brook Experimental Forest has been studied since 1963.

- The study site is a deciduous forest with several valleys, each drained by a small creek that is a tributary of Hubbard Brook.
- Preliminary studies confirmed that internal cycling within a terrestrial ecosystem conserves most of the mineral nutrients.
- Some areas were completely logged and then sprayed with herbicides for three years to prevent regrowth of plants.
- All the original plant material was left in place to decompose.
- Water runoff from the altered watershed increased by 30–40%, apparently because there were no plants to absorb and transpire water from the soil.
- The concentration of Ca2+ in the creek increased four-fold, while concentration of K+ increased by a factor of 15.
- Nitrate loss was increased by a factor of 60.
- This study demonstrates that the amount of nutrients leaving an intact forest ecosystem is controlled by the plants.
- Results of the Hubbard Brook studies assess natural ecosystem dynamics and provide insight into the mechanisms by which human activities affect ecosystem processes.

3.6 Types of Ecosystem

3.6.1 Terrestrial Ecosystem

(a) Grassland Ecosystem

This is a type of terrestrial ecosystem. Grasslands occupy a comparatively fewer area, roughly 19 per cent of the earth's surface. The various components of a grassland ecosystem are as follows:

Abiotic component

These are the nutrients present in soil and the aerial environment. Thus the elements like C, H, **O, N,** P, S etc. are supplied by carbon dioxide, water, nitrates, phosphates and sulphates etc., present in air and soil of the area. Moreover, in addition to the above, some trace elements are also present in soil.

Biotic component

These may be categorised as:

1. **Producers:** They are mainly grasses, as species of *Dichanthium, Cynodon, Desmodium, Digitaria, Dactyloctenium, Brachiaria, Setaria, Sporobolus* etc. Besides them few herbs and shrubs are also contribute to primary production.
2. **Consumers:** These occur in the following sequence:

   (a) **Primary consumers:** The herbivores feeding on grasses are mainly such grazing animals as cow, buffalo, deer, sheep, rabbit, mouse etc. Besides them, there are also present some insects as *Leptocorisa, Dysdercus, Oxyrhachis, Cicincella, Coccinella,* some termites and millipeds etc, that feed on the leaves of grasses.

   (b) **Secondary consumers:** These are the carnivores feeding on herbivores. These include the animals like fox, jackals, snakes, frogs, lizards, birds etc. Sometimes the hawks feed on the secondary consumers, thus occupying tertiary consumers level in the food chain.
3. **Decomposers:** The microbes active in the decay of dead organic matter of different forms of higher life are fungi, as species of *Mucor, Aspergillus, Penicillium, Cladosporium, Rhizopus, Fusarium* etc., and some bacteria and actinomycetes. They bring about the minerals back to the soil, thus making them available to the producers.

(b) Forest Ecosystem

Forests occupy roughly 40 per cent of the land. In India, the forests occupy roughly one-tenth of the total land area. The different components of a forest ecosystem, like others, are as follows:

Abiotic component

These are the inorganic as well as organic substances present in the soil and atmosphere. In addition to the minerals present in forests we find the dead organic debris — the litter accumulation, chiefly in temperate climate. Moreover, the light conditions are different due to complex stratification in the plant communities.

Biotic component

The living organisms present in the food chain occur in the following order:

1. **Producers:** These are mainly trees that show much species diversity and greater degree of stratification especially in tropical moist deciduous forests. The trees are of different kinds depending upon the kind of the forest formation developing in that climate. Besides trees, there are also present shrubs and a ground vegetation. In these forests, dominant members of the flora, the producers, are such trees as *Tectona grandis, Buteafrondosa, Shorea rubusta* and *Lagerstroemia parvifiora.* In temperate coniferous forests, shrubs and ground flora are insignificant. In temperate deciduous forests the dominant trees are species of *Quercus, Acer, Betula, Thuja, Picea* etc., whereas in a temperate coniferous forests, the producer trees are species of *Abies, Picea, Pinus, Cedrus, Juniperus, Rhododendron* etc.
2. **Consumers:** These are as follows:
   - (a) **Primary consumers:** These are the herbivores that include the animals feeding on tree leaves as ants, flies, beetles, leafhoppers, bugs and spiders etc., and larger animals grazing on shoots and fruits of the producers, the elephants, nilgai, deer, moles, squirrels, shrews, flying foxes, fruit bats, mongooses etc.
   - (b) **Secondary consumers:** These are the carnivores like snakes, birds, lizards, fox etc. feeding on the herbivores.
   - (c) **Tertiary consumers:** These are the top carnivores like lion, tiger etc. that eat carnivores of secondary consumers level.
3. **Decomposers:** These are wide variety of microoganisms including fungi (species of *Aspergillus, Coprinus, Polyporus, Ganoderma, Fusarium, Alternaria, Trichoderma* etc.), bacteria species of *Bacillus, Clostridium, Pseudomonas, Angiococcus* etc., and actinomycetes, like species of *Streptomyces* etc. Rate of decomposition in tropical and subtropical forests is more rapid than that in the temperate ones.

(c) Desert Ecosystem

Deserts occupy about 17 per cent of land, occurring in the regions with an annual rainfall of less than 25 centimeters. The species composition of such ecosystem is much more varied and typical due to extremes of both, temperature and water factors.

The various biotic components are:

1. **Producers:** These are shrubs, especially bushes, some grasses and a few trees. The shrubs have widespread, branched root system with their stems and branches variously modified. Sometimes a few succulents like cacti are also present. Some lower plants like lichens and xerophytic mosses may also be present.
2. **Consumers:** Themost common animals are reptiles and insects, able to live under xeric conditions. In additions to them, there are also found some nocturnal rodents and birds. The 'ship of desert', camels feed on tender shoots of the plants.
3. **Decomposers:** These are very few, as due to poor vegetation the amount of dead organic matter is correspondingly less. They are some fungi and bacteria, most of which are thermophilic.

(d) Cropland Ecosystem

The ecosystems, described so far, are natural in the sense that they all operate as self-regulating systems without much direct interference and manipulations by man. However, in nature, we also find another kind of ecosystems, where man is very much involved in their operation. These are the cropland ecosystems, which are artificial or man-engineered, where in order to obtain more food, cloth, timber, medicines and other useful products; man becomes responsible for the replacement of natural systems. To secure maximum production, man makes much planned manipulations in the physic chemical environment. These include addition of fertilizers to soil, use of chemicals for disease control, proper irrigation practices etc. Thus, a cropland ecosystem is an artificial system aimed primarily to grow a single species of one's choice. We have ecosystems of dominant crop species like wheat, maize, jowar, paddy, sugarcane, vegetable etc. under most suitable conditions of their growth and yield. It is generally argued that in a natural ecosystem, the nature maximizes for gross production, whereas in an artificial ecosystem, man maximizes for net production. In a cropland ecosystem, there is not necessarily an increase in the total dry matter production of the **whole plants,** but generally most of the production goes into grain and less into leaves, stems and roots. Thus, in agriculture (where all the systems are artificial), there is an objective to achieve high **rates of production** (P) of readily harvestable products with little **standing crop** (biomass — B) left in the field for accumulation, or we may say that there is a high P/B efficiency. Nature (natural ecosystem), on the other hand, follows just a reverse efficiency--i.e. a high B/P ratio, where the standing crop is generally accumulated to its maximum. The following are the chief components of a maize cropland ecosystem.

Abiotic component

These include the climatic conditions of the region, where the crop may grow most successfully, and the various minerals particularly C, H, O, N, P, K in soil and atmosphere. In such field man generally makes additions of a number of chemical fertilizers to soil. Maize generally grows best in slightly alkaline soil with good aeration.

Biotic component

The various living organisms in the food chain occur as follows:

1. **Producers:** The dominant plant species would naturally be *Zea mays*. Besides maize, a number of weeds like *Cynodon dactylon, Launaea nudicaulis, Euphorbia hirta, Cyperus rotundus, Digitaria* spp. and *Alysicarpus* sp. also contribute to primary production of the field.
2. **Consumers:** These are ***(a) Primary consumers:*** These are the herbivores represented by a variety of animals, big as well as small. The smaller animals include chiefly the insects as aphids, thrips, beetles etc. which feed and lay their eggs on maize leaves. Larger animals are rabbits, rats, birds and man feeding on leaves, flower and fruits of maize. **(b)** ***Secondary consumers:*** These are carnivores like frogs and some birds that eat insect. **(c)** ***Tertiary consumers:*** These are carnivores like snakes and hawks which feed on the secondary consumers, frogs and smaller birds.
3. **Decomposers.** These are microbes present in soil as well as air, that decompose the dead organic matter of plants and animals. These are chiefly bacteria, actinomycetes and fungi, responsible for decay, decomposition and humification, making the minerals available again to the producers.

3.6.2 Aquatic Ecosystem

An aquatic ecosystem is an ecosystem in a body of water. Communities of organisms that are dependent on each other and on their environment live in aquatic ecosystems. The two main types of aquatic ecosystems are freshwater ecosystems and marine ecosystems.

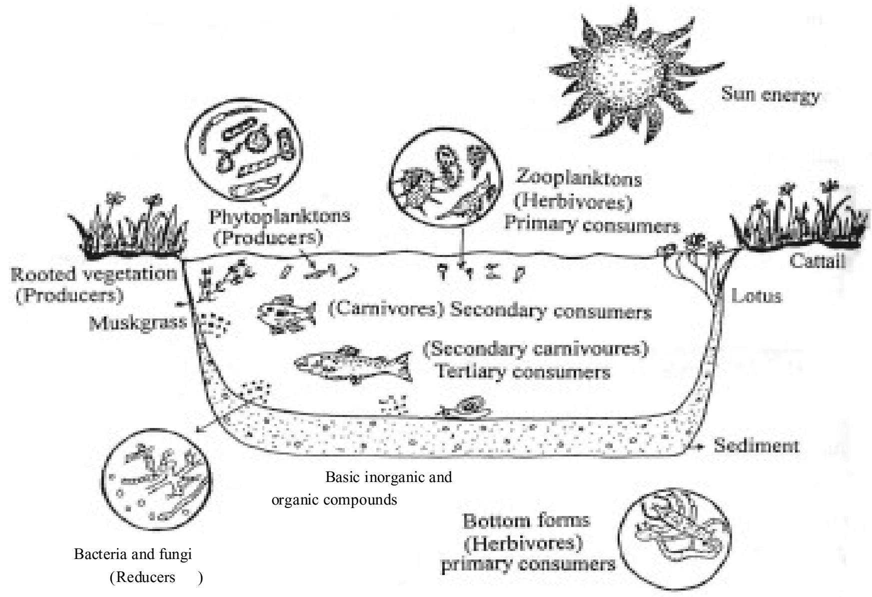


Fig. 3.4 : Aquatic Ecosystem

(a) Freshwater Ecosystem

Only 3% of the world's water is fresh. And 99% of this is either frozen in glaciers and pack ice or is buried in aquifers. The remainder is found in lakes, ponds, rivers, and streams.

Lakes and Ponds Ecosystem

Deep lakes contain three distinct zones, each with its characteristic community of organisms.

- **Littoral zone-** The zone close to shore. Here light reaches all the way to the bottom. The producers are plants rooted to the bottom and algae attached to the plants and to any other solid substrate. The consumers include tiny crustaceans, flatworms, insect larvae, snails, frogs, fish, and turtles.

- **Limnetic zone-** This is the layer of open water where photosynthesis can occur. As one descends deeper in the limnetic zone, the amount of light decreases until a depth is reached where the rate of photosynthesis becomes equal to the rate of respiration. At this level, net primary production no longer occurs. The limnetic zone is shallower in turbid water than in clear and is a more prominent feature of lakes than of ponds. Life in the limnetic zone is dominated by

- floating microorganisms - called **plankton**
- actively swimming animals - called **nekton**
- The **producers** in this ecosystem are planktonic algae.
- The **primary consumers** include such animals as microscopic crustaceans and rotifers the so-called **zooplankton**.
- The **secondary (and higher) consumers** are swimming insects and fish. These nekton usually move freely between the littoral and limnetic zones.

- **Profundal zone-** Many lakes (but few ponds) are so deep that not enough light reaches here to support net primary productivity. Therefore, this zone depends for its calories on the drifting down of organic matter from the littoral and limnetic zones. The profundal zone is chiefly inhabited by primary consumers that are either attached to or crawl along the sediments at the bottom of the lake. Such bottom-dwelling animals are called the **benthos**. The sediments underlying the profundal zone also support a large population of bacteria and fungi. These decomposers break down the organic matter reaching them, releasing inorganic nutrients for recycling.

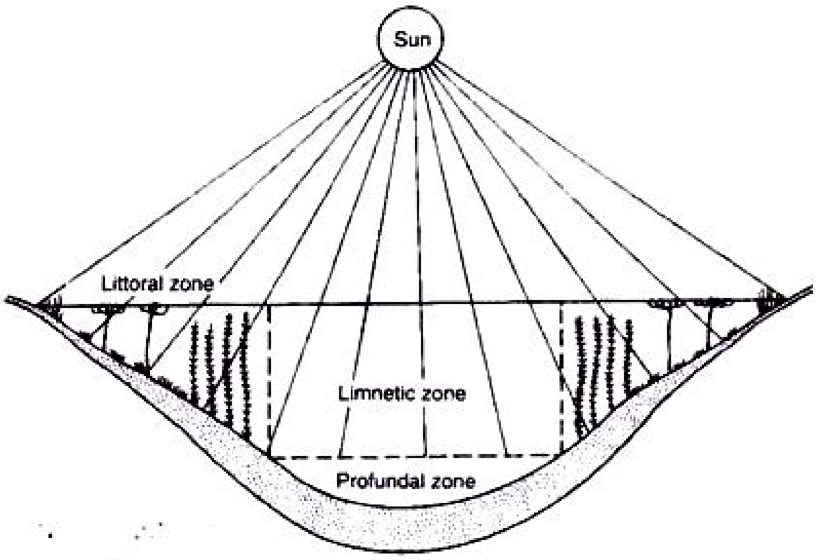


Fig. 3.5: Fresh Water Ecosystem

(b) Ocean (Marine) Ecosystem

Major oceans of the world, Atlantic, Pacific, Indian, Arctic and Antarctic cover approximately 70 per cent of the earth's surface. Each ocean indeed represents a very large and stable ecosystem. **Marine environments,** as compared with fresh water, appear to be more stable in their chemical composition due to being saline, and moreover other such physico-chemical as dissolved oxgen content, light and temperature are also different. These aspects would be considered in some detail later under **'Habitat Ecology'.**

The **biotic components** of an ocean ecosystem are of the following orders:

1. Producers: These are autotrophs and also designated as primary producers, since they are responsible for trapping the radiant energy of sun with the help of their pigments. Producers are mainly the phytoplanktons, such as diatoms, dinoflagellates and some microscopic algae. Besides them, a number of macro-scopic seaweeds, as brown and red algae (members of Phaeophyceae and Rhodophyceae), also contribute significantly to primary production. These organ-isms show a distinct zonation at different depths of water in the sea.

2. Consumers: These all are heterotrophic macroconsumers, being dependent for their nutrition on the primary producers. These are:

(a) Primary consumers- The herbivores that feed directly on producers are chiefly crustaceans, molluscs, fish etc.

(b) Secondary consumers- These are **carnivorous** fish, as *Herring, Shad, Mackerel* etc., feeding on the herbivores.

(c) Tertiary consumers- Still in the food chain, there are other carnivorous fishes like Cod, Haddock, Halibut etc. that feed on other carnivores of the secondary consumers level. Thus these are the top carnivores in the food chain.

3. Decomposers- The microbes active in the decay of dead organic matter of producers and macro-consumers are chiefly bacteria and some fungi.

3.6.3 Estuarine

An estuary is a semi-enclosed (partially enclosed) coastal body of water (with one or more rivers or streams flowing into it) which has a free connection to the open sea. According to Perillo (1995) "an estuary is a semi-enclosed coastal body of water that extends to the effective limit of tidal influence, within which sea water entering from one or more free connections with the open sea, or any other saline coastal body of water, is significantly diluted with fresh water derived from land drainage, and can sustain euryhaline biological species from either part or the whole of their life cycle." Examples are The Sundarban river estuay, The Amazon river estuary, The Mississippi River estuary, The Nile river estuary etc.

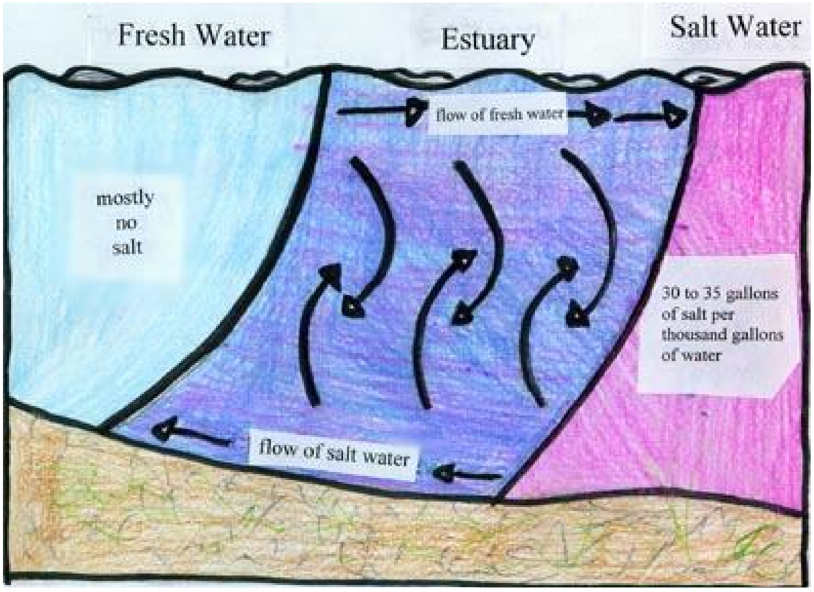


Fig. 3.6: Estuarine Ecosystem

Characteristics of Estuarine Ecosystem

This ecosystem is made up of brackish water which is quite different from both freshwater and marine water. Estuaries are marine environments whose pH, salinity, and water levels vary, depending on the river that feeds the estuary and the ocean from which it derives its salinity. Both ocean and land contribute to form a unique environment which plants and animals have specially adapted. Estuaries are protected from ocean forces by reefs, barrier islands, headlands and deltas. In estuaries circulations is more or less continous and are mainly two types -

i. Estuarine circulation occurs when fresh or brackish water flows out near the surface, while denser saline water flows inward near the bottom.

ii. Anti-estuarine flow near the bottom and less dense water circulates inward at the surface.

Estuaries are extremely rich in organic matter and nutrients, as transport and traps, nutrients. Estuaries provide a calm refuge from the open sea for millions of plants and animals, which supports enormous abundance and diversity of species e.g. fish, shellfish, lobsters, marine worms, seagrasses, algae and phytoplankton etc.

The margins of the estuary contain the food webs important producers e.g. algae, eelgrass, rushes and mangroves providing a huge amount of organic matter. Marshes and mangroves produce up to ten tones of plant detritus per hectare per year considered organic factories. Sediments are important as they store organic matter and are the site of microbial activity. Microorganisms decompose complex organic compounds into useable forms ammonia, nitrates and phosphates.

Values of Estuaries

Estuaries are important from the ecological, economical, social and cultural point of view.

Ecological Value: Estuaries are one of the most productive ecosystems on earth. They maintain water quality through natural filtration. Water draining from the land carries sediments, nutrients and other pollutants. Much of the sediments and pollutants are filtered out as the water flows through these fringing marshes. This creates clearer and clearer water, which benefits both people and marine life.

Economic Value: Estuaries maintain water quality which benefits both people and marine life. They help to maintain biodiversity by providing a diverse range of unique habitats that are critical for the survival of many species.

Cultural Value: People value estuaries for recreation, scientific knowledge, education, aesthetic and traditional practices. Boating, fishing, swimming, surfing, and bird watching are few of the numerous recreational activities people enjoy in estuaries. These are laboratories for scientists and students.

3.7 Summary

Thus, an ecosystem provides both products as well as services (the ecological functions) to humans. Each ecosystem has a unique set of environmental services provided and goods that it provides (for example, grasslands are usually the fodder source for browsers and grazers, while wetlands recharge aquifers), what is important for us is to understand that these ecosystem services can be provided to us only when the integrity and overall wellbeing of the ecosystem is maintained. For example, the moment we start looking at forests as timber and start cutting down trees for their economic value, we would be deprived of several other functions of the forests, like their recharging of the water table, appropriation of carbon-dioxide, prevention of top soil loss.

It is further important to understand that ecosystems are both the source as well as the sink of human activities.

This means that human beings derive resources from food, fibre, timber to the various raw material for the industries, from ecosystems; and that all the products and by products of human activities from domestic to industrial, finally go back to the ecosystems, which could be the rivers, the oceans or even the forests.

3.8 Glossary

- **Food web:** A complex network of many interconnected food chains and feeding relationships.
- **Grassland**: A biome found in regions where moderate annual average precipitation (25 to 76 centimeters, or 10 to 30 inches) is enough to support the growth of grass and small plants, but not enough to support large stands of trees.
- **Habitat:** A place or type of place where an organism or a population of organisms lives.
- **Heterotrophic succession:** It is characterized by early dominance of heterotrophs; occurs in cases where environment is primarily organic.
- **Ecological diversity**: the variety of forests, deserts, grasslands, oceans, streams, lakes, and other biological communities interacting with one another and with their non-living environment.
- **Ecological niche**: total way of life or role of a species in an ecosystem. It includes all physical, chemical, and biological conditions a species needs to live and reproduce in an ecosystem.
- **Ecology:** study of the interactions of living organisms with one another and with their non-living environment of matter and energy; study of the structure and function of nature.
- **Competition:** two or more individual organisms of a single species (intraspecific competition) or two or more individuals of different species (interspecific competition) attempting to use the same scarce resources in the same ecosystem.
- **Consumer:** organism that cannot synthesize the organic nutrients it needs and gets its organic nutrients by feeding on the tissues of producers or of other consumers; generally divided into primary consumers (herbivores), secondary consumers (carnivores), tertiary (higher-level) consumers, omnivores, and detritivores.

- **Ecosystem**: an inter-connected and symbiotic grouping of animals, plants, fungi, and microorganisms.
- **Biodiversity**: large number and wide range of species of animals, plants, fungi, and microorganisms. Ecologically, wide biodiversity is conducive to the development of all species.
- **Biomass**: the amount of living matter in an area, including plants, large animals and insects.
- **Biosphere**: the part of the earth and its atmosphere in which living organisms exist or that is capable of supporting life.
- **Consumer:** An organism within an ecosystem, plant or animal that derives its food from another organism.
- **Decomposer:** Organisms (bacteria, fungi, heterotrophic protists) in ecosystems that break down complex organic material into smaller inorganic molecules that then are recirculated.
- **Denitrification:** The conversion of nitrate to gaseous nitrogen; carried out by a few genera of free-living soil bacteria.
- **Energy:** The power to perform chemical, mechanical, electrical or heat related tasks.
- **Energy Flow in Ecosystems:** Movement of eneryin an ecosystem.
- **Ecological Pyramid :** Energy relationship among various feeding levels involved in a particular food chain; autotrophs (at the base) represent the greatest amount of available energy; herbivores are next; then primary carnivores; secondary carnivores; and so forth; similar pyramids of mass, size, and number also occur in natural communities.
- **Food:** Organic compounds used in the synthesis of new biomolecules and as fuel in the production of cellular energy; i.e. carbohydrates (glucose), starch (amylose, amylopectic), proteins (from aminoacids), fatty acids, vitamins, trace elements.
- **Food Chain:** A sequence of organisms through which energy captured from sunlight by photosynthesis is transferred from one consumer/ trophic level to the next; each organism in the chain eats the preceding and is eaten by the

following member of the sequence; there are seldom more than six links in a chain, with autotrophs at the bottom and the largest carnivores at the top.

- **Food Web:** Representation of feeding relationships in a community that includes all the links revealed by dietary analysis; it depends upon the number of species involved and their connectiveness.

3.9 Self- Learning Excercise

Section- A : (Very Short Answer Type Questions)

1. Define deforestation.
2. What is primary productivity?
3. Define biomass.
4. What are phytoplanktons?
5. Where will you search for the decomposers in a pond?
6. Draw a simple food chain.
7. What is a food web?
8. Give examples of inverted pyramids.

Section- B : (Short Answer Type Questions)

1. Define the following terms-
   (i) Autotrophs
   (ii) Heterotrophs
   (iii) Primary carnivores
   (iv) Saprotophs
   (v) Omnivores
2. Write short note on trophic level.
3. Write two importance of food web.
4. Write the difference between producer and consumer?
5. What do you understand by productivity?
6. Explain interlocking pattern of food chains.
7. Give types of ecosystem in detail.

Section- C : (Long Answer Type Questions)

1. What is an ecosystem? How is it different from an ecological community?
2. Name a few biotic and abitoic components of an ecosystem.

3. Define the terms autotrophs and heterotrophs.
4. Define pollution. Give sources and types of household pollution.
5. Write a detailed note on Forest resources.
6. Write in detail about overexploitation of natural resources.
7. Write short notes on any two:
   (a) Ecological pyramid
   (b) Food web
   (c) Artificial ecosystem
8. Write short notes on:
   (a) Ecological energetics
   (b) Detritous food chain

3.10 References

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Unit - 4

Global Biogeochemical Cycles

Structure of the Unit:

4.0 Objectives

After studying this unit you will understand the -

- Importance of water cycle.
- Cyclic pathway of Carbon, Nitrogen and Phosphorous.
- Bio-geochemical circulation of Sulphur and mineral Cycles in ecosystem.

4.1 Introduction

Biogeochemical cycle or substance turnover or cycling of substances is a pathway by which a chemical substance moves through both biotic and abiotic compartments of Earth. A cycle is a series of change which comes back to the starting point and which can be repeated.Water, for example, is always recycled through the water cycle as shown in the diagram. The water undergoes evoperation, condensation and precipitation, falling back to Earth. Elements, chemical compounds, and other forms of matter are passed from one organism to another and from one part of the biosphere to another through bio-geochemical cycles.

The term **"bio-geochemical"** means that biological, geological and chemical factors are all involved. The circulation of chemical nutrients like carbon, oxygen, nitrogen, phosphorus, calcium, and water etc. through the biological and physical world are known as biogeochemical cycles. In effect, the element is recycled, although in some cycles there may be places (called reservoirs) where the element is accumulated or held for a long period of time (such as an ocean or lake for water).

4.2 Water Cycle

Water molecules are made of hydrogen and oxygen atoms. Hydrogen and oxygen are nutrients that organisms need. Clearly, there is no problem obtaining these nutrients in aquatic ecosystems. However, they are sometimes in short supply in terrestrial ecosystems. The cycling of water in nature involves both aquatic and terrestrial ecosystems and the air above them.

Water vapour enters the atmosphere through transpiration from vegetation. **Transpiration** is the loss of water through pores in the leaves of plants. It also enters the atmosphere through **evaporation** from bodies of water and the soil. In the cool upper atmosphere this vapour **condenses**, forming clouds. In time, enough water collects in the clouds to cause **precipitation**. When this occurs, some of the water falling on the ground runs along the surface of the ground to a stream, pond or other body of water. This is called **surface runoff**. Some of the water also soaks into the ground by a process called **percolation**. Some water percolates down to the bedrock. Then it becomes ground water and gradually runs back to lakes and other bodies of water.

Some of the water in the soil moves up to the roots of plants by **capillarity**. The roots absorb the water. This is how most plants get the hydrogen and oxygen they need. Animals can obtain water by eating plants or by eating other animals. Of course, they can also obtain water by drinking it directly from a body of water. When plants and animals die, they **decompose**. During the **decomposition** process, the water present in their tissues is released into the environment.

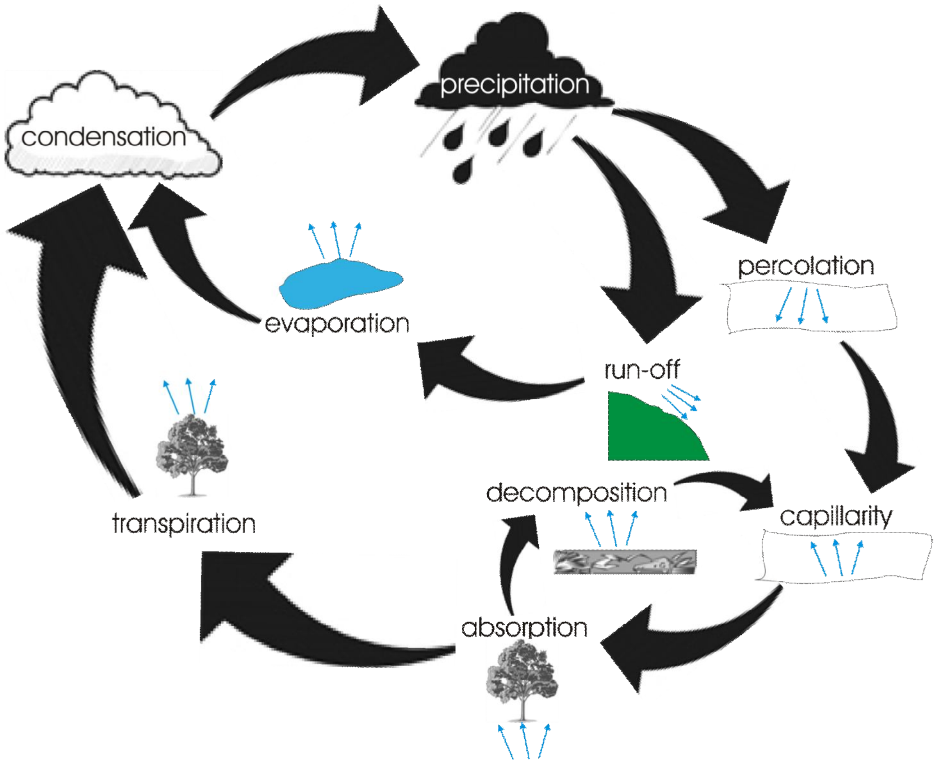

Fig. 4.1: Water Cycle

4.3 Carbon Cycle

Carbon is another nutrient that all organisms need. In fact, it is the basic building block of all living things. Like water, carbon moves through an ecosystem in a cycle.

Carbon is present in the atmosphere as carbon dioxide. Water also contains carbon dioxide as it can dissolve it. Producers (plants and algae) use it to perform photosynthesis and make food. Now the carbon is in the producers. Herbivores eat the plants and carnivores eat the herbivores. Now the carbon is in animals. Both plants and animals respire. Their respiration returns carbon dioxide to the atmosphere. Decomposers break down dead plants and animals as well as animal waste. This too returns carbon dioxide to the atmosphere or soil.

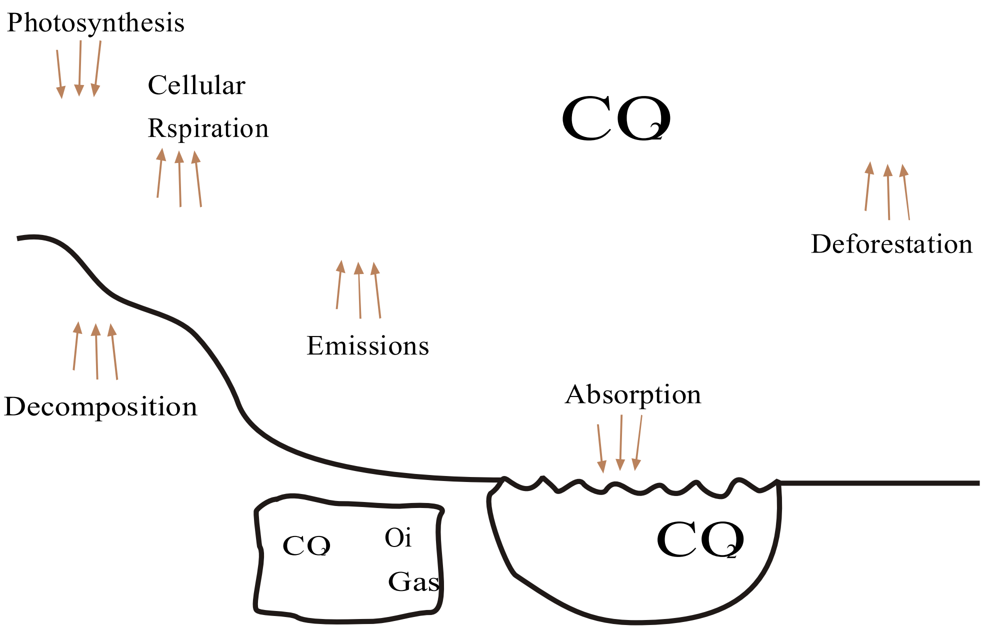

Fig. 4.2: Carbon Cycle

Some organic matter does not decompose easily. Instead it builds up in the earth's crust. Oil and coal were formed from the build-up of plant matter millions of years ago.

At one time, the carbon cycle was almost a perfect cycle. That is, carbon was returned to the atmosphere as quickly as it was removed. Lately, however, the increased burning of fossil fuels has added carbon to the atmosphere faster than producers can remove it. Also, de-forestation reduces the amount of carbon dioxide being used in photosynthesis. Further, the use of land for agriculture releases carbon dioxide into the environment.

Plants in water need carbon dioxide to perform photosynthesis and release oxygen. Fish use the oxygen to breathe and the plants for food. Thus, fish depend on the carbon dioxide cycle.

4.4 Nitrogen Cycle

Nitrogen is another important nutrient that all organisms need. All living things need nitrogen to make proteins.

Almost 78% of the atmosphere is nitrogen. However, neither plants nor animals can use this form of nitrogen directly. Usually, the nitrogen must be in the form of chemicals called **nitrate.** Then the plant roots can absorb it. Lightning forms some nitrate by causing oxygen and nitrogen in the atmosphere to join. *Rhizobium* bacteria can do the same thing. These bacteria lives on the roots of plants called legumes such as beans, peas and alfalfa. Many bacteria and blue-green algae also form nitrates. The changing of nitrogen to nitrates is called **nitrogen fixation.**

Plants use the nitrates that they absorb to make plant proteins. Animals get the nitrogen that they need to make proteins by eating plants or other animals.

When plants and animals die, bacteria change their nitrogen content to ammonia. The nitrogen in the urine and **fecal** matter of animals is also changed to ammonia by bacteria. The pungent odour of outhouses, chicken pens, hog yards, cat litter boxes and wet baby dipers is ample evidence of this fact. Ammonia, in turn, is converted to nitrites and then to nitrates by bacteria. This process is called **nitrification** and completes the main part of the cycle.

Many plants are able to use ammonia directly. Therefore all of it does not have to be converted to nitrate before plants absorb it.

When people use synthetic fertilizers they add nitrite or nitrate into the soil. This skips most of the nitrogen cycle and thus the bacteria and micro-organisms loose their food source.

Plants and algae in the water need nitrogen to grow. Some fish species depend on these plants for food.

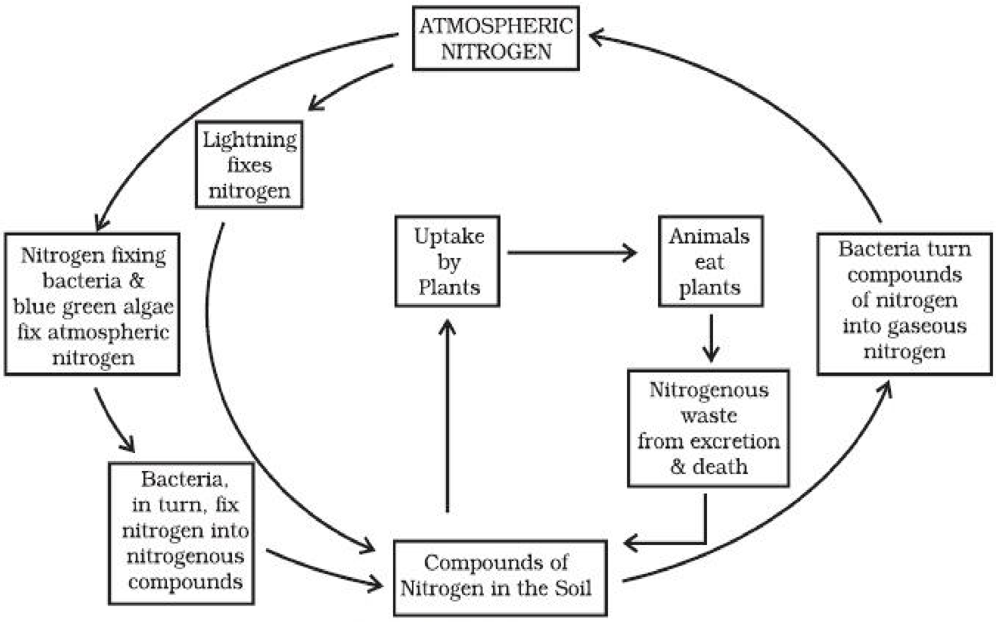

Fig. 4.4: Nitrogen Cycle

4.5 Phosphorus Cycle

The phosphorus cycle describes the movement of phosphorus through the lithosphere, lithosphere and biosphere. Unlike many other biogeochemical cycles, the atmosphere does not play a significant role in the movement of phosphorus, because phosphorus and phosphorus-based compounds are usually solids at the typical ranges of temperature and pressure found on Earth.

On the land, phosphorus (chemical symbol, P) gradually becomes less available to plants over thousands of years, because it is slowly lost in runoff. Low concentration of P in soils reduces plant growth, and slows soil microbial growth. Soil micro-organisms act as both sinks and sources of available P in the biogeochemical cycle. Locally, transformations of P are chemical, biological and microbiological: the major long-term transfers in the global cycle.

Humans have caused major changes to the global P cycle through shipping of P minerals, and use of P fertilizer, and also the shipping of food from farms to cities, where it is lost as effluent.

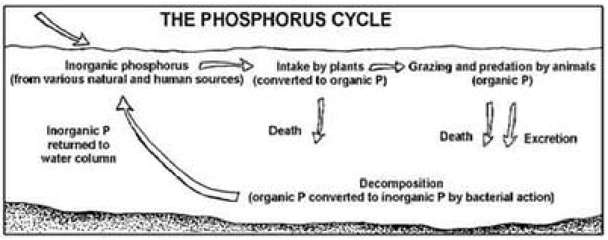

Fig. 4.5: The aquatic Phosphorus Cycle

Phosphorus is an essential nutrient for plants and animals. Phosphorus is a limiting factor for aquatic organisms. Phosphorus forms parts of important life-sustaining molecules that are very common in the biosphere. Phosphorus does not enter the atmosphere, remaining mostly on land and in rock and soil minerals. Eighty percent of the mined phosphorus is used to make fertilizers. Phosphates from fertilizers, sewage and detergents can cause pollution in lakes and streams. Over enrichment of phosphate in both fresh and inshore marine waters can lead to massive algae blooms which, when they die and decay, lead to eutrophication of fresh waters only. An example of this is the Canadian Experimental Lakes Area. These freshwater algal blooms should not be confused with those in saltwater environments. Recent research suggests that the predominant pollutant responsible for algal blooms in salt water estuaries and coastal marine habitats is Nitrogen.

The primary biological importance of phosphates is as a component of Nucleotide which serves as energy storage within cells ATP or when linked together, forms the nucleic acids DNA and RNA. The double helix of our DNA is only possible because of the phosphate ester bridge that binds the helix. Besides making biomolecules, phosphorus is also found in bone and the enamel of mammalian teeth, whose strength is derived from Calcium phosphatein the form of Hydroxylapatite.

Phosphates move quickly through plants and animals; however, the processes that move them through the soil or ocean are very slow, making the phosphorus cycle overall one of the slowest bio-geochemical cycles.

Initially, phosphate weathers from rocks and minerals, the most common mineral being apatite. Overall small losses occur in terrestrial environments by leaching and erosion, through the action of rain. In soil, phosphate is absorbed on iron oxides, aluminium hydroxides, clay surfaces, and organic matter particles, and becomes incorporated (immobilized or fixed). Plants and fungi can also be active in making P soluble.

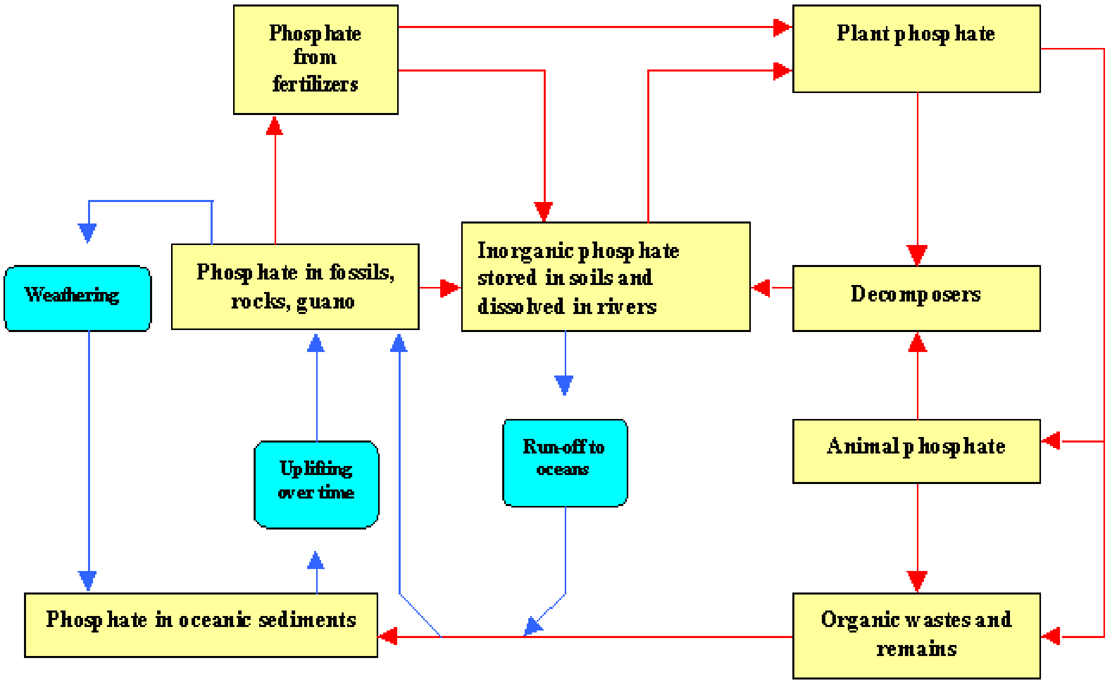

Fig. 4.6: Phosphorus Cycle

Human influences

Nutrients are important to the growth and survival of living organisms, and hence, are essential for development and maintenance of healthy ecosystems. Humans have greatly influenced the phosphorus cycle by mining phosphorus, converting it to fertilizer, and by shipping fertilizer and products around the globe. Transporting phosphorus in food from farms to cities has made a major change in the global Phosphorus cycle. However, excessive amounts of nutrients, particularly phosphorus and nitrogen, are detrimental to aquatic ecosystems. Waters are enriched in phosphorus from farms run off, and from effluent that is inadequately treated before it is discharged to waters. Natural eutrophication is a process by which lakes gradually age and become more productive and may take thousands of years to progress. Cultural or anthropogenic eutrophication, however, is water pollution caused by excessive plant nutrients, which results in excessive growth in algae population. Surface and sub-surface runoff and erosion from high-phosphorus soils may be major contributing factors to fresh water eutrophication. The processes controlling soil Phosphorus release to surface runoff and to subsurface flow are a complex interaction between the type of phosphorus input, soil type and management, and transport processes depending on hydrological conditions

4.6 Sulphur Cycle

The sulphur **cycle** is the collection of processes by which sulphur moves to and from minerals including the waterways and living systems. Such cycles are important in geology because they affect many minerals. Biogeochemical cycles are also important for life because sulphur is a trace element being a constituent of many proteins.

Sulphur is found in oxidation state ranging from +6 in SO_4 to -2 in sulfides. Thus elemental sulphur can either give or receive electrons depending on its environment. Minerals such as pyrite (FeS_2) comprise the original pool of sulphur on earth. Owing to the sulphur cycle, the amount of mobile sulphur has been continuously increasing through volcanic activity as well as weathering of the crust in an oxygenated atmosphere.Earth's main sulphur sink is the oceans as SO_2, where it is the major oxidizing agent.

When SO_4^{2-} is assimilated by organisms, it is reduced and converted to organic sulphur, which is an essential component of proteins. However, the biosphere does not act as a major sink for sulphur, instead the majority of sulphur is found in seawater or sedimentary rocks especially pyrite rich shales and evaporite rocks.

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

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

There is no significant amount of sulphur held in the atmosphere with all of it coming from either sea spray or wind blown sulphur rich dust, neither of which is long lived in the atmosphere. In recent times the large annual input of sulphur from the burning of coal and other fossil fuels adds to a substantial amount SO_2 which acts as an air pollutant. In the geologic past, igneous intrusions into coal measures have caused large scale burning of these measures, and consequential release of sulphur to the atmosphere. This has led to substantial disruption to the climate system, and is one of the proposed causes of the great dying.

Dimethylsulfide is produced by the decomposition of dimethylsulfoniopropionate from dying phytoplankton cells in the shallow levels of the ocean, and is the major biogenic gas emitted from the sea, where it is responsible for the distinctive “smell of the sea” along coastlines.DMS is the largest natural source of sulphur gas, but still only has a residence time of about one day in the atmosphere and a majority of it is redeposited in the oceans rather than making it to land. However, it is a significant factor in the climate system, as it is involved in the formation of clouds.

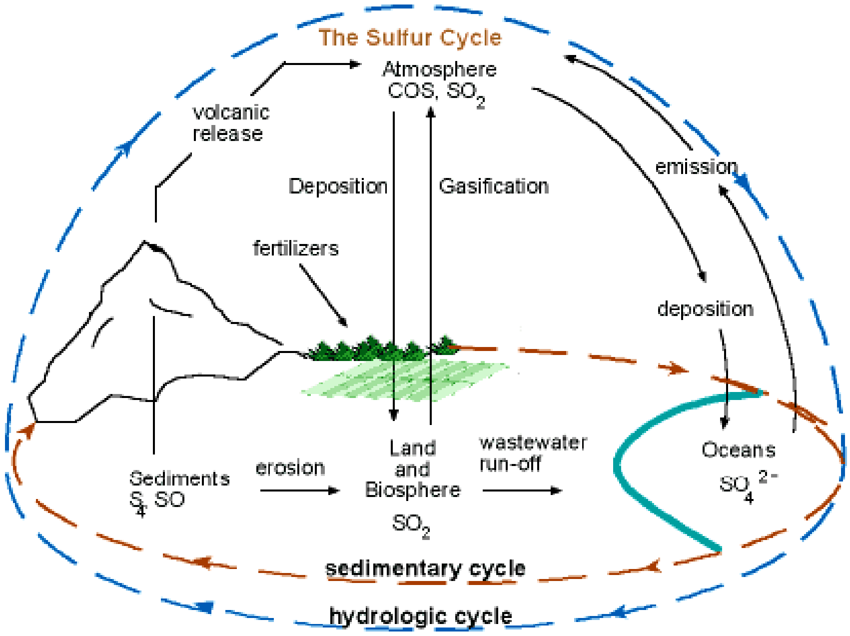

Fig. 4.7: The Sulphur cycle

Human influences

Human activities have a major effect on the global sulphur 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, sulphur 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. Instead it is being drilled, pumped and burned at a steadily increasing rate. Over the most polluted areas there has been a 30-fold increase in sulfate deposition.

Although the sulphur curve shows shifts between net sulphur oxidation and net sulphur reduction in the geologic past, the magnitude of the current human impact is probably unprecedented in the geologic record. Human activities greatly increase the flux of sulphur to the atmosphere, some of which is transported globally. The result of human impact on these processes is to increase the pool of oxidized sulphur (SO_4) in the global cycle, at the expense of the storage of reduced sulphur in the Earth's crust. Therefore, human activities do not cause a major change in the global pools of S but they do produce massive changes in the annual flux of S through the atmosphere.

When SO_2 is emitted as an air pollutant, it forms sulphuric 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. According to the EPA, acid rain is a broad term referring to a mixture of wet and dry deposition (deposited material) from the atmosphere containing higher than normal amounts of nitric and sulphuric acids. Distilled water (water without any dissolved constituents), which contains no carbon dioxide, has a neutral pH of 7. Rain naturally has a slightly acidic pH of 5.6, because carbon dioxide and water in the air react together to form carbonic acid, a very weak acid.

4.7 Mineral Cycle

Nutrients such as carbon, nitrogen, and calcium are cycles between living things and the atmosphere and soils. Where mineral cycles are healthy, nutrients cycle tend to stay within living things or accessible to them (for instance, as a ‘nutrient bank’ in the upper layers of soil). Where mineral cycles are unhealthy, nutrients tend to get tied up in biologically unavailable forms or lost through erosion, leaching, or burning.

By way of examining the mineral cycle, we will have a brief description of the carbon cycle. Carbon is the building block of life, essential to the structure, nutrition and chemistry of all living things. Its growing presence in the atmospheric part of the carbon cycle is also the main ‘culprit’ of man-made global warming.

The movement of carbon through the environment happens in a much more complex way than water because carbon plays an important role in many different things.

To begin the carbon cycle, the energy of the sun shining on plants allows them to take in carbon dioxide from the atmosphere and turn it into carbohydrates, which they use to grow bigger, releasing oxygen as they do so. In this way, young, growing trees take more carbon from the atmosphere than old mature forests, which exhale carbon dioxide at night.

Animals eat the plants, (and other animals eat the animals), using the carbon within the plants to build tissue, cycling that carbon through their bodies. When plants and animals die, the carbon they contain is eventually released back into the atmosphere through the processes of digestion and decay.

Some of this cycle can be rapid (for example, when trees burn because of a bushfire) and some might be slow (for example, the conversion of plant material into coal, which takes millions of years). Without human intervention (coal mining), the carbon in a coal deposit would remain there millions of years longer, until it is burnt or becomes exposed to the atmosphere through geological action.

The oceans are responsible for the largest reservoirs of carbon, and a lot of marine animals use that carbon, for example in the building of shells. There is a large spontaneous exchange of carbon between the atmosphere and the surface of the ocean, but carbon also sinks to the ocean bottom, where it may form limestone and remain for millennia.

Most of the world's oil fields, huge reservoirs of hydrocarbons, have been created by marine organisms that have died and sunk to the bottom, taking with them the carbon they have captured from the ocean, to create the energy-rich gloop we call oil. That carbon is being cycled into the atmosphere now, as we extract the oil and then burn it in our cars and power stations. Without our intervention, that carbon would have remained sequestered for an indefinite, but lengthy time.

Rocks and soils can contain a lot of carbon, which can be released slowly through erosion or rapidly as a function of land clearing and soil disturbance. The making of cement, which involves heating limestone to create lime, is a significant source of man-made carbon dioxide and a relatively rapid cycle for carbon that has been previously incorporated into rock.

4.8 Summary

Biogeochemical cycles are pathways for the transport and transformation of matter within four categorical areas that make up planet Earth (biosphere, hydrosphere, lithosphere, and the atmosphere).

The transfer of matter involves biological, geological and chemical processes; hence the name biogeochemical cycles derives. Matter is continually recycled among living and abiotic elements on earth.Biogeochemical cycles facilitate the transfer of matter from one form to another and from one location to another on planet earth. Additionally, biogeochemical cycles are sometimes called **nutrient cycles**, because they involve the transfer of compounds that provide nutritional support to living organisms.

In this unit biogeochemical cycle of water N, P, S and minerls discussed in detail to develop better understanding of transformation of matter from one form to another.

4.9 Glossary

- **Acid precipitation:** Acidic rain, snow, or dry particles deposited from the air due to increased acids released by anthropogenic or natural resources.
- **Biogeochemical cycles :** Movement of matter within or between ecosystems; caused by living organisms, geological forces, or chemical reactions. The cycling of nitrogen, carbon, sulphur, oxygen, phosphorus, and water are examples.
- **Carbon cycle :** The circulation and reutilization of carbon atoms, especially via the processes of photosynthesis and respiration.
- **Carbon source :** Originating point of carbon that reenters the carbon cycle; cellular respiration and combustion.
- **Crust :** The cool, lightweight, outermost layer of the earth's surface that floats on the soft, pliable underlying layers; similar to the "skin" on a bowl of warm pudding.
- **Denitrifying bacteria :** Free-living soil bacteria that converts nitrates to gaseous nitrogen and nitrous oxide.

- **Sedimentary cycles :** these cycles involve the transportation of matter through the ground to water; that is to say from the lithosphere to the hydrosphere.
- **Phosphorous cycle :** Phosphorus is commonly found in water, soil and sediments. Phosphorus cannot be found in air in the gaseous state. This is because phosphorus is usually a liquid at standard temperatures and pressures. Phosphorus is mainly cycled through water, soil and sediments.
- **Sulphur cycle :** Sulphur in its natural form is a solid, and restricted to the sedimentary cycle in this form. It is transported by physical processes like wind, erosion by water, and geological events like volcanic eruptions. However, in its compounds such as sulphur dioxide, sulphuric acid, salts of sulphate or organic sulphur, sulphur can be moved from the ocean to the atmosphere, to land and then to the ocean through rainfall and rivers.
- **Gaseous cycles :** these involve the transportation of matter through the atmosphere.
- **Nitrogen cycle :** Nitrogen gas is the most abundant element in the atmosphere and all the nitrogen found in terrestrial ecosystems originate from the atmosphere. The nitrogen cycle is by far the most important nutrient cycle for plant life.
- **Oxygen cycle :** The oxygen cycle describes the movement of oxygen within and between its three main reservoirs: the atmosphere, the biosphere, and the lithosphere. The main driving factor of the oxygen cycle is photosynthesis and because of this, oxygen and carbon cycles are usually linked and the two cycles are collectively called oxygen-carbon cycle.
- **Hydrological cycle** : This is also called the **water cycle.** Water is the most important chemical of life for all living organisms on earth. Water in the atmosphere is usually in form of vapor but condenses to liquid water and can solidify when temperatures are 0^0C to form ice. Ninety three percent of water on earth is in solid state mainly comprising the ice caps and glaciers of Polar Regions.

4.10 Self-Learning Excercise

Section- A : (Very Short Answer Type Questions)

1. Define biogeochemical cycle.
2. The most important process in carbon cycle which is related to plants?
3. What is precipitation?
4. What is condensation?
5. Name the important steps in Nitrogen cycle?
6. What is mineralisation?
7. How sulphur cycle is important in ecological cycling?
8. Rhizobium is related to which cycle?

Section- B : (Short Answer Type Questions)

1. Write short note on Water cycle.
2. Write two importance of ecological cycling.
3. What is sedimentation?
4. Write the difference between weathering and mineralisation?
5. What do you understand by Biogeochemical cycle?
6. Write the role of sedimentation in phosphorous cycle.

Section- C : (Long Answer Type Questions)

1. Write an essay on Biogeochemical cycles.
2. Write detailted description notes on -

   (a) Carbon cycle

   (b) Sulphur cycle
3. Describe Nitrogen cycle in detail with the help of outline diagram.
4. Write about phosphorous cycle in detail.
5. Define biogeochemical cycle. Explain sulphur cycle in detail.

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Unit – 5

Climate, Soil and Vegetation of the India

Structure of the Unit:

5.0 Objectives

After going through this unit you will be able to -

- to understand the basic concepts of climatology.

- discuss the types of climates in India, season and monsoon.
- discuss the types of soil of India and their location.
- discuss the soil distribution pattern and vegetations.
- discuss the vegetation pattern in different regions of India.

5.1 Introduction

The climate of an area is the totality of the atmospheric conditions of that area during the specific period of time, with reference to their mean conditions and their variability. The branch of meteorology deals with climate called as **Climatology.** The elements of weather and climate are the same i.e. temperature, atmosphere, pressure wind, humidity, precipitation. On the basis of the generalized monthly atmospheric conditions, the year is divided in to seasons, such as winter, summer and rainy.

The world is divided in to a number of climatic regions. The climate of India described as the **monsoon type**. The word monsoon is derived from Arabic word **mausin** which literary means season. Monsoon refers the seasonal reversal in the wind direction during a year. The monsoon type depend on two elements i.e. temperature and precipitation.

The Meteorological Department of India identified four seasons in the country-

1 The seasons of the North East Monsoon
   - The cool season from mid-December to February.
   - The hot season from March to June.

2 The seasons of South –East Monsoon
   - The wet season from mid June to mid September.
   - The season of retreating monsoon from mid September to mid December.

5.2 The Climatic Regions of India

The climatic regions of India are based on annual precipitation; India has been divided into four climatic regions.

5.2.1 Wet zone

Here the rainfall is more than 200cm. It covers the area of western slope of Western Ghats, hill of Meghalaya and Bengal, Tarai region of Bihar and Uttar

Pradesh. In these regions geographic features play an important role because the moisture laden monsoon winds strike against physical barriers like mountains to cause heavy rainfall. This zone is of evergreen forest and paddy is the main crop.

5.2.2 Intermediate zone

The rain fall in this zone varies 100-200 cm. This zone covers the areas like West Bengal, Bihar, Orissa, Eastern Madhya Pradesh, Himachal Pradesh, Yamuna, Eastern slope of Ghats, north eastern Andhra Pradesh, east Tamil Nadu. Basically with deciduous forests and the important crops is paddy, millets, jowar etc.

5.2.3 Dry zone

The rainfall in this zone is 50-100 cm. The areas covered in this zone are Punjab, Uttar Pradesh, Delhi, Western Madhya Pradesh, Gujarat, Maharashtra, Karnataka, Southern Andhra Pradesh, Tamil Nadu, The forest of this climatic zone are dry deciduous thorn and scrub and the wheat and millets are the chief crops of this region.

5.2.4 Arid zone

The rain fall in this zone is less than 50cm. It occupies North-West low lands, North West Plateau and Western part of the country. It covers southwest Punjab, Rajasthan North West Gujarat. Thorn forests dominant are in this zone.

Table - 5.1 : Mean Annual Rainfall

Area of Heavy Rainfal (200-400cm) Wet zone	**Area of Moderate Rainfall (100-200cm) Intermediate zone**	**Area of Less Rainfall (50-100cm) Dry zone**	**Area of Scanty Rainfall (<50cm) Arid zone**
The Arabian Sea branch of south west monsoon cause rainfall all along the western Ghats and western coastal regions from June to September.	The average rainfall over north Indian plain generally remains between 100-200cm. Other areas of moderate rainfall is north eastern	Rainfall between 60-100cm occurs in upper Ganga valley, eastern parts of Arawalis, eastern Gujarat , internal parts of	Part of Punjab, Haryana, northern and western Rajasthan and kutch, Katiawar region of Gujrat. A narrow stripe of land lying in the rain shadow area of peninsular India

	part of peninsular India, highland of central India and Tamil nadu	Andhra Pradesh, Maharastra and Karnataka	receives rainfall below 60 cm.
In North East India the bay of Bengal branch of monsoonal winds which causes monsoon in southern hills of Shillong plateau, Garo, Khasi, Jaintia hills of Meghalaya and other states.	The intensity of rainfall decreases from east to west and north to south in northern plain.		The dry region of Rajasthan, west of the Arawalli hills receive rainfall bellow 20cm. Northern part of Gujarat, Punjab and Jammu Kashmir are other region which receives scanty rainfall

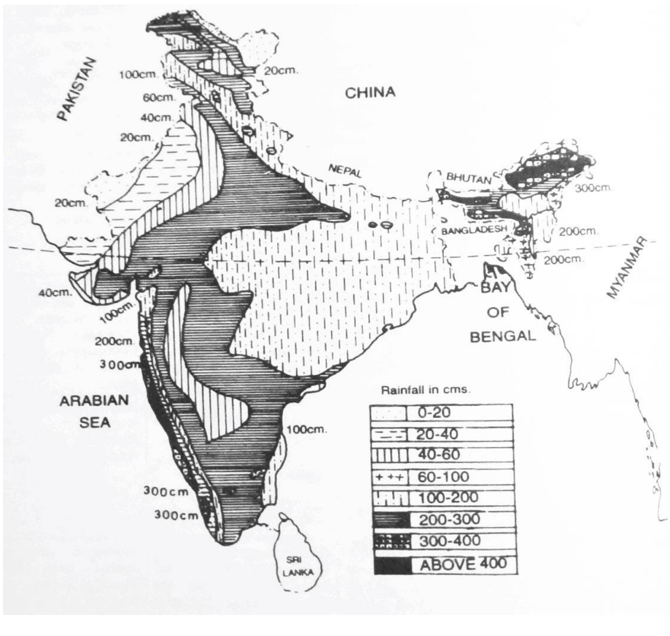

Fig. 5.1 : Mean annual rainfall of India

Area of Winter Rainfall—

1. Northwest part of India –Jammu and Kashmir, Punjab and Uttar Pradesh plains.
2. Tamil Nadu due to north east monsoon.

5.3 Soil Types of India

Due to temperature extremes and marked seasonal fluctuations throughout the year, climatic conditions of India become of much ecological interest, Moreover, soil in different parts of the country also differ from each other.

Soil is loose material and the uppermost layer of earth crust. It is the important natural resource made by weathering of rocks. It provides nutrients and water to the plants. The factors affecting the soil formation are- Climate, Vegetation, type and age of parent rocks and relief etc. Based on the composition of soils, the Indian soils have been classified in to four groups. These are; **Alluvial soil, Black soils**, **Lateritic soils** and Red soil. In addition to these there, are four other soil groups' under forest, the desert and semi desert soil the saline and alkaline soil and peaty and marshy soils.

5.3.1 Alluvial soils

These occur chiefly in to indo-gangatic plain covering the states of Punjab and Haryana in the north-west, and Bihar in the north and Bengal and part of Meghalaya and Orissa. In the soil map, this group includes alluvial soil, deltaic alluvium, calcareous alluvial soil, chestnut brown soils (alluvial), coastal alluvium and coastal sands. This soil is rich in loam and clay components, generally alkaline or neutral in reaction. This group is largest and most important because most of the alluvial soils are used for crop production; the main features of alluvial soils are due to silt deposition by numerous tributaries of Indus, Brahmaputra and Gangaes systems. Geologically, these soils are divided as follows-

1. **Khandar,** new alluvial soil composed of sand, generally light coloured and less kankary. Khadar is found along the water channels, flood plains and deltas.
2. **Bhangar,** i.e. old alluvial soils composed of clay, generally dark coloured and full of kankar. The Bhanger is found usually in the hill foot zones on Ganga and Brahamputra plains, and also along the western margin of the Bengal delta.

5.3.2 Black Soils

These soils are designated as the shallow black, medium black, deep black, and mixed red and black soils. The typical black soil derived from Deccan trap is known as **regur or black cotton soil**. This type of soil is common in Maharashtra, Mysore, M.P and Tamil Nadu. These soils predominate in clay and chiefly consist of iron, aluminium, magnesium and calcium oxides with poor phosphorus, nitrogen and organic matter. The soil has high water holding capacity. When the soil comes in contact with water, it swells, however due to considerable concentration on drying, large and deep cracks are formed. These soils are highly fertile and the deep black soils are well known for growing cotton.

5.3.3 Red Soils

It covers large areas in south, and in north east of peninsula. Such soil occur in Andhra Pradesh, Tamil Nadu, parts of Bihar, Orissa, UP, and West Bengal. These are mainly sandy to loam in texture, with gravel in upper slopes, sandy to loam on lower slopes and loam to clay in valley in bottom. The red loamy soil, red sandy soil and red and yellow soil are included in this group. These soils have been originated from the ancient crystalline and metamorphic rocks. However, some are lateritic in origin and of quite different in nature. The wide diffusion of the iron compound in the soil is responsible for its red colour. The yellow colour of the soil is due to high degree of hydration of the ferric oxide than that of red soils. These soils are poor in nitrogen, thin, gravelly and light coloured, however in plain and valleys, red soils are fertile, deep and dark coloured. Very little is known about yellow soils; however red and yellow may occur side by side.

5.3.4 Lateritic soils (Latosols)

These are present in Western Ghats, the northern half of Eastern Ghats. These soils are porous clay, soil are brown in colour and formed by atmospheric weathering of many types of rocks. It is peculiar to India and some other tropical countries with intermittently moist climate. This group of soil is rich in hydroxides of iron, manganese and aluminium. Because under monsoonal conditions the soluble minerals (including silica) leached away almost completely during weathering. These soils are poor in lime, manganese, potash, nitrogen as well as in organic matter. Large concentration or aluminium minerals occurring as lenses or layers in the vegetation soils are termed as lateritic. As lower elevations, these soils are best suited for paddy cultivation; however, these are also best for cinchona, rubber and coffee cultivation.

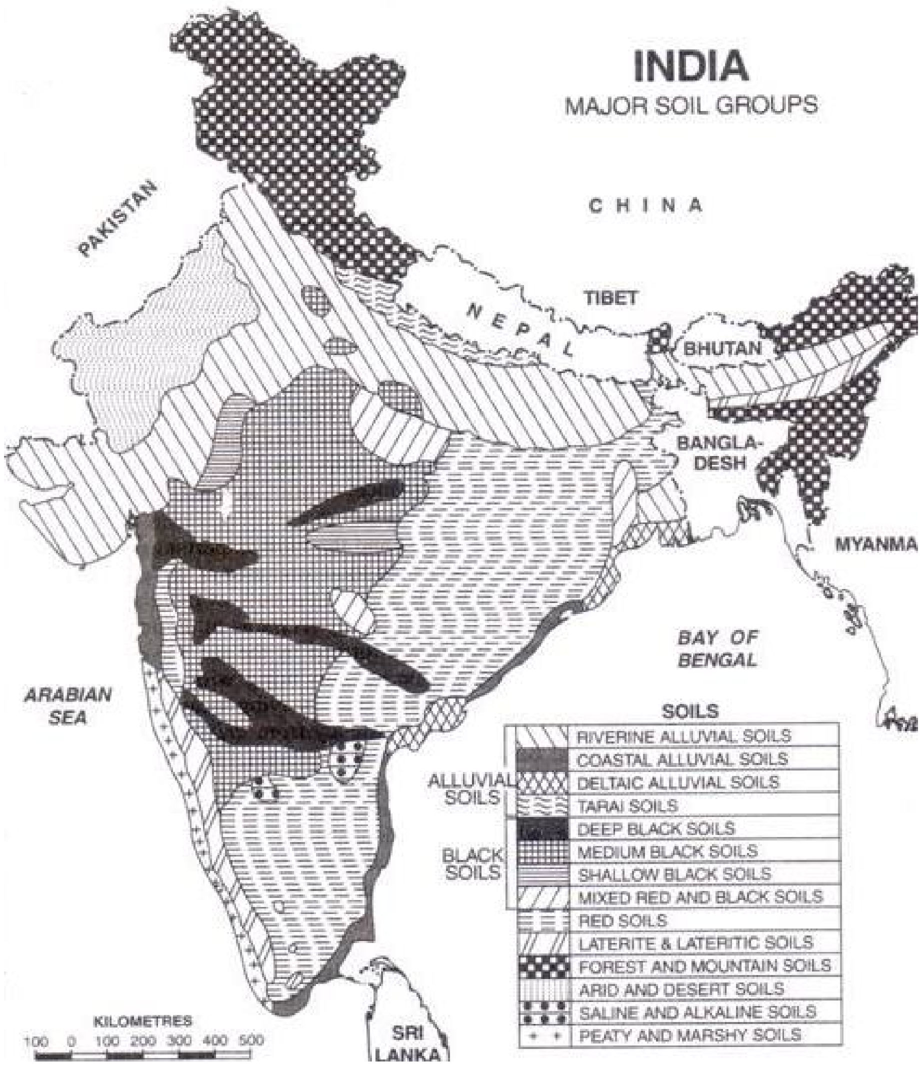

Fig. 5.2 : Major Soil types of India

5.3.5 Forests Soil

The forest occurs from hot to cold deserts, a large area in the country supports deciduous forests, tropical rain forests and the coniferous forests. The physico-chemical properties of soils associated with topography and climate control the distribution and growth of vegetation, thus different forest types are developed in different soil types.

Chaturvedi (1952) identified three main geographical regions in the country in respect to the forest growth. These regions are-

A **Himalayan and Shivalik region;** It is hilly region where soil are formed from sedimentary and metamorphic rocks. The soil includes podsoils, brown forest soil etc.

B **Indo-Gangetic alluvium;** It is alluvial or aeolion deposit and includes deltaic alluvium, desert deposits, sub recent formations (Bhabar and Tarai) Saline and Alkaline soil, Yellow and brown soils.

5.3.6 Desert Soils

The arid climate results in the formation of desert soil in western Rajasthan and south Punjab. Desert soils are alkaline and poor in organic matter.

5.3.7 Saline and Alkaline Soils

These soils occur in almost all climatic zones and are developed due to high salinity of sodiumization or both. The soil classes as red soil, black soil, desert soil and alluvial soil includes in this group. These lands are not fertile and left as uncultivated waste lands. These soils are characterized by high content of exchangeable monovalent bases. In Uttar Pradesh the saline and Alkali soil are known as **User or Reh.**InPunjab, these soils are known as **Kallar**. Alkali soils are also frequent in other parts of the country as in the state of Maharastra, Gujrat, Karnataka and also in Deccan.

5.3.8 Peaty and Marshy Soils

In humid regions, the accumulation of large amount of organic matter (10-40%) results in the formation of peaty soils. These soils are black heavy and highly acidic due to the decomposition of organic matter under anaerobic conditions. It is porous with good water holding capacity. It is not very fertile being soft and week, after monsoon these soils are put under paddy cultivation.

In alluvial and coastal areas, the dried river basin and lakes give rise marshy soils which are usually blue in colour. The blue colour is due to the presence of iron (ferrous), aluminium salts, and organic matter content. The characteristic areas of marshy soils include coastal tracts of Orissa, sunder bans, north Bihar (central portion), Almora district (UP) and south east coast of Madras. The soil is rich in organic matter and acidic in reaction.

Table 5.2 : Major Soil Types of India

S.No.	Soil Types	Formation	Characteristics	Regions & States
1.	Alluvial Soil (Distribution-7.7 lakh Km^2)/24% of country's total area	Formed due to deposition of alluvium brought by river over millions of years. Terms---Newer Alluvium-Khadar, Older-Bhanger, Terai soil-Bhabar, Infertile soil Usar.	Very fertile soil Rich in Potash and Lime Deficient in Humus nitrogen and phosphorous.	Northern plain or river basin-Punjab Haryana, eastern parts of Rajasthan, Gujarat ,UP, Bihar, west Bengal and Assam valley
2.	Black cotton Soil REGUR (Distribution-5.18 lakh Km^2)/16% of country's total area	Formed over Deccan lava gneiss and graynite	Black in colour due to Fe and Mg. Deficient in N&P.	Plateau of Maharashtra, south Orissa North Karnataka, parts of Rajasthan , (Bundi ,Tonk), central and South TamilNadu.
3.	Red soil (Distribution-5.1 lakh Km^2)	The soil developed on old crystalline rock under moderate to heavy rainfall. It is in	Red colours due to presence of Fe.deficient in organic plant material, phosphorus, nitrogen, lime	Large parts of Tamil Nadu, Andhra Pradesh, Karnataka.Southern part of Maharashtra, eastern MP, part of Orrisa,

		different shades of Red and Yellow.	content. Potash and Alumina content	chotanagpur, bundelkhand.
4.	Laterite soil (Distribution- 1.26 lakh Km^2)	The laterite soil is the result of intense leaching due to heavy tropical rain with alternate wet and dry seasons.	More acidic on higher areas due to presence of Al and Fe.	Tropical humid areas where rainfall is more then 200cm.western ghats, Karnataka, Tamil Nadu.north eastern states.
5.	Arid or desert soil Distribution- 1.42 lakh Km^2)	Sand and windblown. Weathering due to temperature help in formation of these soils. developed in arid and semiarid conditions in north western part of country	Deficient in humus and nitrogen, rich in phosphorous	Panjab, Haryana, western Rajasthan, and run of kuch in Gujrat.
6.	Mountain soil	Formed by the deposition of organic matter derived from the forest growth.	Rich in humus but deficient in potash, phosphorus and lime, most suitable for	Himalayan region of Jammu and Kashmir, Himachal Pradesh also in western and eastern ghat and some

		Characteristic 7of soil varies with variation of soil, ground configuration and climate.	plantation crops like tea and coffee.	regions of peninsular India.
7.	Peaty and organic soil	Developed in hot humid conditions as a result of accumulation of large amount of organic matter.	Dark and almost black in colour, very strongly acidic and saline.	They are confined to depression caused by dried lakes in alluvial and coastal areas and developed under water logged environments eg Kerala, Tamil Nadu, coastal Orissa, WB and North Bihar.

5.4 Vegetation Patterns of India

India is one of the twelve mega biodiversity countries of the world with about 47,000 plant species**.** Natural vegetation refers to a plant community which has grown naturally without human aid and has been left undisturbed by human for a long time. This is term as **virgin vegetation**. **T**he botanical regions of India are classified by different botanist in different ways; D. Chaturjee (1939) classified the vegetation pattern and phytogeographical zones in the following way and dissussed thoroughly the floristic patterns.

1. Deccan
2. Malabar
3. The Indus plain
4. Gangetic plain
5. Assam

6. Eastern Himalayas and Western Himalayas
7. Central Himalayas
8. Central India
9. Andamans
10. Upper Burma
11. Lower Burma

But subsequently Chaterjee (1962) deleted the upper and lower Burma from this list.

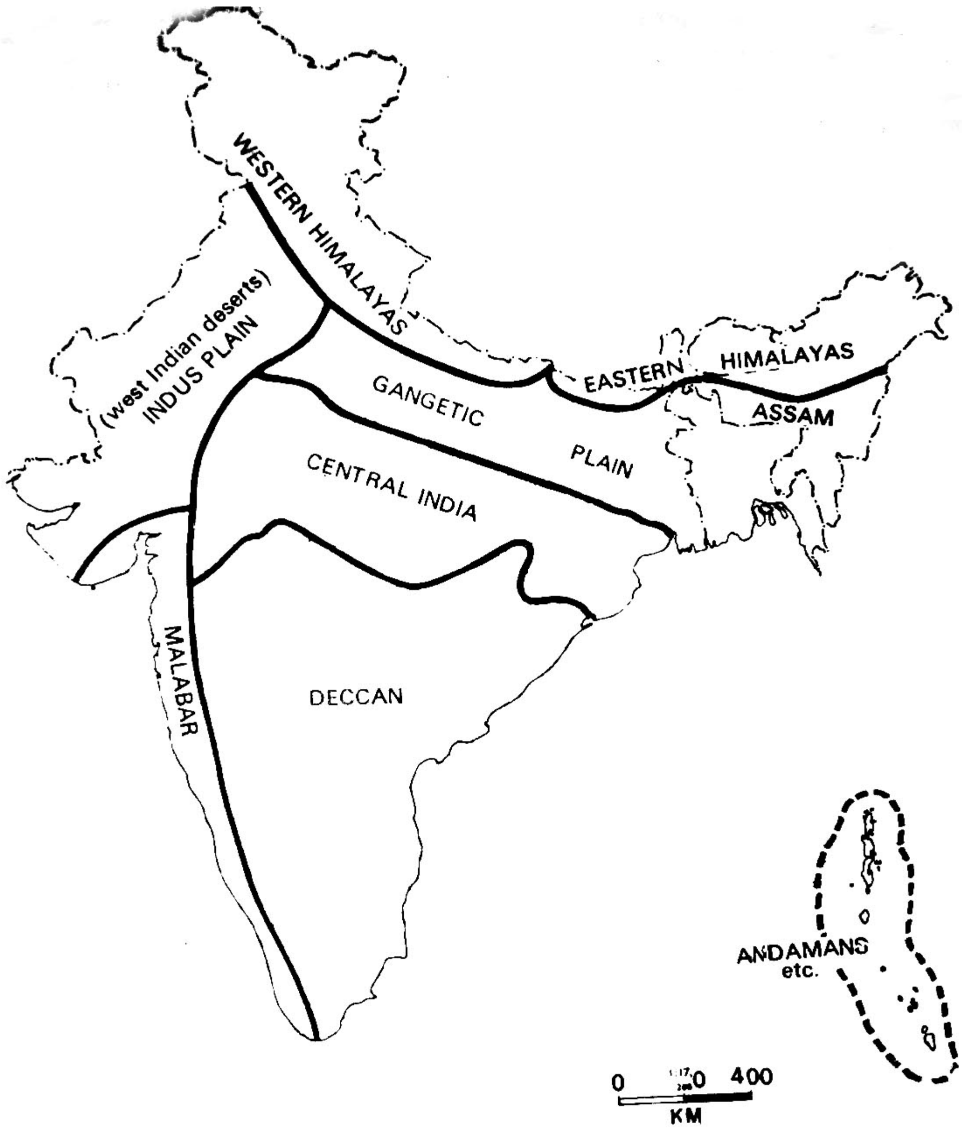

Fig. 5.3 : Floristic regions of India

Phytogeographical zones

1. **Deccan-** It includes major part of peninsular India as Andhra Pradesh, Tamilnadu and Karnataka except Malabar. It is divided in to-

   a. High hilly plateau, which is with dry climate and with rainfall around 10cms. It is occupied by dry tropical thorn forest with the dominance of trees like, *Boswellia serrata, Santalum, Prosopis, Acacia, Tectona grandis, Terminalia, Hardwickia pinnata.*

   b. Coromandal coast is with >100cms rainfall and consists of tropical even green forests. The common trees are- *Strychnos, Eugenia, Pterosprmum, Cedrela toona.*

2. **Malabar (West Coast)-** This extends from Gujarat to the southern tip of Indian Peninsula, (cap camorin). All along the west of the Western Ghats are in the form of long and narrow strip. Here the rainfall is heavy and epiphytic orchids and ferns are abundant.

   The vegetation is of 4 types –

   a. The tropical wet evergreen forest- Very luxuriant and multistoreyed, tall trees are present as (*Dipterocarpus indicus, Hopea, Sterculia alata, Artocarpus).*

   b. The mixed deciduous forests (*Tectona grandis, Dalbergia latifolia, Bamboos as Dendrocalamus strictus and Bambusa arundinacea).*

   c. The sub-tropical or temperate even green forest- In the nilgiri hills, forest known as sholas)(*Eurya japonica, Michalia nilagirica and Gordonia obtusa,)*

   d. The mangrove forest (Bombay, Elephanta islands, Uttain islands, Madh islands).

3. **The Indus Plain**- (West Indian desert) : It includes the north-western arid low land of Delhi, Punjab, Rajasthan, Kutch and North Gujarat. The climate is very hot and dry summer and winter is very cold. Here the rainfall is <75cm (July-September) and in Rajasthan it is less than 10-15cm. Vegetation is tropical thorn forest, plants are mostly xerophytes like, *Acacia nelotica, Prosopis spicifera, Salvadora oleoides, Capparis aphylla, Tamarix dioica, Zizypus nummularia, Boswellia, Stercularia, Butea, Euphorbia spp, Calotropis procera, Penicum antidotale, Tribulus terrestris,*

Acacia senegal, Prosopis juliflora, Agave, Opuntia, Argemone, Carthamus, Solanum, etc.

4. **Gangetic Plain**- This includes Eastern Delhi, whole Uttar Pradesh, North Bihar, West Bengal. It comprising most fertile region. The chief climatic factors, the temperature and rainfall together are responsible for distinct type of vegetation. Rainfall is 200cm in east and 100cm in west. It is with tropical moist and dry deciduous forests. The dominant tree species in Uttar Pradesh Himalayan foothills are *Dalbergia sissoo, Acacia nelotica*. The south west UP is occupied by *Capparis aphylla and Saccharum munga,* while eastern UP with *Butea monosperma and Madhuca indica, Cardia myxa, Acacia catechu, Azardirichta indica, Mangifera indica, Ficus bengalensis, Ficus religiosa*. The gangetic delta is dominated by tidal forest with halophytic plants like *Rhizophra mucronata, R. conjugate, Sonneratia sp, Acanthus illicifolius, Ceriops roxburghiana, Kandelia rheedii, Bruguiera gymnorhiza.*

5. **Assam-** This zone is with heavy rainfall i.e., above 1000 cm. the temperature and wetness is also high. The vegetation is dense tropical wet evergreen forests. The dominant plant species are *Dipterocarpus macrocarpus, Mesua ferrea, Artocarpus chaplasha, Alstonia scholaris Lagerstroemia flos-regina, Michelia champaca, Shorea robusta, Dillenia indica, Ficus elastic*. Some bamboos as *Bambusa pallida, Dendrocalamus hamiltonii, Calamus spp. insectivorous plants like Nepenthes sp* are also present.

6. **Western Himalayas-** Comprises the Himalayas maintains from Kumaon to Kashmir. Rainfall ranges from 40-100 inches. The snow fall is high. Altitudinally, there are three zones of vegetation corresponding to three climatic belt.

Submontane or lower region (tropical and subtropical) – It is about 1,000 to5,000ft above sea level in region of Siwaliks and adjacent areas. Forest is dominated by timber trees of *Shorea robusta*. In riverain region trees of *Dalbergia sissoo* are dominant. In dry belt xerophytes as *zizyphus spp, Acacia spp* are present with thorny succulents euphorbians on slopes. *Pinus roxburghii* appears at 3,000 to5,000ft.

Temprate or montane zone- It is about 5,000 to 11,675ft above the sea level. At about 5,500ft *Pinus longifolia* is generally replaced by *Pinus excelsa*. From 5,500ft to 6,000ft *Cedrus deodara* is quite abundant forming pure forest stands. At these altitudes *Quercus incana* also grow as separate patches. In inner Himalayas in Kashmir*Betula, Salix* and *Populous* are abundant conifers as *Abies pindrow, Picea morinda, Taxus baccata* etc common. In wet region of Kashmir valley saffron (*Croccus sativus*), apples, peaches, walnut almonds, rice are cultivated.

Alpine zone- It is the limit of tree growth at about 12,000ft known as timber or tree line, where the plants height is considerably reduced. Plants are mostly dwarfed and cushion shaped shrub and grasses. At about 15,000ft and above snow line, plant growth is almost nil. On lower levels of this zone, some *Rhododendrons, Betula utilis* and small *Junipers* are present. Above this zone there are present many types of herbs, with short period of vegetation growth and flowering. These include *Primula, Potentilla, Polygonum, Geranium, Saxifraga, Aster* etc

7. **Eastern Himalayas-** It consists of region of Sikkim and extends in to the eastern boundaries. In its vegetation zones, it is similar to the western Himalayas. On the whole, the eastern Himalayas have more tropical elements, greater variety of Oaks and *Rhododendrons* and less of conifers than the western Himalayas. The chief differences are the higher rainfall and warmer conditions in this part of Himalayas. The tree and snow lines are by about 1,000ft than the corresponding lines on western Himalayas, species diversity and vegetation density is higher in the east. This region is also divided in to three zones.

Submontane zone- Due to warm and humid weather it is typically tropical with dense forest of *Shorea rubusta.* It extends from the plain foot of the hill up to 6,000ft altitude. Mixed forests of deciduous trees like *Sterospermum, Cedrela toona, Bauhinia, Anthocephalus cadamba, Lagerstoemia pavriflora* are predominant. Tall tresses are as *Albizzia procera, Salmalia, Artocarpus, Acacia catechu.*

Temperate zone- It ranges between 6,000 to 12,000ft altitudes above sea level. The lower region has several species of oak, such as *Quercus lemellosa and Quercus lineate, Michelia, Cedrela and Eugenia.* The upper region which is cooler has such conifer as *Juniperus, Cryptomeria, Picea, Abies and Tsugais* also common.

Alpine zone- It is above 12,000ft where vegetation is devoid of trees. Shrubby growth of *Juniperus and Rhododendron* is found in grassy areas.

8. **Central Himalayas-** The central Himalayas lie between Eastern and Western Himalayas and dominated by *Quercus, Ergenia and Taxus*.

9. **Central India-** This vegetation zone runs from eastern part of Rajasthan in the west to coastal area of Orissa in the east. Whole Madhya Pradesh, southern Bihar and northern Orissa, eastern Rajasthan comes under this zone. The rain fall here varies in between 60-80' and dominated by epiphytic orchids.

   The vegetation is of two types are two;

   1 Thorn forest (west); *Acacia, Butea, Zizypus, Prosopis*

   2 Mixed deciduous forests (middle and East); *Tectona, Terminalia, Dalbergia, Diospyrus, ficus, Lagerstomia, Phyllanthus, Shorea.*

10. **Andamans-** It is with luxuriant vegetation of ever green tall trees and also with tidal forest and beach forests. *Dipterocrpus, lagerstromia, Terminalia, Rhizophora, Mimusops* are main vegetation. Most of the area is now cleared for paddy cultivation.

5.5 Summary

The important climatic factors are responsible for different phytogeographic zones, vegetation types, climatic regions and soil types which influence the diversified ecosystems. Based on climatic factors there are three four identified seasons in India. Winter, summer, rainy, season of retreating monsoon. These seasons form important climatic regions of India; they are Wet zone, Intermediate zone, Dry zone, Arid zone.

There are four major and few minor groups of soil in India, i.e. Alluvial soil, Red soil, Black soil, Laterite soil, other are Peaty and Marshy soils, Saline or Alkaline soil, Desert soil etc. Based on influence of climatic factors different vegetation pattern formed in India, they are Deccan, Malabar, Indus plain, Gangetic plain, Assam, Central India, Andaman and Western and Eastern Himalayas.

5.6 Glossary

- **Arid :** Very dry desert region, where rain fall is below 25cm.
- **Alpine zone :** hilly region having height above 12000 ft, where no tree vegetation is seen.
- **Altitude :** defines height usually in upward direction, from sea level.
- **Epiphytes :** Plants grows harmlessly on other plant.
- **Desert :** Barren area of land, or dry climatic zone where rain fall is very less (10-25cm) living condition are hostile to the plant and animals.
- **Halophytes :** vegetation find in saline and Alkaline soil/water (high salt content)
- **Mangrove vegetation :** special type of vegetation find in marshy areas and saline coastal line.
- **Peninsula:** Piece of land bordered by water from three sides but connected to main land.
- **Precipitation:** Rainfall
- **Temperate :** region where temperature is moderate, neither extreme cold nor hot,
- **Tidal region :** also known as fore shore or sea shore, it is a intermediate region between sea/ocean and land, where tides reaches.

5.7 Self -Learning Exercise

Section- A : (Very Short Answer Type Questions)

1. Name the desert of India.
2. Central Himalaya lies between.
3. Name two thorny vegetations.
4. Andaman lies in which side of Indian subcontinent.
5. Name two halophytes.
6. Indus plain also known as........
7. Malabar coast is the part of............

8. Saline soil also known as ....in Punjab.

Section- B : (Short Answer Type Questions)

1. Name the subparts of vegetation pattern of Himalaya.
2. Explain four seasons of India.
3. Describe the climatic region of India.
4. Write about the alluvial soil.

Section- C : (Long Answer Type Questions)

1. Give the classification of different soil types and there special features in detail.
2. Describe the different vegetation types in various physiographic regions of India.

Answer key of section A

1. Thar
2. Eastern and western Himalayas.
3. *Acacia, Prosopis, Zizypus, Capparis*
4. South East side in Bay of Bangal
5. Rhizophora, Sonneratia
6. West Indian desert
7. West coast of India along the western ghat
8. kallar

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Unit - 6

Vegetation Organization

Structure of the Unit:

6.0 Objectives

After going through this unit you will be able to understand-

- Concept and characters of different plant communities
- Composition and structure of a community

- Characters used in community structure
- Raunkiaer's Concept and Braun Blanquet Scheme
- Methods of analysis of plant communities Floristic methods, Physiognomic methods and Phytosociological methods-Quadrate Method, Transect Method, Point Method

6.1 Introduction

Population of many different species in a local association constitutes a **community.** This universe of living organisms is a sum total of communities of different types. The communal habitat comes under community ecology as terrestrial, aquatic, epiphytic etc. The basic concept of the community is 'several species are somewhat related to everything else', it is the relationship includes interlocking functions of many other organisms.

The recognition of communities depends on their floristic composition. Subdivision of the field is useful to simplify the work, but these are somewhat hypothetical, not natural. The method of study adopted will naturally depend on these subdivisions. Communities are treated from various angles including floristic, physiognomy, topography, chronology (developmental history), climatology, pedology (soil relations) etc.

Species diversity, growth forms, structure, dominance and successional trends are characterising the community. A particular species is dominant in the community based on their analytic and synthetic characters.

A**nalytical characters-** it include quantitative and qualitative characters.

Quantitative characters these include characters such as, Frequency, Density, Abundance, Cover and Basal area etc.

Qualitative character- these include physiognomy, phenology, stratification, abundance, sociability or gregariousness, vitality and vigour, life forms etc.

Synthetic characters- these are actually computed from analytical characters.

6.2 Concept and Characteristics of Community

In nature different kinds of organisms grow in association with each other. A group of several species (Plants and animals) living together with mutual tolerance (adjustment) and beneficial interactions in a natural area is known as a community. In a community organisms share the same habitat growing in a uniform environment. A forest, grassland, a desert and a pond are natural communities. The concept regarding its organisation that have developed firstly by observation and secondly by experimentation, reveal that a biotic community is an organised or supper organised unit. The concept of community organisation is by no means a recent one, and may be traced back to the time of Theophrastus (370-250BC) who recognised the existence of plant communities or association of species in different climatic areas. The concept of community was first visualised by Forbes (1844), while studying the molluscs of Aegean Sea. Mobius (1877) recognised the biotic nature of the community.

The basic concept of community is **interdependence, limitation and complexity**.

- The interdependence includes interacting and interdependent components and they are open and linked to each other.
- The limitation means that limits are ubiquitous and that no individual species in community goes on growing indefinitely. Various species control and limit their own growth in response to overcrowding or other environmental signals and the total number keep pace with the resource available.
- The complexity is the three dimensional interactions of the various constituents or elements of community are highly complex.

Community has its own characteristics which, are not shown by its individual component species. These characteristics have meaning only with reference to community level of organisation, are as follow;

6.2.1 Species diversity

Each community is made up much different organism as plants, animals, microbes, which differ taxonomically from each other. The number of species and population abundance in community also vary greatly.

There are two levels of species diversity; (1) Regional diversity of whole nations or parts of continents within which many different communities exist, and (2) Local diversity in a given nation where different communities exist at different latitudes.

6.2.2 Growth form and structure

Community is describe in major growth form as trees, shrubs, herbs, mosses etc. In each growth form as in trees, there may be different kinds of plants as broad leaved trees, evergreen trees etc. These different growth forms determine the structural pattern of a community. Communities show different patterns according to mode of arrangements- zonation horizontal layering, stratification (vertical layering).

6.2.3 Dominance

In each community all the species are not equally important there are relatively only a few of these which determine the nature of the community. These few species exert a major controlling influence on the community. Such species are known as **dominants.**

6.2.4 Succession

Each community has its own developmental history. It develops as a result of a directional change in it with time. This directional change with time called **succession.**

6.2.5 Trophic structure (self sufficiency)

Nutritionally, each community, a group of autotrophic plants as well as heterotrophic animals, exists as a self sufficient, perfectly balanced assemblage of organisms.

6.3 Composition and Structure of a Community

Each community has its own composition, structure and developmental history.

- **Composition**- Community may be large or small, large extend over area of several thousand kilometres as forest and desert etc, other occupies restricted areas such as meadow, river, pond, etc. Very small sized communities are the groups of microorganisms in such micro habitats as leaf surface, fallen log, litter, soil etc. The number of species and population abundance in communities vary greatly.

  In such communities there are diverse species. All these species are not equally important but these are only a few overtopping species which by their bulk growth can modify habitat and control the growth of other species of the community, thus forming a sort of characteristic nucleus of the community, these species are called the **dominants.** Generally in most of the communities, only a single species, due to being particularly conspicuous, is dominant, and in such case the community is called by the name of dominant species as for example spruce forest community. In other, there may be more than one species are dominants as in oak hickory forest.

- **Structure-** besides composition and dominance, the community exhibit a structure or recognizable pattern in the spatial arrangements of their members. Thus structurally, a community may be divided horizontally in to sub communities which are unit of homogenous life forms and ecological relation. This horizontal division constitutes the zonation in the community. Latitudinal as well as altitudinal zonation of vegetation is observed in mountains, ponds, lakes etc. e.g. In lake these are three zones littoral zones, limnetic zone, profundal zone, in each zone differ from each other.

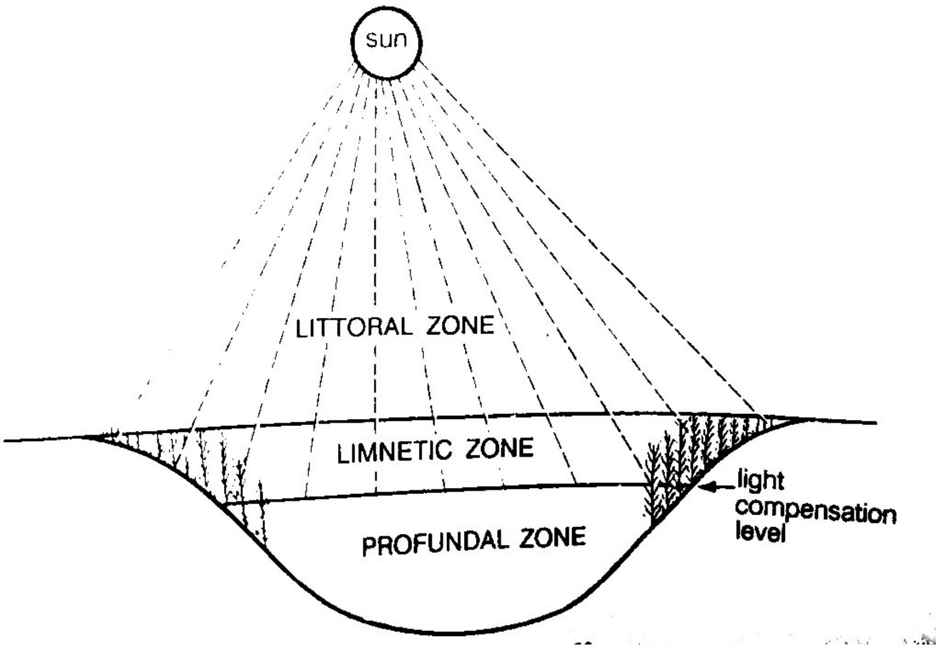


Fig. 6.1 : Diagrammatic sketch of three major zones of fresh water body as lake

Another aspect of structure that is more common is stratification which involves vertical rather than horizontal changes within the community. In each horizontal zone, there may be recognised distinct vertical storeys. Sometime the stratification is very complex where communities possess a number of vertical layers of species, each made up of a characteristic growth form. In grassland community there a sub-terranean flora, containing basal portions of vegetation such as rhizomes of grass covered by litter and debris of plants as well as animals and herbaceous sub-stratum consisting of upper part of the grasses or herbs with a characteristic fauna.

Stratification in forest is more complicated where as many five vertical subdivisions may be recognised. These are 1. Subterranean 2. Forest floor 3. Herbaceous 4. Shrubs 5.trees. In tropical rain forest there are as many as eight vertical strata based upon light and humidity requirements.

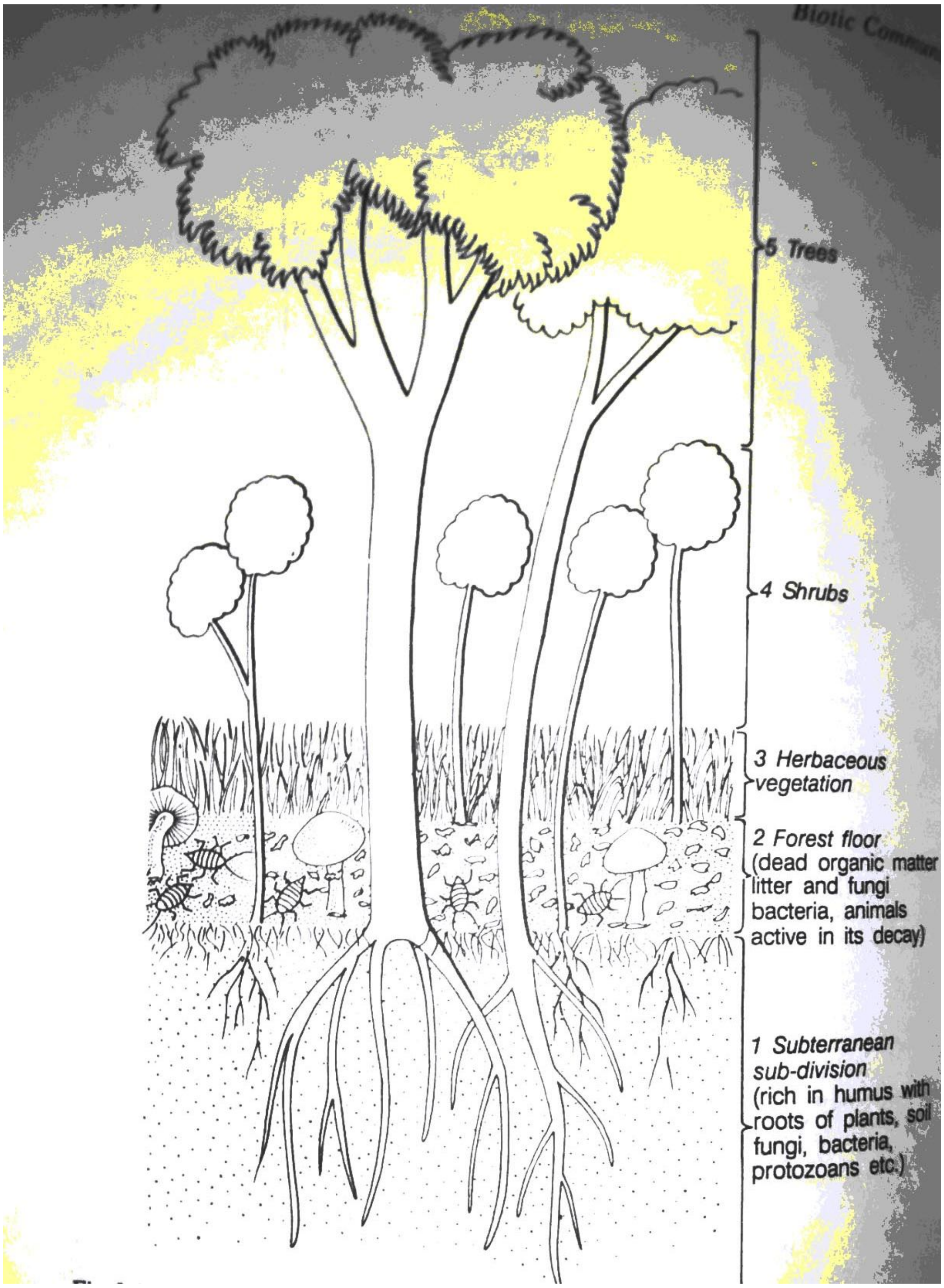


Fig. 6.2 : A forest community showing stratification, with five vertical sub-divisions of different vegetation types

6.4 Characters used in Community Structure Analysis

To study the detail aspects of any community number of characters are taken in to consideration, these are then used to express the characteristics of community. These characters are broadly classified in to two major categories-

1. **Analytical characters**- these are generally expressed in terms of 5 point scale.

   These are of two types- a. Quantitative characters, b. Qualitative character

   a. **Quantitative characters-** These include characters such as, Frequency, Density, Abundance, Cover and Basal area etc

   b. **Qualitative character-** These include physiognomy, phenology, stratification, abundance, sociability or gregariousness, vitality and vigour, life forms etc

2. **Synthetic characters**- These are actually computed from analytical characters. These are determined after computing the data from the quantitative and qualitative characters of the community. For comparing the vegetation of different area, community comparison needs the calculation of their synthetic characters. These are determined by terms of- Presence and Constance, Fidelity, Dominance, and synthetic characters.

6.4.1 Raunkiaers Concept of Life Forms

A life form can be defined as the characteristic vegetative appearance of plant regarding its shape, size, crown, histological features, modes of branching and its life span. Raunkiaer's (1934) viewed the concept as location of over wintering parts. Hanson and Churchill (1961) visualized that the floristic habit succession status, physiognomy and geographical character are the basis for life forms. But in general, it is noted that the genetic constitution and environmental factors determine the life forms. The sum of the adaptations of the plant to climate is the life form. The way in which different species overcome the adverse environmental conditions determine their limits of distribution. Thus the plants climate can be expressed by the statistical distribution of life forms in the flora of particular region. This statistical distribution of species among the life forms of a flora is defined as **biological spectrum.**

Raunkiaer classified the vegetation life forms on the basis of (a) temperature and (b) position of buds in the plants.

Based on the temperature the vegetation of the world has been classified in to;

i) **Megatherms -**plant requires constant and high temperature for their growth throughout the year. Tropics are the regions for these types of life forms.

ii) **Mesotherms-** plants that can tolerate low temperature for a longer or shorter period of year. The sub tropical conditions are favourable for the growth of such life forms.

iii) **Microtherm-** Plants that grows well under low temperatures and cannot tolerate high temperature. The temperate regions are good for growth of these life forms.

iv) **Hekistotherms-** Plants that requires constant low temperatures for the growth throughout the year. The alpine and arctic areas support this type of vegetation.

Based on the position of the buds on the plant, Raunkiaer classified the vegetation of the world in to five classes.

i) **Phanerophytes-** The buds in this group of plants are naked or covered by scales and are situated high up to the plants. The tree shrubs, climbers are included in the group and are generally occupy the tropical climates. Further, depending on the height of the plant the phanerophytes are divided in to;

a) Mega phanerophytes- Tree more than 30 meters of height.
b) Meso phanerophytes- Trees that are 8-30 meters of height.
c) Micro phanerophytes- Trees that are 2-8 meters of height.
d) Nano phanerophytes- Trees that are below 2 meters in height.

Epiphytes are also added in phanerophytes or sometimes included under separate life forms. Recently three more groups of plants are also added to phanerophytes and those are epiphytic phanerophytes, stem succulent phanerophytes and lianas phanerophytes.

ii) **Chamaephytes-** the plants that have the buds situated just above the surface of the ground. These groups of the plants are very common on high altitudes. These plants die during winter season and their buds survive below ground and develop into new individuals during favourable periods. In this way, these plants can avoid the unfavourable situations and survive. This positioning of the buds and their survival is an adaptive character of these plants.

iii) **Hemicryptophytes-** the buds in such life forms are hidden below the surface of the soil or are protected by fallen litter and over winter there. These plants grow in cold temperate zones and their shoots generally die each year. Most of the biennial and perennial herbs are the best examples for such life forms.

iv) **Cryptophytes-**The buds of these life forms are completely hidden in the soil as bulbs and rhizomes. Mostly, these life forms are found in arid zones (desert and steppes). Hydrophytes are also included in this life forms as their buds are embedded in the below the waste water surface.

v) **Therophytes-** this life form are drought evading and completes their life cycle in single favourable season. They are dormant throughout the unfavourable season. They are dormant though out the unfavourable period in to the form of seeds. The hot or cold deserts are the appropriate climate conditions for the growth of their life forms.

Raunkiaer's life forms are also discussed based on the leaf size classes;

i) Leptophyll- Leaf size of the plant 25sqmm

ii) Nanophyll- Leaf size of the plant 225sqmm

iii) Microphyll- Leaf size of the plant 2025sqmm

iv) Mesophyll- Leaf size of the plant 18,222sqmm

v) Macrophyll- Leaf size of the plant 1,64,025sqmm

vi) Megaphyll- Leaf size of the plant more than macrophyll

The percentage of different life forms in the total flora is known as **biological spectrum.** This will be varying in different ecological situation based on the climatic and edaphic conditions accordingly, all the ecosystems with their peculiar characteristics are compared with the normal Raunkiaer's biological spectrum.

6.4.2 Braun Blanquet's Scheme

Braun Blanquet (1951) modified Raunkiaer's classification and proposed the following scheme;

i) **Phytoplankton-** It includes microscopic forms that grow suspended in air, snow, or water surface.

ii) **Phytoedaphon-** It includes the microscopic soil forms

iii) **Endophytes-** It includes plants that grow within the bodies of other plants e g. Some algae and fungi.

iv) **Therophytes-** It includes annual e g. Algae, liverworts, mosses, ferns and some seed plants.

v) **Hydrophytes-** The plants that grow in water.

vi) **Geophytes-** It includes the plants with perennating structure buried under the soil.

vii) **Hemicryptophytes-** These Plants are with buds hidden below surface protected by litter.

viii) **Charmophytes-** plants with buds just above surface.

ix) **Epiphytes-** plants that grow on other plants.

Sociability is one of the fundamental qualitative characters of communities. Proximity of plant to one another forms the patches, colonies and groups. This is the degree of association between species. Braun Blanquet used five sociability groups.

S1-Plant (stem) found growing quite separately from each other thus occurs singly.

S2- A group of 4-6 plants at one place.

S3- Many smaller scattered groups at one place.

S4- Several bigger groups of many plants at one place.

S5- A large group occupying larger area.

The capacity of normal growth and reproduction for successful survival of plant species is called as **viability.** The stem height, root length, leaf area, leaf number, number and weight of flower, fruits, seed etc. determine the viability of the community. Braun Blanquet classified the plants based on the specific character related to viability. It is;

V1- plants whose seedling die

V2 – plants whose seedling grow, but unable to reproduce

V3- plants that reproduce vegetatively

V4- plants that reproduce sexually, but uncommon

V5- plants that reproduce sexually, but grow regularly

To obtain various characters used to characterize a particular community several methods have been used from time to time. The field of community ecology has been investigated in detail particularly for plant communities, and thus methods described are mainly related to plants.

6.5 Methods of Study of Communities

The various characters used to characterise a particular community, to obtain these characters several methods have been used from time to time.

Various methods of study of plant communities are broadly classified into three major categories;

(1) Floristic methods- There are rather obsolete methods. Here the flora is studied by listing various genera and species present in the community. Thus, vegetation is described in terms of the flora. These are actually descriptive methods. Such methods, however give little or no idea of the composition, structure, growth form etc of the community.

(2) Physiognomic methods- The various species of the community are studied chiefly in terms of their life-forms (growth forms), general stature, spread etc, Out of a number of physiognomic methods. Raunkiaer's (1934) life-form method because most popular. We will describe this method in detail here.

Raunkiaer's life form method-this method has two parts;

(a) Record of different life-forms. The various species of the community are recorded. These are than distributed among the different life forms- i.e. phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes, on the basis of position of renewal bud or organs in the species.

(b) Biological (phyto-climatic) spectrum. Biological spectrum represents the percentage (% of the total species in the community) distribution of species among the various life forms. Thus, through calculation of percentage value of each life form, biological spectrum of the area is obtained.

(3) Phyto-sociological methods- None of the above said methods provides detailed information on the composition, structure, species diversity, growth, trends of succession and other characteristics of the community. Methods, based upon some such characteristics- phytosociological methods were developed.

Sampling unit- In phytosociological methods, there are three forms of sampling units; area, line and point.

In area and line as sampling units, there is a definite area (suitable size) for sampling. However, in such communities as thick forests with long grassy and shrubby belts, it becomes difficult to have a definite area. For such analysis, point is taken as a sampling unit.

On the basis of the nature of sampling units, there are three popular methods of study of communities.

1. **Quadrat method**, where the sampling unit is definite area which is taken in form of a square, a rectangle, or a circle.
2. **Transect method,** where the sampling unit is line of suitable length. In fact a segment of suitable length along the line may be considered as quadrate.
3. **Point method**, where the sampling unit is a point.

6.5.1 Quadrat Method

Sample unit is a quadrate which is an area of a definite size. In shape, it may be square, rectangle or a circle. Depending upon the type of vegetation and purpose of study a quadrat may be

- List quadrat. The species present in the area are simply listed
- List-count quadrat. Besides listing the various species, numerical counts of individuals of each species are also made.
- Chart quadrat. Here a detailed to scale growth and distribution of each species in space is recorded. The individuals are recorded on a miniature quadrat on graph paper by the use of pantograph at intervals of months or years.

Experimental permanent quadrat. The chart quadrat is left undisturbed and the area is studied for vegetation changes over a long period, to study periodic changes in community. Such quadrates are useful in succession studies.

Study of community by quadrat method involves three steps;

1. To determine the minimum size of quadrate by Species Area Curve method
2. To determine the minimum number of quadrates to be laid down,
3. Record of the species- Their listing and counting of the individuals of each species.

After the record of various species, the value of frequency, density, abundance is determined for each species of the community.

In this method, the list of different species and other data is systematically assessed and presented in tabular form consisting of the following items;

Name of the plant species

1. The number of quadrant are laid down(1-10)
2. Total number of individuals of the species
3. Total number of quadrants of occurrence
4. Frequency percentage

Frequency- Frequency is thenumber of sampling units in which a particular species occurs. Thus frequency of each species is calculated as follows-

$$\text{Frequency}(\%) = \frac{\textit{Numberofsamplingunitsinwhichthespeciesoccurred}}{\textit{Totalnumberofsamplingunitsstudied}} \text{X } 100$$

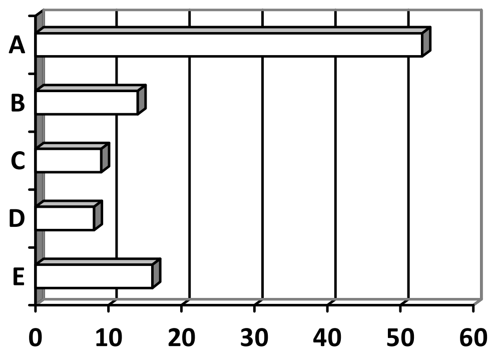
After determining the frequency(%) of each species, these are then distributed among Raunkiaers(1934) five frequency classes-A,B,C,D,E, depending upon their frequency(%) value as follows;

Frequency%	Frequency class
0-20	A
21-40	B
41-60	C
61-80	D
81-100	E

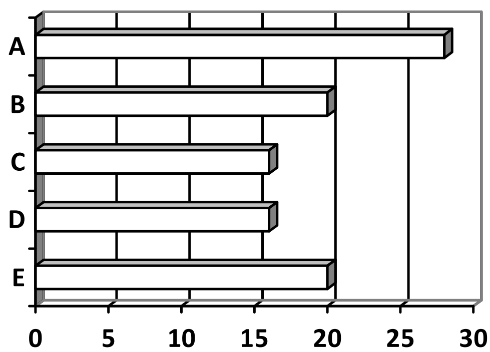
Now find out the values (as % of the total species) of each of the five prepare the frequency classes to prepare the frequency diagram.

>
A>B>C=D<E
<

As a result of his extensive study, he also proposed a normal frequency diagram in which the % values of different frequency classes are-A-53, B-14, C-9, D-8 and E-16. The frequency diagram prepared for the area studied is then compared with normal frequency diagram. A comparison makes it clear that values of frequency classes BCD are comparatively higher than their respective value in normal diagram , Thus community studied is a heterogeneous one, Higher values of E indicate the homogenous nature of the community.



	E	D	C	B	A
☐ 1st Qtr	16	8	9	14	53



	E	D	C	B	A
☐ 1st Qtr	20	16	16	20	28

Fig. 6.4 : Frequency diagram of a grassland community showing that the value of frequency classes B,C,D are higher than upper figure, thus the community is heterogeneous in nature

Density-Frequency does not give correct idea of the distribution of any species, unless it is correlated with other characters such as density etc. Density represents the numerical strength of a species in the community. The number of individuals of the species in any unit area is its density. Density gives an idea of degree of competition. It is calculated as follows-

$$\text{Density}=\frac{totalnumberofindividualsofthespeciesinallthesamplingunit}{Totalnumberofsamplingunitstudied}$$

The value thus obtained is then expressed as number of individuals per unit area.

Abundance- this is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows-

$$\text{Abundance}=\frac{totalnumberofindividualsofthespeciesinallthesamplingunit}{Numberofsamplingunitinwhichthespeciesoccuerred}$$

Abundance thus obtained in quantitative terms give little idea of the distribution of the species.

6.5.2 Transect Method

A transect is a sampling strip extending across a stand or several stands of vegetation where line is the sampling unit. It may be a

(a) **Line transect**- Line transect is a thin line, which is generally used for grasslands, or

(b) **Belt transect-** Belt transect is a belt of suitable breath, used for forests. The transect is divided into segments of suitable length. This method is useful to analyse the vegetation changing in its composition through an ecotone. Each segment may be taken as a quadrate. Frequency, density values of each species is calculated.

6.5.3 Point method

The sampling unit is a point. For convenience, a number (usually10) of moveable pins (about 50cm long) are inserted in a wooden frame, known as point frame. The pins are laid down at random in the area. Plants hit by pins are recorded. Thus frequency of each species is taken as its occurrence in the sampling unit. For density values, there are two alternative procedures.

1. Random pair method and
2. Point centred quarter method

For each of the above methods, frequency diagrams may be prepared which are compared with Raunkiaers (1934) normal frequency diagram to draw possible conclusions.

6.6 Summary

The basic of association of various populations i.e. community is the interdependence, limitations and complexity. Species diversity, growth forms, structure, dominance and successional trends are characterising the community.

The dominance of a species in the community is based on their analytic and synthetic characters. The analytical characters include quantitative and qualitative characters. Quantitative characters these include characters such as, Frequency, Density, Abundance, Cover and Basal area etc. Qualitative character- these include physiognomy, phenology, stratification, abundance, sociability or gregariousness, vitality and vigour, life forms etc. Synthetic characters- these are actually computed from analytical characters.

Raunkiaer's biological spectrum explains the vegetation life forms based on the temperature and position of bud on the plant. The life forms related to temperature are classified in to megatherms, mesotherms, microtherms, and hekistotherms. The position of bud on the plant has classified the life forms in to phanerophytes, chamaephytes, hemicryptophytes, cryptophyetes and therophytes. Further he classified the life form into leptophylls, nanophylls, microphylls, masophylls and macrophylls.

Considering various climatic situations and organism behaviour Bran Blanquet has modify the Raunkiaer's life forms and regrouped them into phytoplankton, phytoedaphon, endophytes, therophytes, hydrophytes, geophytes, hemicryptophytes , chaemophytes and epiphytes. These plant communities occupying in various terrestrial habitats are studied for their distributional levels by floristic, physiognomic and phytosociological methods. Among them the important approach is phytosociological methods which are evaluated by quadrat, transect and point method. In quadrat method frequency abundance and density of population is calculated and compared to normal biological spectra of Raunkiaer. The possible conclusions are made on the community dynamics and also the homogeneity or heterogeneity of the population is established.

6.7 Glossary

- **Abundance :** this is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows.
- **Biological spectrum :** it represents the percentage (%) of the total species in the community.
- **Community :** A group of several species living in similar habitat.
- **Density :** it represents the numerical strength of a species in the community.
- **Desert :** Barren area of land, or dry climatic zone where rain fall is very less (10-25cm) living condition are hostile to the plant and animals.
- **Dominant :** main species of community control other all factor and species.
- **Epiphytes :**Plants grows harmlessly on other plant.
- **Floristic :** vegetation is described in terms of the flora.
- **Frequency :** Frequency is the number of sampling units (as%) in which a particular species occurs.
- **Quadrat method :** Sample unit is a quadrate which is an area of a definite size. In shape, it may be square, rectangle or a circle.
- **Sociability :** Sociability is one of the fundamental qualitative characters of communities.
- **Species :** The group of organism which can interbreed
- **Synthetic characters :** the actually computed or derived characters.

6.8 Self-Learning Exercise

Section- A : (Very Short Answer Type Questions)

1. Stratification is one of the characteristic of a...................
2. Seasonal plant completing their life cycle in a................
3. Scientific study of seasonal change in life cycle is called.............
4. Physiognomic method of study of plant community was given by.......................

5. Detailed information on the composition, srtructure, species composition of community provided by.................. method.
6. Write the formula of abundance.
7. Define viability.
8. Microscopic soil forms are included in .... by Braun Blanquet.

Section- B : (Short Answer Type Questions)

1. Which method is suitable for study of forest community and why?
2. Define community and write its characters.
3. Write an account on the modified life forms of Braun Blanquet.
4. Explain the analytic characters of community.

Section- C : (Long Answer Type Questions)

1. Describe the normal biological spectrum of Raunkiaer based on the position of buds.
2. Explain the types and procedure of population study by quadrat method.

Answer key of section A

1. Community
2. Therophytes.
3. Phenology.
4. Raunkiaer.
5. Phytosociological method
6. Abundance=

$$\frac{\text{total number of individuals of the species in all the sampling unit}}{\text{Number of sampling unit in which the species occuerred}}$$

7. The capacity of normal growth and reproduction for successful survival of plant species is called as viability
8. Phytoedaphon.

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Unit - 7

Vegetation Development

Structure of the Unit:

7.0 Objectives

After going through this unit you will be able to comprehend-

- The basic concept and causes of succession
- Trends and types of succession
- General process of succession
- Climax concept of succession and theories

7.1 Introduction

Communities are never stable, but dynamic, changing more or less regularly over time and space. Communities interact biotic factors as well as physical factors i.e. the environment. Environment is always kept on changing over a period of time due to; variation in climate and physiographic factors and the activities of the species of the communities themselves. These influences bring about marked changes in the dominants of the existing community which is thus sooner or later replaced by another community at the same place. This process continues and successive communities develop one after other over a period of time in the same area, until the terminal final community, becomes more or less stable for a period of time. This occurrence of relatively definite sequence of communities over a period of time in the same area is known as Ecological succession.

Ecological succession may be defined in term of the following three parameters---

- It is orderly process of community development that involves changes in species structure and community processes with time, it is reasonably directional and therefore predictable.
- It results from modification of the physical environment by the community, that is succession is community controlled even though the physical environment determines the pattern, the rate of change, and often sets limits as to how far development can go.
- It culminates in a stabilised ecosystem in which maximum biomass (or high information content) and symbiotic functions between organisms are maintained per unit of available energy flow.

Hult (1885) firstly used the term "succession" for orderly change in communities.

Clements (1916) while studying plant communities defined "succession" as the natural process by which the same locality become successively colonised by different group or communities of plants.

Knight (1965) has defended the ecological succession as an orderly sequence of different communities over a period of time in some particular area.

Smith (1966) Ecological succession is the orderly and progressive replacement of one community by another till the development of a stable community.

Benton and Smith (1969) Succession is the occurrences of gradual, orderly and predictable changes in the composition of the communities towards the climax type.

Odum (1971) preferred to call this orderly process as ecosystem development in place of ecological succession.

7.2 Causes of Succession

Since succession is a process, more properly a series of complex processes, it is natural that there may not be a single cause for this, generally there are three types of causes;

1. Initial or initiating cause- These are climatic as well as biotic. The former includes factors such as erosion and deposits, wind, fire etc caused by lightning or volcanic activity, and the latter includes the various activities of organisms. These produce bare areas or destroy the existing population in an area.
2. Ecesis or continuing causes- These are the processes as migration, ecesis, aggregation, competition, reaction etc. which cause successive waves of populations as a result of changes, chiefly in the edaphic feature of the area.
3. Stabilizing causes- These cause the stabilization of the community. According to Clements, climate of the area is the chief cause of stabilization; other factors are of secondary value.

7.3 Trends of Succession

An ecological succession proceeds along the following four lines;

A continuous change in the kind of plants and animals

A tending increase in the diversity of species

A increase in the organic matter and biomass supported by the available energy flow (in heterotrophic succession reverse is true)

Decrease in net community production or annual yield.

7.4 Basic types of Succession

The various types of succession have been grouped in different ways on the basis of different aspects; some basic types of successions are as follows-

1. **Primary succession**- In any of the basic environments (terrestrial, fresh water, marine) one type of succession is primary succession which starts from the primitive substratum, where there was no previously any sort of living matter. The first group of organisms establishing there are known as the pioneers, primary community or primary colonisers, *e.g.* a new exposed rock, sand dune, new island or recent lava flow etc.

2. **Secondary succession**- Another general type of succession which starts from previously built up substrata with already existing living matter. The action of any external force as a sudden change in climatic factors, biotic intervention, fire etc, courses the existing community to disappear, thus, area becomes devoid of living matter but its substratum, instead of primitive, is build up where conditions for existence are already favourable. Such succession is comparatively more rapid, *e.g.*Cut over forests, Abandoned cropland and ploughed fields

On the basis of factors responsible for environment changesuccessions are sometimes classified as;

Autogenic succession- After the succession has begun, in most of the cases; it is the community itself which as a result of its reactions with the environment modifies its own environment and thus causing its own replacement by new communities. This course of succession is known as autogenic succession. e.g all common successions.

Allogenic succession- The replacement of the existing community is caused largely by any other external condition and not by the existing organisms. Such a course is referred to as allogenic succession.e.g water body where nutrients and pollutants enter from outside and modify the environment.

On the basis of successive change in nutritional and energy contents, successions are sometimes classified as;

Autotrophic succession- it is characterised by early and continued dominance of autotrophic organisms like green plants. It begins in a predominantly inorganic environment and the energy flow is maintained indefinitely. There is gradual increase in the organic matter content supported by energy.

Heterotrophic succession- it is characterised by early dominance of heterotrophs, such as bacteria, actinomycetes, fungi and animals it begin in a predominantly organic environment, and there is a progressive decline in the energy content.*e.g.*polluted stream, in fallen log,etc

Some other kinds of succession based upon nature of the environment where the process is begun

Hydrosere or hydrarch- starting where water is plenty, as lakes, streams etc

Mesarch or mesarch- where adequate moisture conditions are present as garden, farms, forest etc

Xerosere or xerach- where the moisture presents in minimal amount as desrt, rocks etc.

Lithosere- initiating on rocks,

Psammosere- on sand.

Halosere- saline water or soil.

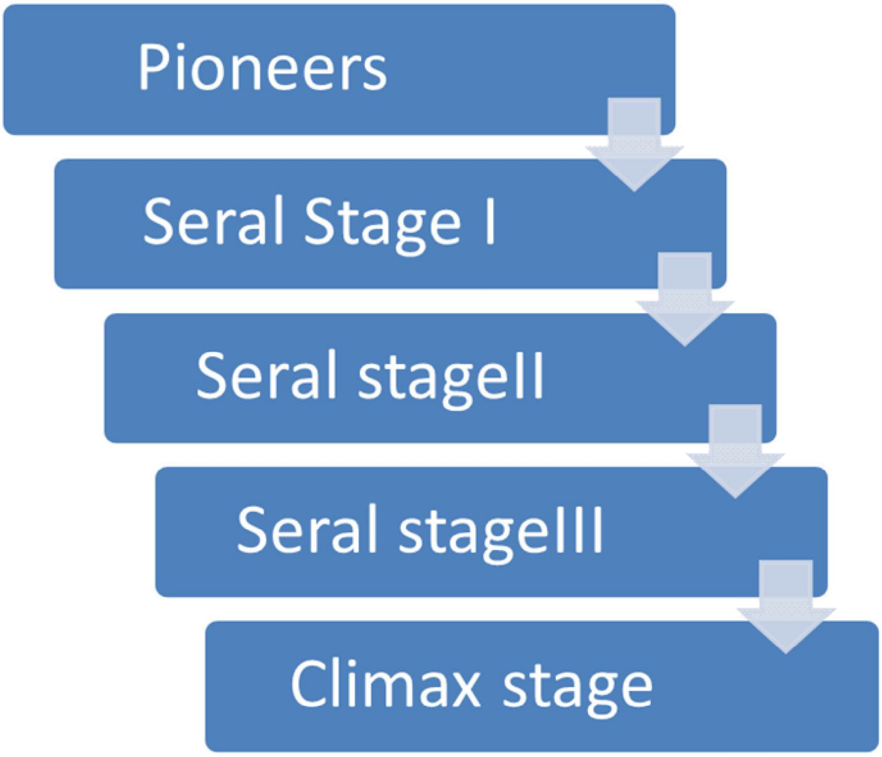

Fig. 7.1 : Hypothetical diagram of various stages of Ecological succession

7.5 General Process of Succession

The whole process of a primary autotrophic succession is actually completed through a number of sequential steps, which follow one another. These are as follows-

(1) **Nudation :** This is the development of a bare area without any form of life. The area may develop due to several causes such as landslide, erosion, deposition or other catastrophic agency. The cause of nudation may be-

a. **Topographic-** Due to soil erosion by gravity, water or wind the existing community may disappear. Other causes may be deposition of sand, landslide, volcanic activity and other factors.

b. **Climatic-** Glaciers, dry period, hail and storm, frost, fire etc may also destroy the community.

c. **Biotic-** man is most important, responsible for destruction of forests grasslands for industry, agriculture, housing etc. other factors are disease epidemics due to fungi, virus etc, which destroy the whole population.

(2) **Invasion** : This is successful establishment of a species in a bare area. The species actually reaches this new site from any other area. This whole process is completed in following three successive stages

a. **Migration (dispersal) -** The seeds, spores, or other propagules of the species reach the bare area. This process, known as migration, is generally brought by air, water etc.

b. **Ecesis (establishment)-**After reaching to new area the process of successful establishment of the species, as a result of adjustment with the conditions prevailing there, is known as ecesis. In plants, after migration, seeds or propagules germinate, seedling grows, and adults start to reproduce. Only a few of them are capable of doing this under primitive harsh conditions, and thus most of them disappear. Thus as a result of ecasis, the individuals of the species become established in the area. The species which colonise the bare area in the beginning of succession are called pioneers.

c. **Aggregation-** After ecasis, as a result of reproduction, the individual of the species increase in number, and they come close to each other. This process is known as aggregation.

(3) **Competition and coactions** : After aggregation of a large number of individuals of the species at the limited place, there develops competition(inter/ intra specific) mainly space and nutrition. Individuals of a species affect each other's life in various ways and

this is called **coactions**. The species, if unable to complete with other species, if present, would be discarded.

(4) **Reaction** : This is the most important stage in succession. The mechanism of the modification of the environment through the influence of living organism on it, known as reaction. As a result of reactions, change takes place in soil, water, light conditions, temperature etc. of the environment. Due to all these the environment is modified, becoming unsuitable for the existing community which sooner or later is replaced by another community (seral community). The whole sequence of communities that replace one another in the given area is called a sere, and various communities the sere, as seral communities, seral stages or developmental stages. The pioneers are likely to have low -nutrient requirements, more dynamic and able to take, minerals in comparatively more complex forms. They are small-sized and make less demand from environment.

(5) **Stabilization (climax) :** Finally, there occurs a stage in the process, when the final terminal community becomes more or less stabilised for a longer period of time and it can maintain itself in equilibrium with the climate of the area. This final community is not replaced, and is known as climax community and the stage as climax stage.

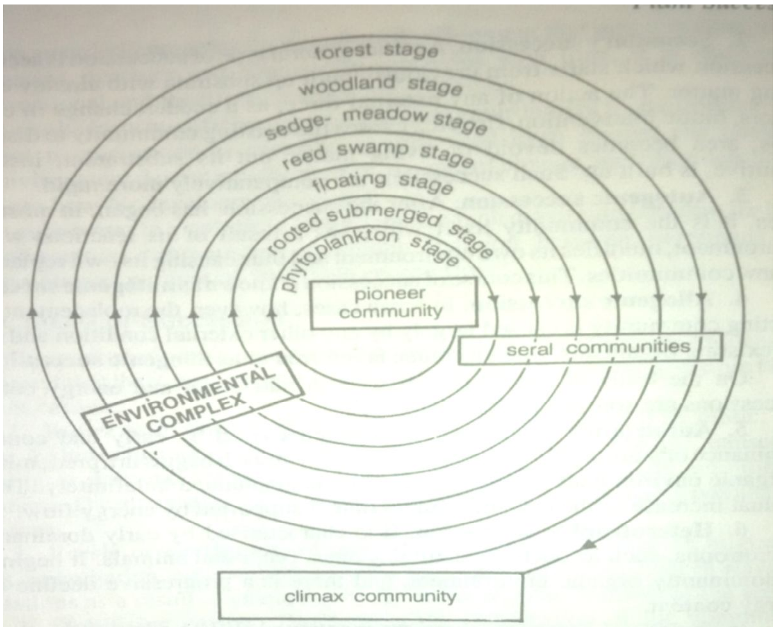

Fig. 7.2 : Process of Succession

Different types of Succession

Retrogressive succession : Some ecologists (Gleason, 1929), have talked of retrogressive succession in which continuous biotic influences have some degenerating influence on the process. Due to destructive effects of organisms, sometimes the development of disturbed communities does not occur and the process of succession instead of progressive becomes retrogressive. For example forest may change to shrubby or grassland community. This is called retrogressive succession.

Deflected succession : sometime due to change in local conditions as soil characteristics or microclimate, the process of succession becomes deflected in a different direction than that presumed under climatic condition of the area. Thus the climax communities are likely to be different from presumed climatic climax community. This type of succession is called **deflected succession.**

Seasonal succession- In India, with a monsoon type of climate, in some habitats like temporary ponds, pools etc the development of different kinds of communities are observed in different seasons of the year.

7.6 Concept of Climax in Succession

The final terminal and more or less stabilised community in succession that is able to establish some sort of equilibrium with the environmental conditions of that area was climax by Clements (1916). The subject of climax has been much controversial and is reviewed from time to time by many ecologists. According to Clements (1916, 1935), climax has the following three principal characteristics;

1. **Unity-** Climax is a unit, and index of climate of area.
2. **Stability-**The form of climax community is more or less stable with the climate.
3. **Origin and phylogenetic relations -** Climax community is to be treated equivalent to an organism, which take birth, grows and develops and become mature. Similar to the development of organism with changing age, climax communities have also simultaneously undergone changes with changing climate. Thus phylogenetic relation may be established between different climax communities of world.

There have been three popular theories about the climax concept in ecology.

Monoclimax theory- This theory was developed by Clements, he emphasized the importance of only climate in the stabilization of the climax community. According to the monoclimax theory, within a given region all land surfaces eventually tend to be occupied by a single kind of community which is climax. The climax is determined by the regional climate. Given a stable climate the climax community is stable indefinitely. This theory recognises only one climax, determined solely by climate, no matter how great the variety of environmental conditions is at the start. All seral communities in a given region, if allowed sufficient time, world ultimately converge to a single climax.

However, his view was strongly criticised by many ecologists as Cowles, disagreeing with the idea of stability, stated that equilibrium state is never reached and succession is infract a variable rather than constant. According to Cooper, all progressive as well as retrogressive changes in communities reflect succession. Thus he considered climax state as state of minimum change, rather than finally changed state of succession. It is commonly observed that in the same climate, climax communities are different. Because, depending upon their primary stage and habitat characteristic, their successional stages are also different.

Also, in same climate, a lithosere and hydrosere beginning with different pioneer communities and proceeding through different successive developmental stages, might develop into similar climax communities. Similarly, it may not always be true that successions with similar pioneer communities and seral communities would develop in to similar climax communities. In many conditions, in an area of uniform climate, it is common to observe different types of climax communities according to soil, topography and other factors. Under such situations it would not be correct to consider only the climate as determining factor in climax.

Polyclimax theory- The climatic-climax concept of Clements was strongly opposed by ecologists including Tansley (1935) who believed that climax is controlled by many factors. According to this theory a number of different, climax communities may be present in a climatic or geographical region. Thus preclimax, postclimax and disclimax communities are all climax communitiesas they are all self reproducing and able to maintain for an indefinite period of time.This theory does not rule out climax communities but the other stages within the area are also given equal recognition and are not regarded as minor communities. Accordingly it becomes popularly known as **polyclimax theory**. As per this theory the climax stage may be controlled by any factor of the environment and not only by climate. Accordingly the climax stage is to be named, depending upon the nature of the factor in stabilisation. Thus in addition to climatic climax, controlled by climate, there may develop;

1. **Edaphic climax-**On an under developed soil, it develops due to edaphic effects.
2. **Biotic climax-** Developed due to biotic disturbance. Some ecologists make further categorisation in to anthropogenic climax (due to man), grazing climax (due to grazing effects) and zootic climax (due to animals).
3. **Topographic climax-** Due to difference in topographic factors at mountains, hills, mounds etc.
4. **Fire climax-** Due to repeated effects of fire.

Clements introduce in literature a number of new terms, with an attempt to accommodate the intermediate stages in his hypothesis. These are as follows-

Subclimax- the stage in succession just preceding the climatic community was called a subclimax.

Sere climax- the community, which become stabilised at any of the seral stage of succession due to microclimate, or effects of factors a less stabilised dues soil, fire etc, was called a sereclimax.

Disclimax- A disclimax (disturbed climax) is the community which become more or less stabilised due to recurrent disturbance by man or other biotic factors, which prevent the establishment of climatic climax community in the area.

Preclimax - it is the community with life forms lower than those in the expected climatic climax, which might develop in a habitat drier than that of the expected climatic climax.

Postclimax- a strip of community with life forms higher than those in the expected climatic climax and which develops under more moist or colder habitats.

As a result, followers of Clements coined a number of new terms. For instance, coclimax superclimax, quasiclimax, paraclimax, anti-climax, conclimax, peniclimax, metaclimax, pseudoclimax etc.

Climax- pattern hypothesis- This concept about climax was put by R.H. Whittaker (1953). According to this theory, the composition, species structure and balance of a climax community are determined by the total environment of the ecosystem and not by one aspect, such as climate alone. Factors involved are the characters of each populations, their biotic interrelationships, availability of biota to colonise the area, the chance dispersal of seeds and animals, the oil and the climate. The pattern of climax vegetation will change as the environment changes.

On the basis of community gradient analysis, it was postulated that the communities developing at a particular place are in accordance with all the factors of environment. In this area, the vegetation may not be divided into smaller basic units. In fact different climax type is orderly organised parallel to the environment gradient. According to this hypothesis, there is in a sense, only one big community that changes according to soil, slope, and other habitat factors.

Information theory- This theorywas proposed by **Fosberg** (1965, 1967) and **Odum (1969).** It considered succession and climax in terms of ecosystem development. In autotrophic succession, diversity of species tends to increase with an increase in organic matter content and biomass supported by the available energy. Thus in the climax community, the available energy and biomass, which is called **information content**, increases. In contrast to it, in a heterotrophic succession a gradual depletion of energy occurs, because the rate of respiration always exceeds that of production. However in an ecosystem both the autotrophic and heterotrophic successions operate in a coordinate manner. The autotrophic individuals drive mineral elements from the soil and the atmosphere, while the heterotrophic individuals carry on return of the nutrients to the soil and the atmosphere, through the decomposition of complex dead organic matter. Thus succession reaches a stage, the climax stage, when the amount of energy and nutrients received from the environment by the plants is again returned in more or less similar amount to the environment by decomposition through heterotrophs.

7.7 Examples of Succession

Ecological succession can be best illustrated by studying the following examples in different habitats.

Hydrosere (Aquatic succession)

The various stages in a hydrosere are well studied in ponds, in a new virgin pond. Hydrosere starts with the colonisation of some phytoplanktons which forms the pioneer plant community and finally terminates in to a forest (the climax community), the completeprocess of hydrosere includes the following stages.

- Phytoplankton stage
- Rooted submerged stage
- Rooted floating stage
- Reed swamp stage
- Sedge meadow stage
- Woodland stage
- Forest stage

Lithosere (A xerosere on rock)

This type of xerosere originates on rock surface. Substrate is deficient in water and lack of any organic matter.It start from lichen and through a series of serial stages finally terminates in to forest. The serial stages are-

- Custose lichens
- Foliose lichen
- Moss stage
- Herbs stage
- Shrub stage
- Forest stage

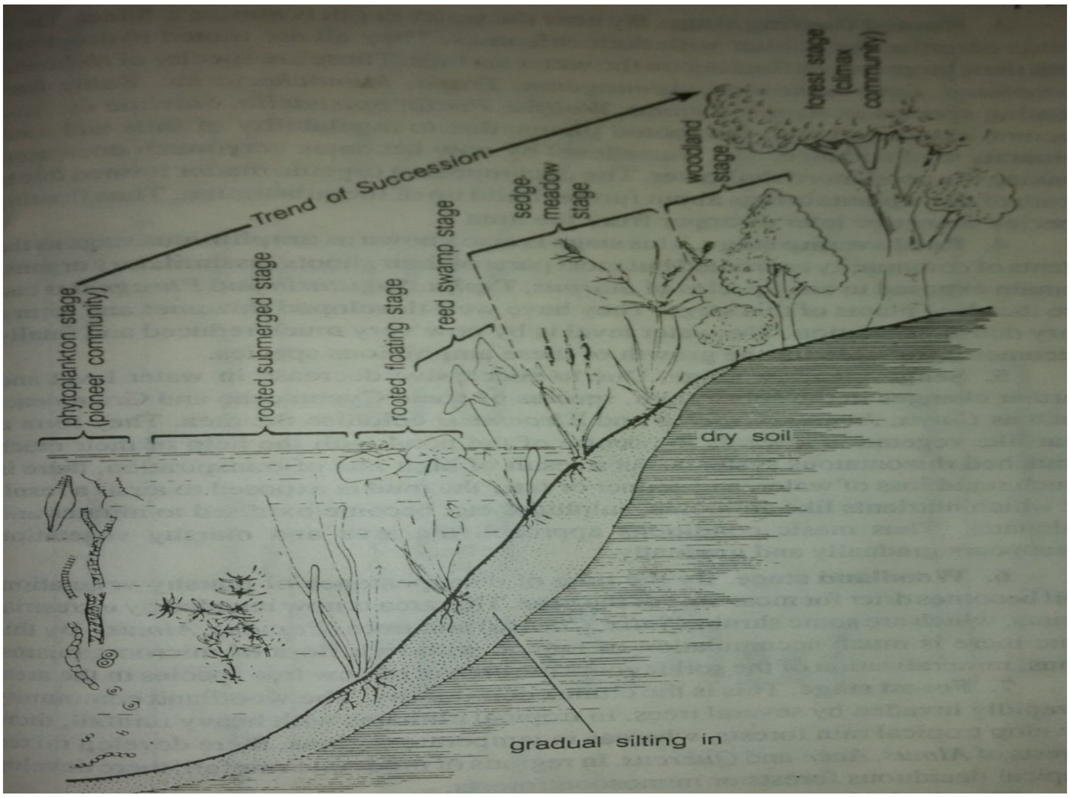

Fig. 7.3 : Hydrosere (Aquatic succession)

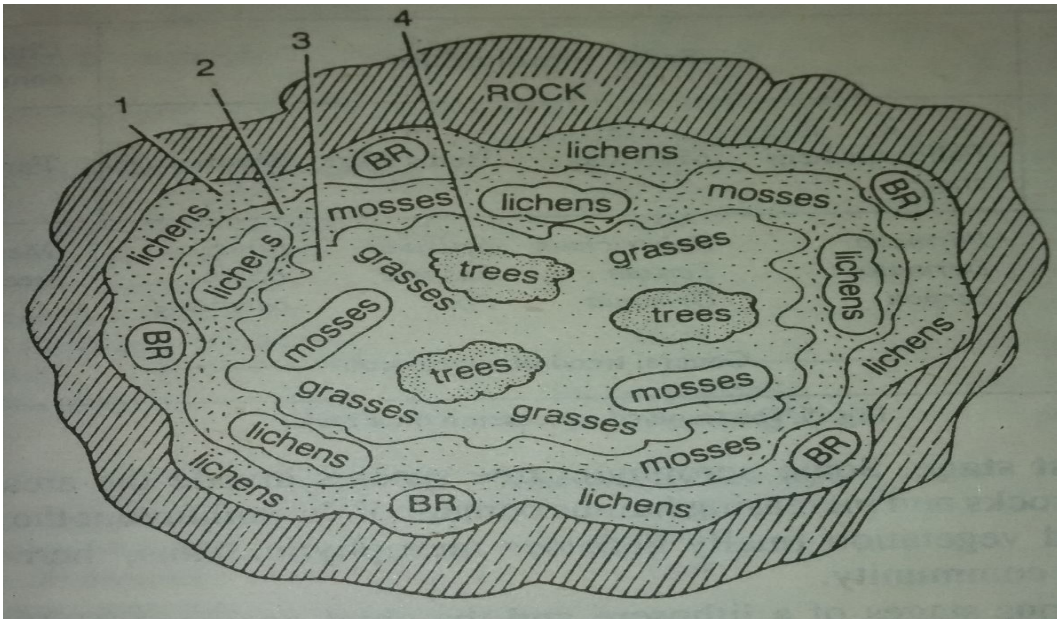

Fig. 7.4 : Lithosere (A xerosere on rock)

7.8 Summary

It can be inferred from above reading that the development of community in an ecosystem begins with pioneer stage which are replaced by a series of more mature communities until a relatively stable community is formed which is in equilibrium with the local conditions. The whole series of communities which develop in a given area is called sere, the relatively transitory communities are called **seral stages** or pioneer stages and the final stabilised community is called **climax community.** The principle of ecological succession is one of the most important aspects of ecology. The remarkable thing about it is directional and predictable, and results from the modification of the physical environment by the community. In the end it culminates in a stabilized ecosystem in which maximum biomass and symbiotic function between organisms are maintained.

7.9 Glossary

- **Abundance :** this is the number of individuals of any species per sampling unit of occurrence. It is calculated as follows.
- **Biological spectrum :** it represents the percentage (%) of the total species in the community.
- **Community :** A group of several species living in similar habitat.
- **Density :** it represents the numerical strength of a species in the community.
- **Desert :** Barren area of land, or dry climatic zone where rain fall is very less (10-25cm) living condition are hostile to the plant and animals.
- **Dominant :** main species of community control other all factor and species.
- **Epiphytes :** Plants grows harmlessly on other plant.
- **Floristic :** vegetation is described in terms of the flora.
- **Frequency :** Frequency is the number of sampling units (as%) in which a particular species occurs.
- **Quadrat method :** Sample unit is a quadrat which is an area of a definite size. In shape, it may be square, rectangle or a circle.
- **Sociability :** Sociability is one of the fundamental qualitative characters of communities.

- **Species :** The group of organism which can interbreed
- **Synthetic characters :** the actually computed or derived characters.

7.10 Self -Learning Exercise

Section- A : (Very Short Answer Type Questions)

1. Stratification is one of the characteristic of a....................
2. Rates of production are generally more than rates of respiration in.......................
3. The hydro sere in a pond begins with..............................
4. The whole sequence from beginning till the climax stage in a succession in a climax in a succession is called a..............................
5. Lichnes are the primary colonisers in a.................... .
6. The final, terminal stabilised stage of a plant succession is called?
7. The earliest stage in plant succession is called?
8. Information theory was proposed by whom?

Section- B : (Short Answer Type Questions)

1. Which method is suitable for study of forest community and why?
2. Define community and write its characters.
3. Write an account on the modified life forms of Braun Blanquet.
4. Explain the analytic characters of community.

Section- C : (Long Answer Type Questions)

1. What is succession? Describe the causes, trends and basic types of succession.
2. Define succession; Give an account of general process of succession in nature.

Answer key of section A

1. Community
2. All Autotrophic successions.
3. phytoplankton.

4. sere.
5. rock
6. climax
7. Nudation
8. Fosberg (1965, 1967) and Odum (1969).

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Unit - 8

Climate Change

Structure of the Unit:

8.0 Objectives

After going through this unit you will be able to

- Understand about climate change and major Global problems
- know the concept of Green House Effect and Green House Gases
- understand the Ozone Layer and its Depletion about Ozone hole
- find out the consequences of climate change

8.1 Introduction

The most significant global environmental problem faced by the world community is related to'Global Environmental Changes' (GEC). Alterations in both physico chemical (Abiotic) and biological (Biotic) components of the biosphere by human, resulted in environmental degradation world over. Major environmental problems, that are infact the manifestation of the degraded environments at global level include air and water pollution, loss of biodiversity, global warming,ozone depletion, emission of green house gases at alarming increasing rate, deforestation etc.

The probable net result of global warming would be climatic changes at local, regional and global levels. The international communities are scared of catastrophic adverse effect of future climatic changes on different spheres of man and nature e.g. sea level changes, submergences of island nations and major coastal low lands, atmospheric dynamics including evaporation and precipitation, global radiation balance, photosynthesis and ecological productivity, plant and animal community, human health and wealth and many more. The major sources of global environmental problems have been identified as rapid rate of industrialization and urbanization, population growth at alarming rate, advancement in productive technology; major land use changes etc and efforts are taking for tackling this alarming problem of global warming leading to climatic changes.

8.2 Consequences of Climate Change

There are many evidences of climate change; these evidences draw the attention at locally and globally. studies of climate were done in past and it is compared with present climatic conditions to prove that climate is changed with time, by various experiments, impact assessments, study of rocks, ice cover, sea levels, radio tagging, analysis of coral rings, tree rings over the time etc. The few facts that indicate the change in atmosphere are-

- Temperature of the earth increased in last few decades called **global warming**.
- Widening of Arctic Ozone hole and **depletion of ozone layer**.
- Oceans are warm leading to sea level rise in different localities.
- Glaciers and snow covers are melting down.
- Arctic ice cover is shrinking in depth and extent.
- Seasonal changes are observed.

- Climatic condition is altered.
- Extreme and erratic weather conditions leading to flood, drought, famine and various diseases.
- More intensive and longer droughts are observed
- Change in vegetation pattern
- Threatened ecosystem, communities and livelihood,
- Loss of land due to inundation and erosion increased flooding and salt water intrusion.
- Effect on coastal agriculture, fisheries, aquaculture, and tourism
- Social economic impacts of climate changes on human civilization

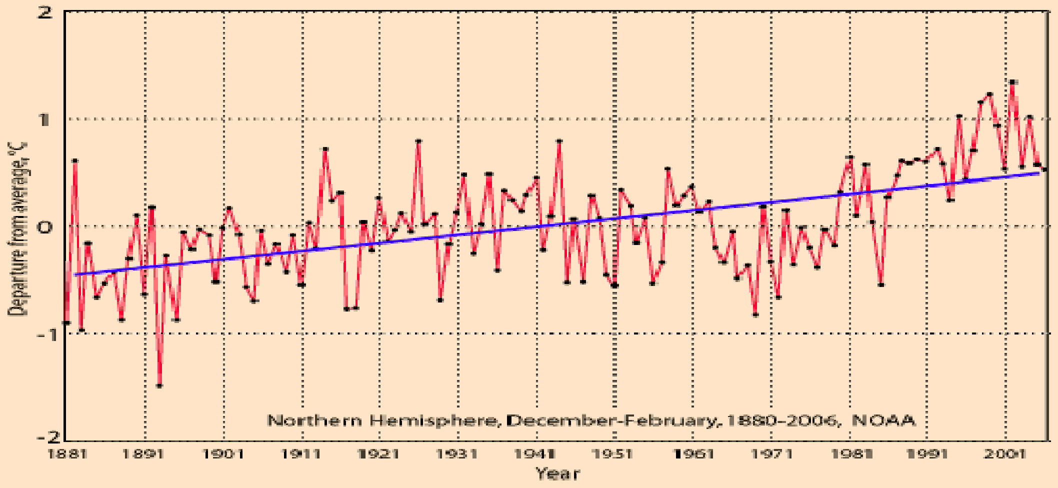
8.3 Global Warming

Global warming refers to gradual rise in atmospheric and ground surface air temperature and consequent change in global radiation balance caused mainly by anthropogenic processes leading to climatic change at different levels (Local, Regional and Global). It may be pointed out that the pattern of global rise in air temperature has been studied and reported by different scientists and agencies but their results are not uniform. Radioactive forcing, as defined and used by intergovernmental panel on climate change(IPCC,1990), refers to the effects which green house gases have in altering the energy balance of the earth atmosphere system'(GWP) is used as a tool to compare the relative warming effect of different gases. There are some differences of opinions, however, about the extent of rise in earth's temperature due to increasing CO_2 levels.

Some analysts believe that changes in the earth's mean temperature will be apparent by 2050, when the temperature would increase by 1.5 to 4.5^0C. According to one projection, changes will be the least in the tropics and the most at the poles.

It has been estimated that the overall increase in the surface air temperature over the past one hundred year has been about 0.05^0 C to 0.7^0 C. It was mentioned that rise of 2^0 C temperature was recorded in the Indian Ocean during 1997-1998 which caused catastrophic coral bleaching leading to 70% death of corals in the Andaman Nicobar and Lakshadweep islands.

Various models have been developed to predict global rise in air temperature. The general circulation model developed by S.Manabe and R.T Wetherald (1975) predicts that if the present amount of carbon dioxide of the atmosphere is doubled, the temperature of the earth's surface will increase by 2.9^0 C.



The temperature has gradually risen over the last 150 years.

Fig. 8.1 : Depiction of the mean temperatures in the northern hemisphere

8.4 Green House Effect

There are two common meanings of the term "greenhouse effect". There is a "natural" greenhouse effect that keeps the Earth's climate warm and habitable. There is also the **"man-made"** greenhouse effect, which is the enhancement of Earth's natural greenhouse effect by the addition of greenhouse gases from the burning of fossil fuels (mainly petroleum, coal, and natural gas).

Fig. 8.2 : **A modern Green House**

The "greenhouse effect" of the atmosphere is named by analogy to Green house which get warmer in sunlight, but the mechanism by which the atmosphere retains heat is different. A greenhouse works primarily by allowing sunlight to warm surfaces inside the structure, but then preventing absorbed heat from leaving the structure through convection i.e. sensible heat transport. The "greenhouse effect" heats the earth because greenhouse gases absorb outgoing radiation energy, heating the atmosphere which then emits radiation energy with some of it going back towards the Earth.

Greenhouse gases keep the Earth warm through a process called the greenhouse effect. CO_2 gas in the atmosphere perform major role of heating up of the atmosphere, due to trapping of infrared rays (from the sun).The sun rays consist of UV, visible, and infrared radiations.

Solar radiation at the frequencies of visible light largely passes through the atmosphere to warm the planetary surface, which then emits this energy at the lower frequencies of infrared thermal radiation. Infrared radiation is absorbed by greenhouse gases, which in turn re-radiate much of the energy to the surface and lower atmosphere. The mechanism is named after the effect of solar radiation passing through glass and warming a green house, but the way it retains heat is fundamentally different as a greenhouse works by reducing airflow, isolating the warm air inside the structure so that heat is not lost by convection.

Thus increasingCO_2 levels tend to warm the air in the lower layers of atmosphere on a global scale. Nearly 100 years ago theCO_2 level was 275 ppm. Today it is

350ppm and by the year 2035-2040 it is expected to reach 450ppm. Every year the world-wide concentration of CO_2 is increasing of a rate of 0.75ppm, and the temperature is rising at a rate 0.05^0C per year. If this continues, the world will go on warming up more and more. This could ultimately melt the glaciers polar icecaps and result in flooding of many low lying areas.

The Green house effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric gases and is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above. If greenhouse gases not trapping the heat in the atmosphere, the Earth would be a very cold place.

Earth's natural greenhouse effect makes life possible. However, human activities, primarily the burning of fossil fuels and clearing of forests, have intensified the natural greenhouse effect, causing global warming.

History- The existence of the greenhouse effect was argued for by Joseph Fourier in 1824. The argument and the evidence were further strengthened by Claude Pouillet in 1827 and 1838. In 1917 Alexander Graham Bell wrote "The unchecked burning of fossil fuels would have a sort of greenhouse effect", and "The net result is the greenhouse becomes a sort of hot-house."

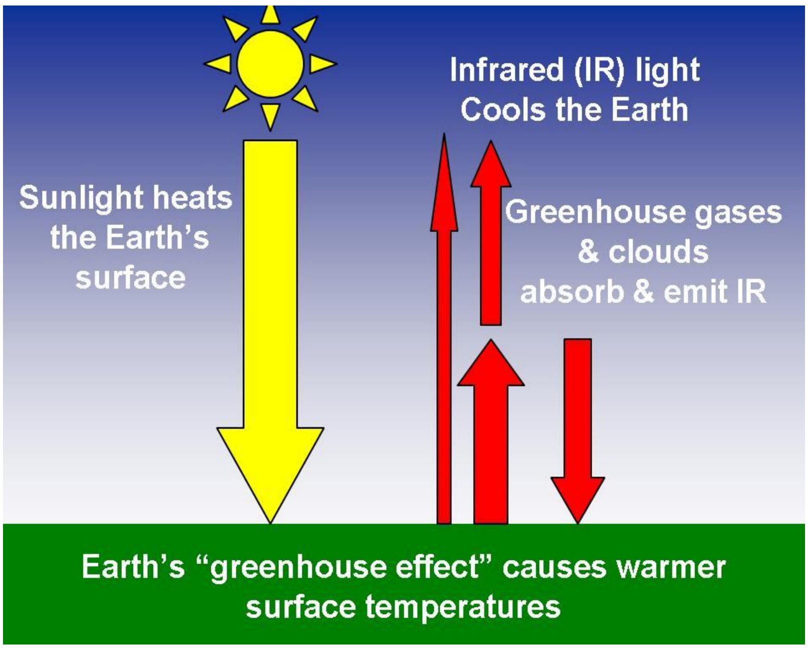


Fig. 8.3 : Green House Effect

Greenhouse gases as sort of a "blanket" for infrared radiation -- they keep the Earth's surface and lower layers of the atmosphere warmer, and the upper layers colder,

Mechanism- The Earth receives energy from the Sun in the form UV, Visible and near IR radiation, most of which passes through the atmosphere without being absorbed. Of the total amount of energy available at the top of the atmosphere (TOA), about 50% is absorbed at the Earth's surface. Because it is warm, the surface radiates far IR thermal radiation that consists of wavelengths that are predominantly much longer than the wavelengths that were absorbed (the overlap between the incident solar spectrum and the terrestrial thermal spectrum is small enough to be neglected for most purposes). Most of this thermal radiation is absorbed by the atmosphere and re-radiated both upwards and downwards; that radiated downwards is absorbed by the Earth's surface. This trapping of long-wavelength thermal radiation leads to a higher equilibrium temperature than the atmosphere were absent.

8.5 Green House Gases

By their percentage contribution to the greenhouse effect on Earth four major gases are-

Water vapours 36-70%

Carbon dioxide 9-26%

Methane 4-9%

Ozone 3-7%

Others (SO_x, NO_x, CFC_s)

About 80-90% of the Earth's natural greenhouse effect is due to water vapour and clouds. Most of the rest is due to carbon dioxide, methane, and a few other minor gases. While the remaining gases in the atmosphere (e.g. nitrogen, oxygen) also absorb and emit a small amount of infrared radiation, their radiative effect on temperature is so weak that they can be neglected. While methane is a much more potent greenhouse gas than carbon-di-oxide, there is far less of it in the atmosphere.

The major non-gas contributor to the **Earth's Greenhouse Effect**, clouds, also absorbs and emits infrared radiation and thus has an effect on radiative properties of the atmosphere.

Strengthening of the greenhouse effect through human activities is known as the **enhanced greenhouse effect**. This increase in radiative forcing from human activity is attributable mainly to increased atmospheric carbon dioxide level. According to the latest Assessment Report from the Inter governmental Panel on Climate Change, "*most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations*". CO_2 is produced by fossil fuel burning and other activities such as cement production and tropical deforestation. Measurements of CO_2 from the Mauna Loa observatory show that concentrations have increased from about 313 ppm in 1960 to about 389 ppm in 2010. It reached the 400ppm milestone on May 9, 2013.The current observed amount of CO_2 exceeds the geological record maxima (~300 ppm) from ice core data. Over the past 800,000 years, ice core data shows that carbon dioxide has varied from values as low as 180 parts per million (ppm) to the pre-industrial level of 270ppm Paleoclimatologist consider variations in carbon dioxide concentration to be a fundamental factor influencing climate variations over this time scale.

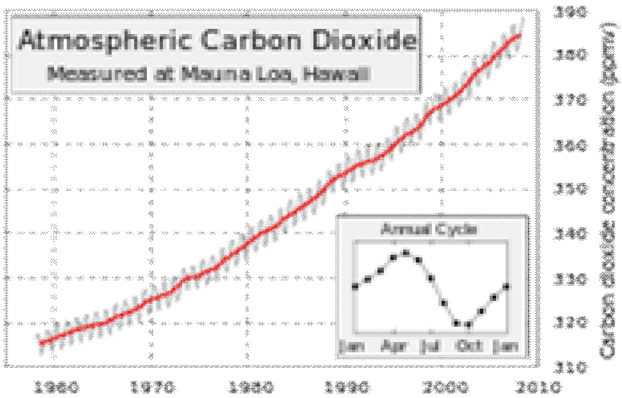


Fig. 8.4 : **The Keeling Curve of atmospheric CO_2 concentrations**

CO_2-Major amount of carbon di oxide is released in atmosphere from burning of fossil fuel, consumed in furnaces of power plants, industries, domestic cooking ete. In our country on average thermal power plants are likely to release around 50 million tonnes of CO_2 each year in the atmosphere. CO_2 is also emitted during volcanic eruptions. To some extent an increase in CO_2 level in atmosphere increases the photosynthesis rate and consequently plant growth, acting as fertilizers especially in hot tropical climates. However an increase in CO_2 concentration in atmosphere may result in to disastrous effects also as green house effect. Since CO_2 is confined exclusively to the troposphere, its higher concentration may act serious pollutants, it is form a layer thus functions like the glass panels of a green house, allowing the sunlight to filter through but preventing the heat from being re radiated in outer space. This is called green house effect. **CO_2** increases the earth temperature by 50% while other is responsible for another 20% increase.

Table-1 : Green House Gases & their Sources

S.No.	GHG's	Sources
1.	CO_2	Burning of solid waste, wood, fossil fuel, deforestation
2.	CH_4	Organic waste deposition,(land fills and livestock farming)Production and transport of fossil fuel.
3.	CFC's	Refrigeration, Solvents, foams, general propellants
4.	NO_x & SO_x	Agricultural and industrial processes.

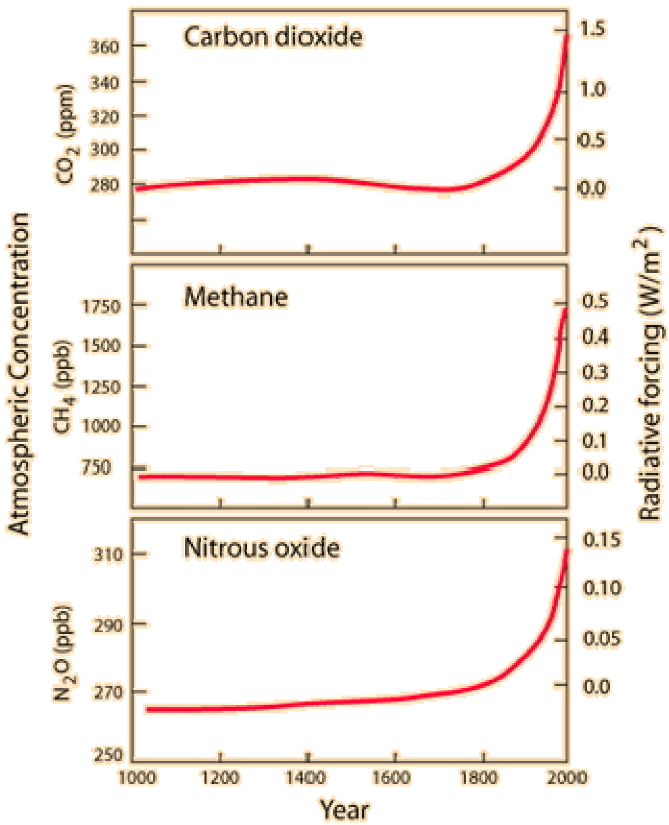


Fig. 8.5 : Grapical Report of increase in Key Green House gases (in IPCC 2007)

IPCC 2007 report shows that most of the increase of the last thousand years has occurred in the past 200 years. The radiative forcing of these gases is related to their concentration.

Methane (CH_4) - The chief source are sulphur springs, volcanic eruptions, organic waste deposition and decaying vegetation , animal matter,(aquatic habitats) combustion processes as stove, furnaces, open fire(forest),burning coal mines, power plants, production and transportation of fossil fuel, etc.

Sulphur compounds- From amongst several other major sulphur compounds in the atmosphere, the oxides of sulphur are the most serious pollutants. The chief sources of oxides of sulphur are the combustion of coal and petroleum. Thus most of the oxides come from thermal power plants and other coal based plants and smelting complexes. Automobiles also released SO_2 in air.

Nitrogen Oxide- Even in unpolluted atmosphere, measurable amount of nitrous, nitric oxide and nitrogen dioxide is present. These are produced by combustion of oxygen and nitrogen during lightening discharges and bacterial oxidation of ammonium in soil.

Chloro floro carbon-These are themajorpollutants responsible for depletion of ozone layer, CFCs are widely used as coolants in air conditioners and refrigerators, cleaning solvents, aerosol propellants and in foam insulation. It is also used in fire extinguishing equipments. Depletion of ozone would lead to serious temperature change on the earth and consequent damage to life support system.

8.6 Ozone Layer, its Depletion and Ozone Hole

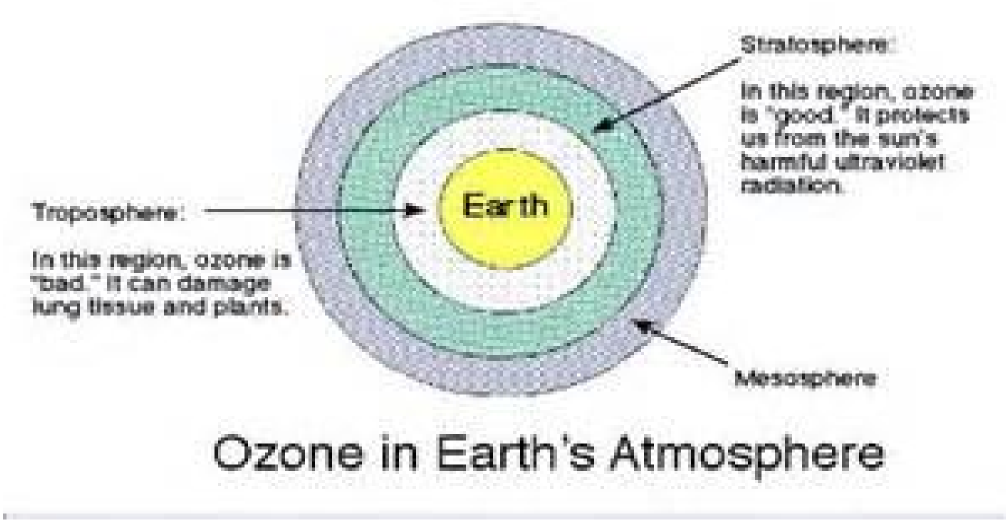


Fig. 8.6 : **Ozone in Earth's Atmosphere**

An allotrope of oxygen is produced in the upper layer about 20km above the earth surface in the atmosphere from oxygen gas by the absorption of ultraviolet light. Air in the upper layer is quite rich in ozone. Ozone checks the entry of ultraviolet light from sunlight; otherwise sunlight would destroy many of the organic materials necessary for life. Life would not have evolved or existed in the present form, if the UV light were not checked from reaching to the surface of the earth. Thus ozone formation has helped in the existence of human life in the present form. If ozone layer in the atmosphere is depleted, then the harmful UV radiation (coming from the sun) would reach to the earth. These UV radiation would; (1) damage the plants (2) cause diseases like skin concer in animals and men and(3) ultimately cause the gradual destruction of life on the earth.

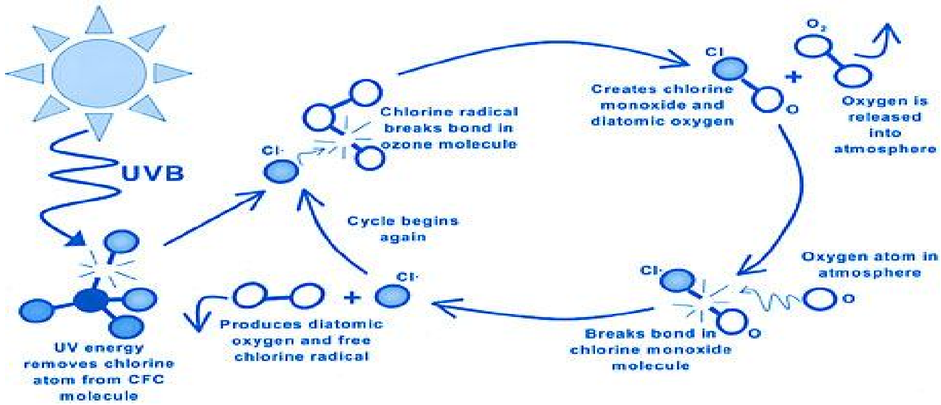


Fig. 8.7 : **Mechanism of Ozone Layer Depletion**

It is universal that the ozone layer in the stratosphere protects us from the harmful UV radiation from sun. The depletion of this O_3 layer by human activities may have serious implications and this has become the subject of much concern over the last few years. Ozone is also formed in the atmosphere through the chemical reactions involving certain pollutants (SO_2, NO_2, aldehydes) on absorption of UV radiations. The ozone near the earth's surface in the troposphere creates pollution problems. Ozone and other oxidants such as peroxyacetyl nitrate (PAN) and hydrogen peroxide are formed by light dependent reactions between NO_2 and hydrocarbons. Ozone may also be formed by NO_2 under UV radiations effect. These pollutants cause **Photochemical Smog**. The atmospheric ozone is now being regarded as potential danger to human health and crop growth. What makes ozone a destroyer as well as a protector needs to be elaborated to have a clear picture of its bio potency from human welfare view point.

Cause of Depletion of Ozone Layer

Chlorofluorocarbons (CFCs) are the exhausts of supersonic aircraft and jumbo jets flying in the upper atmosphere. These got accumulated at high altitudes and undergo decomposition, under the influence of ultraviolet radiation. One of the main decomposition products is chlorine. Each atom of chlorine so released reacts with more than 10^5 molecules of ozone converting ozone in to oxygen. Consequently gradual depletion of ozone layer takes place and the effective capacity of ozone layer to stop ultraviolet radiation from entering the environment diminishes.

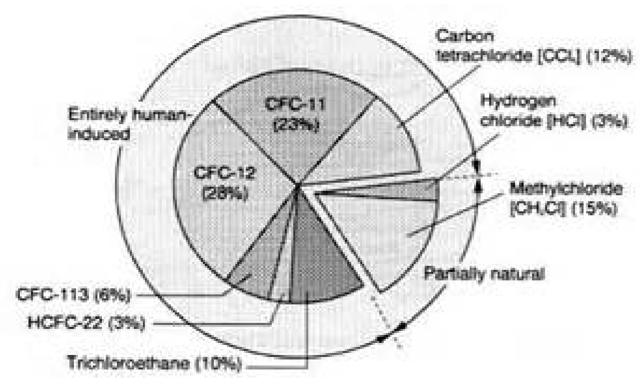


Fig. 8.8 : **Gases responsible for Ozone Layer Depletion**

Table-2 : Important CFCs and their uses

CFC	Uses
Frean-11(CCl_3F)	**Refrigeration, aerosol- propellants, cleaning foams, air conditioning**
Frean-11(CCl_3F_2)	**Refrigeration, aerosol- propellants, cleaning foams, air conditioning, sterilization.**

Ozone Hole-Ozone depletion describes two distinct but related phenomena observed since the late 1970s: a steady decline of about 4% in the total volume of ozone in earth's stratosphere, and a much larger springtime decrease in stratospheric ozone around **Earth's Polar Regions**. The latter phenomenon is referred to as the **ozone hole**. The details of polar ozone hole formation differ from that of mid-latitude thinning but the most important process in both is catalytic destruction of ozone by atomic halogens. The main source of these halogen atoms in the stratosphere is photo dissociation of man-made halo carbons. These compounds are transported into the stratosphere by winds after being emitted at the surface. Both types of ozone depletion were observed to increase as emissions of halocarbons increased.

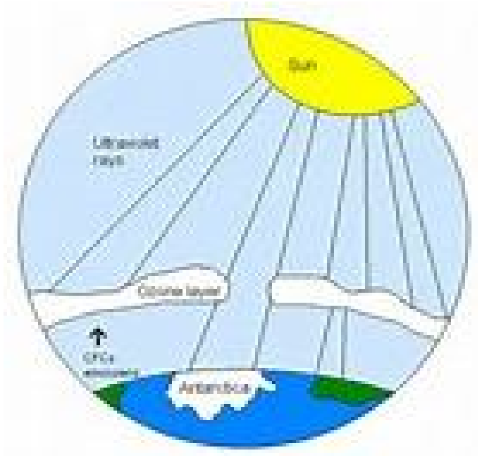


Fig. 8.9 : **Ozone Hole**

CFCs and other contributory substances are referred to as **ozone-depleting substances** (**ODS**). Since the ozone layer prevents most harmful UV wavelengths (280–315 nm) from passing through the earth atmosphere, it is observed and projected decrease in ozone generated worldwide concern, leading to adoption of theory Montreal Protocol that bans the production of CFCs, halons, and other ozone-depleting chemicals such as carbon tetrachloride and trichloroethane. It is suspected that a variety of biological consequences such as increases in sunburn, skin cancer, cataracts, damage to plants, and reduction of plankton's populations in the ocean's Photic zonemay result from the increased UV exposure due to ozone depletion.

The Antarctic ozone hole is an area of the Antarctic stratosphere in which the recent ozone levels have dropped to as low as 33% of their pre-1975 values. The ozone hole occurs during the Antarctic spring, from September to early December

Biological Effect of Ozone depletion

Biological effects

The main public concern regarding the ozone hole has been the effects of increased surface UV radiation on human health. Ozone depletion would magnify all of the effect of UV on human health effects, both positive (including production of Vitamin D) and negative (including sunburn, skin cancer, and cataracts). In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans.

(a) Cancer

The most common forms of skin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Scientists have estimated that every 1% decrease in long-term stratospheric ozone would increase the incidence of these cancers by 2%.

Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15–20% of the cases diagnosed. The relationship between malignant melanoma and ultraviolet exposure is not yet fully understood, but it appears that both UVB and UVA are involved. Because of this uncertainty, it is difficult to estimate the impact of ozone depletion on melanoma incidence.

(b) Cortical cataracts

Epidemiological studies suggest an association between ocular cortical cataracts and UVB exposure, using crude approximations of exposure and various cataract assessment techniques. In this highly exposed group of predominantly white males, the evidence linking cortical opacities to sunlight exposure was the strongest to date. Based on these results, ozone depletion is predicted to cause hundreds of thousands of additional cataracts by 2050.

Increased surface UV leads to increased tropospheric ozone. Ground-level ozone is generally recognized to be a health risk, as ozone is toxic due to its strong oxidant properties. The risks are particularly high for young children, the elderly, and those with asthma or other respiratory difficulties. At this time, ozone at ground level is produced mainly by the action of UV radiation on combustion gases from vehicle exhausts.

Vitamin D is produced in the skin by ultraviolet light. Thus, higher UVB exposure raises human vitamin D in those deficient in it.

(c) Effects on crops

An increase of UV radiation would be expected to affect crops. A number of economically important species of plants, such as rice, depend on cynobacteria residing on their roots for the retention of nitrogen. Cynobacteria are sensitive to UV radiation and would be affected by its increase. "Despite mechanisms to reduce or repair the effects of increased ultraviolet radiation, plants have a limited ability to adapt to increased levels of UVB, therefore plant growth can be directly affected by UVB radiation.

Location of hole-Some people thought that the ozone hole should be above the sources of CFCs. However, CFCs are well mixed globally in the Troposphere and stratosphere. The reason for occurrence of the ozone hole above Antarctica is not because there are more CFCs concentrated but because the low temperatures help form polar stratospheric clouds. In fact, there are findings of significant and localized "ozone holes" above other parts of the earth.

8.7 Carbon di oxide Fertilization

CO_2Fertilization means '**Enhancement of plant growth or the net primary production by CO_2 enrichment that could occur in natural or agricultural systems as a result of an increase in the atmospheric concentration of CO_2'.**

Recent study by the Intergovernmental Panel on Climate Change (IPCC) (2001, 2007) indicate that greenhouse gas (GHG) emissions and resultant atmospheric concentrations have led to changes in the world's climate conditions including temperature and precipitation. The implications of climate change and atmospheric GHG concentrations for crop yields, and economic welfare has stimulated many studies. A wide variety of findings have arisen regarding the effect of climate change on crop yields. Many studies find that climate change alters mean crop yields

In addition to being a greenhouse gas, carbon dioxide (CO_2) plays a central role in one of our planet's most important chemical cycles: the one involving photosynthesis and respiration. Green plants take in CO_2 and emit oxygen (O_2) while making food. We respires eat the food, inhale O_2, burn the food for energy, and exhale CO_2.

So, CO_2 in the atmosphere is essential to green plants — in fact, as atmospheric CO_2 concentrations increase, green plants become more productive. We call this the fertilization effect, and generally it's a good thing because:

- It helps dampen the effects of CO_2 emissions we humans generate (because the more CO_2 in the atmosphere, the more productive green plants are and the more CO_2 they draw down);

- It helps crops grow faster because they are among the myriad plants fertilized by CO_2

Of course, increased CO_2mean an overall increase in crop yields since we must aware of other factors in the confounding effects of climate change (e.g., heat stress, changing precipitation patterns, increasing weather variability, rising sea levels). The overall impact of crop yields will be a mixed bag, And some new research suggests negative points in the fertilization effect‘s in place of positive effect on crops. Sure, increased CO_2 will make crops more productive, but the quality of the crops may be degraded.

The term **'carbon dioxide fertilization'** as it applies to the area of the environment can be defined as **'The enhancement of the growth of plants as a result of increased atmospheric CO_2 concentration**. Depending on their mechanism of photosynthesis, certain types of plants are more sensitive to changes in atmospheric CO_2 concentration.

Carbon fertilization is a theory that states increased CO_2 resulted by global warming would cause a positive agricultural productivity in certain geographical locations, instead of negative which global warming advocates seem to claim. The CO_2 fertilization effect is not going to "save" us from the consequences of global warming. News coverage has focused almost solely on the "greening" angle of increased levels of atmospheric CO_2 and neglects to mention negative impacts of climate change that are highly detrimental to human agriculture and plant ecosystems in general. Climate impacts like drought, floods, extreme weather, shifting seasons, and increasing ranges of weeds, invasive species, and plant pests will all negatively impact crop yields.

Based on satellite observations, researchers found that leaf cover in some arid zones increased by 11% as a result of a process called the **CO_2 fertilization effect**, which helps plants grow more efficiently in high-CO_2environments. Subsequent coverage of the study omitted most of the other known effects of CO_2 and global warming; giving the impression that increasing CO_2 will result in a lush, green planet and more productive agriculture.

The CO_2 fertilization effect is by no means going to "save" us from the devastating consequences of global warming.

- While enhanced CO_2 allows plants to maximize their water efficiency (requiring less water to achieve photosynthesis) the levels of other nutrients still limit growth.
- Weeds and other undesirable plants experience CO_2 fertilization as well. Many weeds are tropical or subtropical, and are likely to move northward to new areas as a response to warming temperatures.
- Increased temperatures and extreme weather events have already begun hurting crop production. For example, Corn production suffered as a result of the 2012 drought.
- Climate change redistributes rainfall around the world, and while increased greening has been observed in some areas, increased drought and desertification has occurred in others.
- So while plant production in some arid regions may benefit from higher CO_2concentrations, in many other regions nutrient limitation will prevent much greening. Furthermore, any benefits that do occur are erased by the many negative impacts associated with climate change that lead to net losses.

8.8 Sea Level Rise

Current sea level rise is about 3 mm/year worldwide. According to the US National Oceanic and Atmospheric Administration (NOAA), "this is a significantly larger rate than the sea-level rise averaged over the last several thousand years", Sea level rises can considerably influence human populations in coastal and island regionsand natural environments like marine ecosystem.

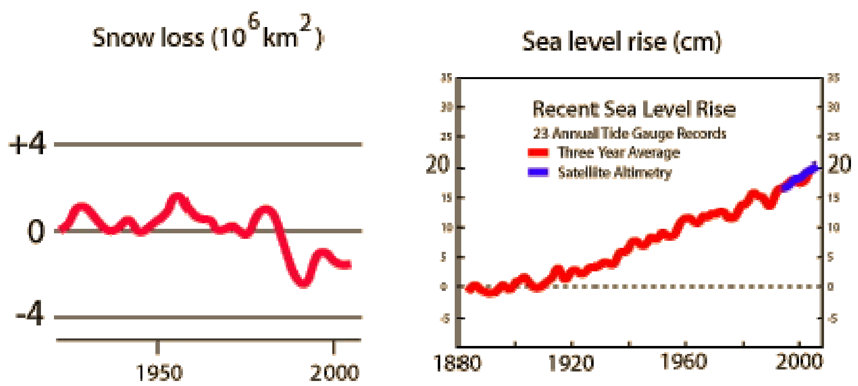


Fig. 8.11 : Loss of Snow Cover and Rise in Sea Level

Because the potential consequences of global warming in terms of loss of snow cover, sea level rise, change in weather patterns, etc are so great, it is a major societal concern.

There are two main mechanisms that contribute to observed sea level rise:

(1) Thermal Expansion- ocean water expands as it warms.

(2) The melting of major stores of land ice like ice sheets and glaciers.

Sea level rise is one of several lines of evidence that support the view that that the global climate has recently warmed. In 2007, the Intergovernmental Panel on Climate Change (IPCC) stated that it is very likely human induced (anthropogenic) warming contributed to the sea level rise observed in the latter half of the 20th century. Sea level rise is expected to continue for centuries.In 2013, the (IPCC) projected that during the 21st century, sea level will rise another 26cm to 82cm in its fifth assessment report.

History- There is strong evidence that global sea level gradually rose in the 20th century and is currently rising at an increased rate, after a period of little change between AD 0 and AD 1900. Sea level is projected to rise at an even greater rate in this century. Global sea level rose by about 120 m during the several millenia that followed the end of the last ice age (approximately 21,000 years ago), and stabilised between 3,000 and 2,000 years ago. Sea level indicators suggest that global sea level did not change significantly from then until the late 19th century. The instrumental record of modern sea level change shows evidence for onset of sea level rise during the 19th century. Estimates for the 20th century show that global average sea level rose at a rate of about 1.7 mm yr–1.

Satellite observations available since the early 1990s provide more accurate sea level data with nearly global coverage. This decade-long satellite altimetry data set shows that since 1993, sea level has been rising at a rate of around **3 mm yr–1,** significantly higher than the average during the previous half century. Coastal tide gauge measurements confirm this observation, and indicate that similar rates have occurred in some earlier decades.

In agreement with climate models, satellite data and hydro graphic observations show that sea level is not rising uniformly around the world. In some regions, rates are up to several times the global mean rise, while in other regions sea level is falling. Substantial spatial variation in rates of sea level change is also inferred from hydro graphic observations. Spatial variability of the rates of sea level rise is mostly due to non-uniform changes in temperature and salinity and related to changes in the ocean circulation.

Causes of Sea Level Rise

Thermal Expansion: Global warming not only causes the temperature on land to increase, but also leads to an increase in sea water warming. This warming started mainly during industrial evolution, and intensified when more and more trees were being cut down. Thermal expansion also affects the movement of hot and cold oceanic currents around the globe these changes ultimately affect the sea level. Due to temperature water expends and its volume increases leads to periodic rise in sea level.

Melting of Glaciers: As glaciers and polar caps melt during the summer seasons, as the ice thicking increases in winter again. This is the normal seasonal rise and fall. But due to slowly increasing global warming more and more ice melt in summer leading to greater run off flow. As the evaporation rate of sea water is constant, a large volume of excess water remains in oceans, adding up the overall volume ultimately cause rise in sea water level.

Effect of sea level rise : Erosion of sea shore line is one of the first effects of sea level rise, and it greatly hampers the coastal cities and towns.

Destabilization of coastal areas due to strong waves that crash on to shoe line and increases the erosion rate.

Waves intrude a longer distance over land areas, posing risk to human life and property

As the water level increases the damage caused by sea storm also penetrates inland region with successive rise in intensity, as the volume of water grows many low lying regions face the possibilities of getting inundated permanently.

Even a few centimeters of rise in sea levels can completely drown several acres of coastal areas.

This also leads to salt water intrusion in freshwater sources present near the coast, make water unfit for consumption and can't be used for agriculture.

Possible solution and Mitigation Measures: Building tall well, levees or similar structures near coast line (primary levels)

Planting and maintaining mangrove consider as natural mitigation strategy it reduces intensity of waves

Other method of maintaining buffer zones including wet lands, marshes, barrier islands, coral reefs etc

Building of artificial islands act as buffer to a sensitive coastal line

Temporary installation of porous rock structures on the shores

The most important and long term mitigation measure is to reduce our carbon footprint, and reduce harmful emissions ultimately reduce global warming.

8.9 Copenhagen Summit (2009) and Montreal Protocol (1987)

Copenhagen summit (2009) was a global effort to come to term in the context of climatic change. However it failed to achieve a meaningful and multi lateral commitment deal, with relation to the climatic crisis. The goal was to reach an agreement to take effect in 2012, and it was widely regarded as humanity's last good chance to prevent and mitigate catastrophic climatic change.

Montreal protocol (1987) - Efforts are being made to control ozone depletion and green house effects at global level, the formulation of Montreal protocol in September 1987 under the leadership of UNO- sponsored United Nations Environment Programme (UNEP), the international conference on depletion of ozone layer in London, held from march 5 to 7 1989, wherein government official scientist and industrialist of 180 countries participated

8.10 Summary

Human activities has very likely been the cause of global warming, since the industrial revolution and the mid- 1950 to till date. Anthropogenic or human induced processes, in time have contributed to the increase in green house gases and Global Warming. Green house effect and ozone layer and its hole are to be understood as problem of 21st century. Carbon di oxide is a major green house gas. The emission of CO_2 is primarily by combustion of fossil fuel. Chloro floro carbons are the major courses of ozone layer depletion. Destruction of ozone layer and the incidence of UV radiation and their effect on human, landscape and material as historical monuments it's evident in present scenario.There is strong evidence that global sea level gradually rose in the 20th century and is currently rising at an increased rate.The potential consequences of global warming in terms of loss of snow cover, sea level rise, change in weather patterns, etc are so great, it is a major societal concern.

CO_2 in the atmosphere is essential for green plants, as atmospheric CO_2 concentrations increase, green plants become more productive. This is known as the fertilization effect of CO_2.. Beside this, we must be aware of other factors in the confounding effects of climate change (e.g., heat stress, changing precipitation patterns, increasing weather variability, rising sea levels).

CFCs and other contributory substances are referred to as **ozone-depleting substances** (**ODS**). Since the ozone layer prevents most harmful UV wavelengths (280–315 nm) from passing through the earth atmosphere and projected decrease in ozone generated worldwide concern, leading to adoption of theory Montreal Protocol that bans the production of CFCs, halons, and other ozone-depleting chemicals such as carbon tetrachloride and trichloroethane.

Climate change and global warming are important environmental issues, which need to be addressed by all nations, with a sense of responsibility and act towards its mitigation. The UNEP has appropriately chosen the slogan **Global Warming; Global Warning'** to alert the people on **World Environment Day, June 5, 1989**.

8.11 Glossary

- **Anthropogenic :** Human induced processes.
- **Carbon dioxide fertilization :** 'The enhancement of the growth of plants as a result of increased atmospheric CO_2 concentration.
- **CFCs :** Chloroflorocarbons.
- **Enhanced greenhouse effect :** Strengthening of the greenhouse effect through human activities is known as the enhanced greenhouse effect.
- **GEC :** Global environment changes.
- **Glaciers :** Snow cover on mountain peaks start melting due to global warming.
- **Global warming : Rise** in earth mean temperature.
- **Greenhouse effect :** Greenhouse gases keep the Earth warm through a process called the greenhouse effect.
- **ODS : Ozone-** depleting substances.

- **PAN :** Peroxyacetyle nitrate.
- **Thermal Expansion :** Sea water warming.
- **UV radiations :** Ultra violet radiations.

8.12 Self-Learning Exercise

Section- A : (Very Short Answer Type Questions)

1. Green house effect is caused by....................
2. The maximum amount of pollutant released by thermal power plant is.......................
3. Electrostatic precipitator is used to control.............................
4. Fertilization effect on plant was shown by .... gas.
5. Depletion of Ozone layer on poles known as.................... .
6. The main cause of ozone depletion is...............
7. Montreal protocol is concern with………………….
8. Write full form of UNEP?

Section- B : (Short Answer Type Questions)

1. Write a short note on global climate changes.
2. What is the importance of stratospheric ozone?
3. Write an account on source, trend and role of green house gases.
4. Explain the phenomena of sea level rise.

Section- C : (Long Answer Type Questions)

1. What is Global warming? Describe the causes, trends and evidences for global warming?

2 Write detailed notes on—

   A. Carbon di oxide Fertilization

   B. Effects of Ozone depletion

Answer key of section A

1. Carbon di oxide

2. Particulate matter, CO, SOx
3. Air pollution
4. CO_2
5. Ozone hole
6. Chlorofluorocarbon
7. Ozone deplition
8. United Nations Environment Programme.

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Unit-9

Environmental Pollution

Structure of the Unit:

9.0 Objectives

After studying this unit the student will come to know

- about environment and environment pollution.
- about air, water, soil and noise pollution

9.1 Introduction

All living organisms of the Earth are depending upon a balanced environment for growth and complete their life cycle in the systematic manner. All components of balanced environment are present in a definite ratio and proportion but sometimes the ratio of the component are disturbed i.e., either increase or decrease or sometimes some other harmful components which are not the part of natural environment enter it, due to which the environment gets polluted and these are harmful for the living organisms. In any desirable change of the physical, chemical and biological characteristics in the atmosphere, lithosphere and hydrosphere which is harmful to man directly or indirectly, plants, industrial units or raw material is called pollution. Most of today's problems are due to man as a pollution source. There is no way for nature to decompose many man made materials and return their elements to the cycle of nature. Such substances will just remain and will cause whatever harmful effects they can until they somehow dispersed so that their action is no longer noticeable. The increase in population of man arise the problem of balanced and clean environment. In large industrialized countries with large cities the problem of disposal of sewage and industrial wastes has become severe and polluted the air, water, soil and sound wave.

Physically environment can divided in the three parts.

1. **Lithosphere-**This environment is included rocks, sands etc. lithosphere is most beneficial for plant kingdom because the plants take minerals from lithosphere.
2. **Hydrosphere-** This environment water is present on lithosphere. It includes rivers, streams, lakes and seas.

3. **Atmosphere-** The Atmosphere is a layer of gases and envelop of the earth. The lithosphere and hydrosphere are surrounded up to 200 miles by atmosphere. The major gases in the atmosphere are Nitrogen, Oxygen, Argon and Carbon dioxide. The lithosphere, hydrosphere and atmosphere in which living organism live and interact with one another is called **biosphere.**

On the variety of pollutants, we recognize the following two basic types of pollutants.

1- **Non-Biodegradable pollutants-** Those substance which are usually not present in the environment e.g., aluminium cans, mercuric salts, long chain phenolics and DDT etc. that either do not degrade or degrade very slowly in nature.
2- **Biodegradable pollutants-** The organic waste are drained out of residential buildings which are easily degraded completely by the help of microorganism. This process is useful for ecosystem.

9.2 Types of Pollution

Various types of pollutions are classified in different ways. On the basis of the type of environment being polluted, mainly there are following types of pollution:

- Air pollution
- Water pollution
- Soil pollution
- Noise pollution

9.3 Air Pollution

Pure air is colourless and odourless. But various pollutants from natural and man-made sources are entering the atmosphere daily and they disturb the dynamic equilibrium in the atmosphere. The activity of living organisms and different gases in the atmosphere are found in a definite ratio and proportions. There is a cycling of the gases between the living organisms and environment. It is due to organisms that oxygen and carbon dioxide are found in the balanced level in the atmosphere. Carbon dioxide constantly released into the atmosphere by the respiration of living organisms and oxygen is constantly taken up from atmosphere by the living organisms for respiration. Green plant absorb carbon dioxide for photosynthesis and release oxygen as a byproduct of photosynthesis due to this process the carbon dioxide and oxygen are maintained in the atmosphere.

The atmosphere is an envelope of gases is divided in to the following layers.

1- **Troposphere-** This layer is up to five kilometers. The lowest atmosphere in which temperature decreases with height bounded by sea surface. In this layer mainly nitrogen, oxygen, carbon dioxide and water vapors are present.
2- **Stratosphere-** This layer is from 5 to 45 kilometers. This layer is above the troposphere. The temperature increase up to 90 degree centigrade. Most common chemical compound of this layer is ozone.
3- **Mesosphere-** This layer is from 45 to 80 kilometers. This layer is between the stratosphere and thermosphere. Most common chemical compound of this layer is oxygen and nitric oxide.
4- **Thermosphere-** This layer is present above the 80 kilometer. This layer is also called the **ionosphere**. Chemical compound oxygen and nitric acid is also present in this layer.

9.3.1 Sources

Air pollution is mainly from industry, thermal power station, automobile and domestic combustion etc. There are a number of industries which are the source of air pollution. Petroleum refineries are the major source of gaseous pollutants. Some air pollutants and their sources are given in table 9.1.

Table- 9.1: Some Air Pollutants and their Sources

S.No.	Air Pollutant	Major sources	%
1	Sulphur oxide	Combustion of fuels Industrial processes	78 18
2	Nitrogen Oxide	Transportation by automobile Combustion of fuels by natural gas and coal	52 44

3	Carbon monooxide	Transportation by automobile Agricultural burning	75 9
4	Ozone	Concentration of ozone depend on reaction of lower atmosphere involving hydrocarbons and automobile exhaust	
5	Hydrocarbons	Transportation by automobile Industrial processes Evaporation of organic solvents	56 16 9
6	Particulates	Industrial processes Combustion of fuels Agriculture burning	51 26 8

The chief gases are sulphur dioxide and nitrous oxide. The major source of sulphur dioxide is the burning of fossil fuels, mostly coal in power plants. Another major source comprises a variety of industrial process, ranging from petroleum refining to the production of cement, aluminum and paper. It is colourless and odourless gas, normally present at the earth surface at low concentration. Higher concentration of sulphur dioxide may cause death of the cells.

Oxides of nitrogen are emitted in several forms like nitric oxide, nitrous oxide and nitrogen dioxide. In unpolluted atmosphere, there are present measurable amounts of nitrous oxide, nitric oxide and nitrogen dioxide. Of these nitric oxide is the pivot compound. It is produced by the combustion of oxygen and nitrogen during lightning discharges and by bacterial oxidation of ammonia in soil. In urban areas about 46% of oxides of nitrogen in air come from vehicles and 25% from electric generation and rest from other sources. In metropolitan cities, vehicular exhaust is the most important source of nitrogen oxide. In atmosphere maximum nitrous oxide levels are about 0.5 ppm, whereas average global levels estimated to be nearly 0.25 ppm. This gas has so far not been implicated in air pollution. At high temperature, combustion of gasoline produces nitric oxide. A large amount of nitric oxide is readily converted to more toxic nitrogen dioxide in the atmosphere. Nitric oxide is responsible for several photochemical reactions in the atmosphere.

Carbon monoxide is highly dangerous gas form when fuels have too little oxygen to burn completely. It spews out in car exhausts and it can also build up to dangerous levels inside your home if you have a poorly maintained stove or fuel burning appliance. Carbon dioxide gas is central to everyday life and it is not normally considered pollutants.

Ozone is formed in the atmosphere through chemical reactions involving certain pollutants on absorption of UV-radiations. The atmospheric ozone is now being regarded as potential danger to human health and crop growth.

Fluorides in atmosphere come from industrial processes of phosphate fertilizers, ceramics, aluminium, fluorinated hydrocarbons, fluorinated plastic, uranium and other metals.

Chloroflurocarbons are one of the harmful gases which are widely used in refrigerators and aerosol cans.

The main source of hydrocarbons is motor vehicles, being emitted by evaporation of gasoline through carburetors, crankcase etc. In India, two and three-wheelers are the main contributors.

In air, the common metal is mercury which is mainly released from industries and human activities in the atmosphere. Mercury compound is mostly used in the production of fungicides, paints, cosmetics, paper pulp etc.

9.3.2 Quality Parameters

Each pollutant in the air has limiting concentration. Air quality measurement is complicated by the lack of knowledge as to what is clean air and by the difficulty in defining quality. Pure air contains only the naturally occurring gases but pure air does not occur in nature. Pollen particle, dust, fog etc. are all natural contaminants. Each pollutant, present in air, has a threshold limit value (TLV) which, if exceeded, causes public health hazards. The list of typical pollutants with their threshold limits are given in table 9.2. For factory workers TLV set the limit of exposure for 40 hours a week (8 hours a day) without adverse effect. These TLV values are determined mainly by experiments on animals.

Table- 9.2: Threshold Limit Value (TLV) for Common Pollutants (Gases and Vapours)

S.No.	Pollutant	ppm (TLV)	Mg/m3
1	Acetone	750	1780
2	Ammonia	25	18
3	Arsenic	0.2-0.5	-
4	Benzene	10	20
5	Cadmium	-	0.05
6	Carbon dioxide	5000	9000
7	Carbon monoxide	50	50
8	Carbon tetrachloride	5	30
9	Chlorine	10	30
10	Chloroform	10	50
11	Hydrogen chloride	5	7
12	Hydrogen sulphide	10	14
13	Lead	-	0.2
14	Nitric oxide	25	30
15	Ozone	0.1	0.2
16	Sulphur dioxide	2.0	5.0
17	Vinyl chloride	5	10

9.3.3 Effects

Air pollution can harm the health of people and animals, damage crops or stop them growing properly, and make our world unpleasant and unattractive in a variety of other ways.

1. Green house effect

The sun light that reaches the Earth warms atmosphere and the earth surface. The Earth's atmospheric system then reradiates the heat as infrared radiation. Water vapors and other several gases, including carbon di-oxide, methane and CFCs, warm the Earth's atmosphere because they absorb and reemit radiation. This is called green house effect because it is like the glass of a greenhouse that allows sunlight to pass through and then traps the resulting heat inside the structure. Carbon dioxide is the principal **"green house gas"** responsible for warming the earth. Carbon dioxide is rising into the atmosphere slowly as a result of large scale burning of fossil fuels. This rise in temperature would result in melting of the polar ice caps and would add more water to the sea. There would be coastal flooding and the possible loss of many cities like Bombay, Calcutta and Trivandrum etc.

2. Ozone shield holes effect

In stratosphere there is a layer of ozone called an **ozone shield** that absorbs the ultraviolet rays of the sun. Ultraviolet radiation cause mutations that can develop skin cancer and causes eye cataracts. Ultraviolet rays also affect our immune system and also kill off microscopic organisms. Depletion of the ozone layer in recent years is of serious concern. There was a severe depletion of some 40-50% above the Antarctic region every spring. Severe depletion of ozone layer is commonly called **"ozone holes".** A United Nations Environment Programmed report predicts a 26% rise in cataracts and nonmelanoma skin cancers for every 10% drop in the ozone level.

The cause of ozone depletion is the breakdown of chloro-fluorocarbons (CFCs). The best known CFC is "Freon", a heat transfer agent found in refrigerator and air conditioners.

3. Acid Rains

The oxides of sulphur and nitrogen are important gaseous pollutants in air. These oxides are swept up into the atmosphere and can travel thousands of kilometers. The longer they stay in the atmosphere, the more likely they are to be oxidized into acids. Sulphuric acid and nitric acid are the two main acids, which then dissolve in the water in the atmosphere and fall to ground as acid rain. Acid rain increase the soil acidity, thus affecting land flora and fauna, cause acidification of lakes and streams thus affecting aquatic life, affects crop productivity and human health. Acid rain leaches metals such as lead, mercury and calcium, from the soil and rocks and discharges them into river and lakes.

4. Effect on Tajmahal

The historical monument is losing its lusture day by day due to ill effects of air pollutants. Sulphur dioxide and sulphur trioxide react with water vapour and oxygen to form sulphuric acid and sulphurous acid that act on Taj's marble. As a result, there is a continuous deterioration of this classical building. Marbel of Tajmahal has to be guarded against pollutants by protective coating which could resist the action of air pollutants.

5. Bhopal gas tragedy

The mid night of 2&3 december 1984, Bhopal gas tragedy is a case of air pollution in which Methyl isocynate (MIC) gas released from a fertilizer manufacturing plant of Union carbide caused death approximately 2500 persons. This gas causes irritation which may be followed by blindness and various lung diseases causing death.

6. Agricultural effects

Farming is as much of an art as a science. One of the things that characterized the 20th century was the huge growth in industrial agriculture using fertilizers, Pesticides and so on to increase crop yields and feed the world's ever-growing population.

7. Smog

Smog is harmful to health. It reduces the respiratory system's ability to fight infection and remove foreign particles.

9.3.4 Control measures

Now we know that what is pollution, but what is solution? Steps are to be taken to control pollution at source (prevention) as well as after the release of pollutants in the atmosphere. There is an urgent need to prevent the emission from the above said major source of air pollution. The control of emission can be released in number of ways.

1- Making electricity in conventional power plants generates pollution, so anything can do save energy will help to reduce pollution.
2- Producing cool, clean water needs huge amounts of energy so cutting water waste is another good way to save energy and pollution.
3- Cars are the biggest source of air pollution in most urban areas. So traveling some other way through a town or city helps to keep the air clean.
4- When we burn plastic that release horrible toxic chemicals in to the local environment.
5- Cigarettes contain addictive chemical called nicotine that causes all kinds of health problems.
6- Replacement of technological processes i.e. increases use of electricity, sunlight. Wind energy in place of coal.

9.4 Water Pollution

Water is essential for all living organisms. All plants absorb essential elements in dissolved form and water is the solvent. In the water many mineral elements, Organic substances and gases are dissolved. If the concentration already present substances increases or some other harmful substances usually not found in water gets dissolved in water it gets polluted. Water pollution is defined as "The addition of any substances to water that changes physical and chemical properties in any way which interferes with its use for legitimate purpose". Normally water is never pure in a chemical sense. Many gases, minerals, suspended matters and some microbes are present in the water. Polluted water is turbid, unpleasant, bad smelling, unfit for drinking.

9.4.1 Sources

The chief sources of water pollution are sewage and other waste, industrial effluents, agricultural discharges, industrial wastes from chemical industries, fossil fuel plants and nuclear power plants.

Sewage is the waterborne waste derived from domestic waste and animal or food processing plants. It includes human excreta, paper, cloth, soap and detergents etc. These are the major proportion of the pollutants entering our water body. There is uncontrolled dumping of waste of rural and urban areas, into pond, lakes or river.

Due to accumulation of sewage and other wastes in these bodies, they are not able to recycle them and their self regulatory capability is lost. The decomposition of these wastes by aerobic microbes decreases due to higher level of pollution. The self purifying ability of the water is lost and water becomes unfit for drinking purpose.

Phosphate is major ingredients of most detergents. They favour the luxuriant growth of algae which form water blooms. This extensive algal growth also consumes most of the available oxygen from water.

Many pathogenic microbes may begin to grow on products coming from tanneries, slaughter houses, sewage disposal plants etc. in the water bodies under anaerobic conditions. These may result into spread of fatal water-born diseases.

Inorganic and organic pollutants are present in effluents from breweries, tanneries, dying textile, paper and pulp mills etc. The pollutants include oils, greases, plastic, phenols, toxins, acids, salts, dyes etc. many of which are not ready for degradation and thus cause serious pollution problem. Coal mine discharges sulphuric acid and ferric hydroxide into local stream through sewage. The acid on entering the water bodies destroys its aquatic life.

The use of radioactive materials in nuclear power plants, use of radioactive isotopes in medical, industrial and research institutes and nuclear tests. The discharge of radioactive wastes into water and sewer systems is likely to create problem in future.

Oil pollution of the seas has increased over the year. Due to increased traffic of oil tankers in the seas that causing oil spill. Also due to oil losses during off-shore drilling oil pollution is increasing.

Pesticides have been largely used for killing pest and insects harmful for crops and there crop production. At present there are more than 10,000 different types of pesticides are to be used. They include insecticide like DDT (dichloro diphenyl tricholoroethane), herbicides and fungicides.

Coal fired thermal power plants are source of thermal pollution. The hot water from these plants is dumped as waste into nearby lake or river where its temperature is rise. This high temperature is harmful for aquatic life.

Ocean covers more than 70% of the earth and is the major importance in the cycling of carbon dioxide, nitrogen and phosphorus. They are valuable resource of people. Ocean currents sometimes transport pollutants back to shore. Like nonbiodegradable plastic bottles, pellets and containers. Offshore mining and shipping add pollutants to the oceans. A significant amount of oil spills into the ocean kills ocean life like planktons, fish larva and marine mammals. Marine pollution adds to reduction in the dissolved oxygen content.

9.4.2 Quality parameters

It is essential to enforce water quality standards in the interest of public health. All developed countries conform to water quality parameter. The United States public health (USPH) has laid down standards for water quality parameters.

Table- 9.3: Water Quality Parameter of Domestic Water Supply

UPSH Standards (upper limits)

S.No.	Parameters	ppm, except pH
1.	pH	6.0-8.5
2.	Dissolved oxygen	4.0-6.0
3.	Total dissolved solid	500.0
4.	Suspended solid	5.0
5.	Chloride	250.0
6.	Sulphate	250.0
7.	Cyanide	0.05
8.	Nitrate and nitrite	10.0
9.	Ammonia	0.5
10.	Calcium	100.0
11.	Magnesium	30.0
12.	Iron	0.3
13.	Lead	0.05

14.	Mercury	0.002
15.	Arsenic	0.05
16.	Zinc	5.5
17.	Phenol	0.001
18.	Chemical oxygen demand	4.0

Water quality is closely linked to water use and to the state of economic development. Quantitative measurements of pollution are necessary before water pollution can be controlled. Some standards methods are use in quality measurement.

1. **Dissolved Oxygen-** The amount of oxygen dissolved in the water is usually measured either by an oxygen probe or the old standard wet technique, the Winkler dissolved oxygen test.
2. **Biochemical Oxygen Demand-** BOD is taken as indirect measure of water quality. It measures the amount of oxygen required by microbes while stabilizing decomposable organic matter.
3. **Chemical Oxygen Demand-** In Chemical oxygen demand organics are oxidised chemically instead of biologically. All organics are oxidized in Chemical Oxygen Demand test and only some are decomposed during the Biochemical Oxygen Demand test, COD values are always higher than BOD values.
4. **Turbidity-** If water is dirty i.e. Light transmission inhibited, it is known as **turbid water**. The standard method of measuring turbidity is the Jackson Candle Turbidmeter.
5. **Solids-** Solids are residue left on evaporation at 103 degree centigrade. Total solids have two fractions, the dissolved solid and suspended solid.

9.4.3 Effects

The effects of water pollution are not only harmful to people but also to animals, and other living beings. Polluted water is unsuitable for drinking, recreation, agriculture and industries. Nobody can escape the effect of water pollution. Some effects by the water pollution are given below.

1. Biochemical Oxygen Demand- To measure water pollution Biochemical oxygen demand (BOD) test is made. In this test amount of oxygen sufficient to destroy waste organic matter by bacteria in a sample is measured. The more oxygen that is used by the bacteria degrade the organic matter in the sample, the greater the BOD. The BOD of household sewage is 200-400 ppm (In one litre polluted water sample).

2. Dissolved Oxygen – Oil pollution reduces light transmission through surface of water and hence reduces photosynthesis by marine plants, decreases dissolved oxygen in water causing damage to marine life and also contaminates sea food which enters the human food chain.

3. Arsenic Contamination-More than one million people in six districts of West Bengal drink arsenic-contaminated ground water from tube wells in the region. Among them 20 lakh people suffer from various diseases related to arsenic poisonings like loss of hair, brittle of nails, bronchitis etc.

4. Minamata diseases-Mercury enters waternaturally as well as through industrial effluents. Mercury is responsible for the minamata epidemic that caused several deaths, In Japan and Sweden. The tragedy had occurred due to consumption of heavily mercury contaminated fishes, by the villagers.

5. Flurosis- Flurosis is a crippling disease that affects the bones. The disorder occurs due to prolonged consumption of fluoride contaminated water and in the affected areas in Unnao the fluoride content has been recorded as high as 15-19 ppm as against the permissible dose of 1 ppm. The affected person suffers from stiff backs, fixed joint, deformed spines and may cann't stand on their own.

6. Selenium-Selenium accumulates in plants growing in selenium rich soils andbecome toxic to animal's grazing on them. Toxicity causes stunted growth, loss of appetite, shedding of hairs and nails and gastrointestinal disturbances.

7. Lead-If present in different foods in traces, it accumulates in the body leading to poisoining and causing severe anaemia and changes in kidney and arteries. Causes decrease in rate of mitosis in root tips. Automobile burning leaded gasoline poured most of the lead in the air. Lead particles enter in to the food chain; an intake of it can also cause mental retardation, partial paralysis, loss of hearing and death.

Oxalic acid-Excess intake of oxalic acid causes renal calculi (Stone of kidney).

Ganga pollution-Ganga along with its tributaries is the largest and a very important river basin of the country. It has been a symbol of purity but today it is grossly polluted.

9.4.4 Control measures

Biodegradable pollution alone is not responsible for water pollution. Water pollution load is contributed by no biodegradable or slow degrading pollutants such as heavy metals, mineral oil, biocide, plastic mineral etc. all pollutants are dumped in to water. Various ways are suggested for control the water pollution.

1. **Stablisation of ecosystem**- The basic principles involved are the reduction in waste input, harvesting and removal of biomass, trapping of nutrients, fish management and aeration.
2. **Recycling of waste-** Various kinds of wastes may be recycled to beneficial use.
3. **Removal of pollution-** So many types of pollutants are to be present in the water body. By the appropriate method we can remove the particular pollutants by the polluted water body. Some pollutants are given below.

   Ammonia- Ammonia can remove by the waste water by ion exchange technique. This can be used for fertilizers.

   Mercury- Mercury can be removed from chlor alkali effluents plants by using mercury selective ion exchange resin.

   Phenolics- Phenolics can be removed by the help of polymeric absorbent.

   Decolorisations of water- The decolorisation of the water remove by the help of electrolyte decomposition technique.

   Salts- Salts can be removed by the help of reverse osmosis method.

Though water act was promulgated in 1974, a serious concern about water quality control could be generated only recently. The water (Prevention and control of pollution) Cess Act, 1977 could recognize the value of this resources.

9.5 Soil Pollution

Soil is essential for all living organisms. It is a store house of minerals, reservoir of water and a conserver of soil fertility. The plant that feed us grow in soil and keeping it healthy is essential for maintaining beautiful planate. However, like all other forms of nature, soil also suffers from pollution. The pollution of soil is common thing in these days, and it happens due to the preseience of manmade element. So many causes are responsible for soil pollution. The main reason of the soil pollution is due to the presence of manmade waste. The wastes produced by nature itself like dead plants, dead animals and rotten fruits and vegetables only add to the fertility of soil. If our waste products are full of chemicals they lead to soil pollution.

Soil pollution may be defined as the presence in the soil of one or more contaminants in such quantities. Mature soil provides the basis for the development of some of the major ecosystems of the world which run the great productivity cycles. Man utilizes the soil in large scale agricultural units to provide food for the growing population. With the increase of population there is increasing demand of food. For more food production more fertilizers are to be used. To save plants from pests, rats and parasitic fungi different pesticides e.g. DDT are being used. These substances get mixed with soil and cause soil pollution.

9.5.1 Sources

The various sources for soil pollution are given below. Of these sources, construction sites are the important source of soil pollution in the urban areas. In general any chemical handled at construction sites may pollute the soil.

Most industries are depending on extracting minerals from the earth. Whether it is iron ore or coal, the by products are contaminated and they are not disposed to in a manner which can be considered safe.

In agriculture chemical utilization has gone up tremendously since technology provide as with modern pesticides and fertilizers. They are fully chemicals that are not produced in nature and cannot be broken down by it. As a result they go down in the soil mix with water and slowly reduce the fertility of the soil.

Waste disposal is also a major source of soil pollution. While industrial waste is sure to cause contamination, there is another way in which we are adding to the pollution. Human being produces certain amount of waste product by way of urine and faces. It moves into the sewer the system, there is also a large amount that is dumped directly into landfills in the form of diapers. Our body is full of toxins and chemicals which are now seeping into the land and causing pollution of soil.

Oil leaks at the time of storage and transport of chemicals. This can be mostly seen at most of the fuel station. The chemical present in the fuel deteriorates the quality of soil.

Acid rain is the source of soil pollution. When pollutants present in the air mixes up with the rain fall back on the ground. Then the soil becomes impure.

9.5.2 Quality Parameters

It is impossible to select universal soil parameters for sustainable soil. A significant role in the selection of parameters is played by their variability in time, related to parameter stability. The biological soil parameters are not as plentiful as it is in the case of physical and chemical parameters. There are a great number of enzymes in soil, depending on the diversity of soil organisms and the conditions of organic substances transformation. They are important in catalyzing several important reactions necessary for the life processes of micro-organisms in the soils and the stabilization of soil structure, the decomposition of organic wastes, organic matter formation and nutrient cycling. Soil quality cannot be judged directly, it must be determined from the changes of its parameters. Soil quality is significantly affected by physical, chemical, biological and biochemical properties sensitive to change in environment and land management. Soil parameter is usually determined only in relation to specific topsoil. Certain physical and chemical parameters in subsoil cannot be neglected, since they guarantee soil functions.

9.5.3 Effects

Soil pollution may affect all of us as well as plants and animals. However, children are usually more susceptible. Because kids are more sensitive to various pollutants and they may come in close contact with soil.

1. Growth of plants- The ecological balance of any system gets affected due to the widespread contamination of the soil. Most of the plants are unable to adapt when the chemistry of the soil changes. Fungi and bacteria are found in the soil that binds it together being to decline.

2. Soil fertility decrease- The toxic chemical present in the soil can decrease the soil fertility. The contaminated soil is than use in the production of vegetables, which lacks quality nutrients and may contain some poisonous substance.

3. Toxic dust- The emission of toxic and foul gaseous from landfills pollutes the environment and cause serious effect on the health.

4. Soil contamination- Contaminated soil affects the health of plants that depend on them.

5. Vietnam war- The dioxin, used during the Vietnam War, is considered to be the most toxic component of the herbicide used to defoliate large areas in war zone. Dioxin is extremely toxic to mammals, causing liver disorders, never damage and even it is carcinogen. It also damages the ecosystem.

9.5.4 Control Measures

Soil pollution is the reduction in the productivity of soil due to the presence of soil pollutants. Soil pollutants have an adverse effect on the physical chemical and biological properties of the soil and reduce its productivity. Pesticides, fertilizers, organic manure, chemicals, clothes leather goods, paper, bottle, plastic bottle and carcasses all are contribute the cause of soil pollution. Many factors which control the soil pollution are given below.

1. **Dumping of unwanted materials**- The excess wastes by man and animals pose a disposal problem. Open dumping is the most commonly practiced technique. For controlled tipping is followed for solid waste disposal. The surface so obtained is used for housing and sports field.
2. **Recycling of waste materials**- For minimize the soil pollution, the waste like paper, plastic, metals, glass, petroleum products and industrial effluents etc should be recycled and reused.
3. **Use of natural fertilizers**- Bio-pesticides should be used in place of toxic chemical pesticides. Organic fertilizers should be used in place of synthesized chemical fertilizers. Organic waste in animal dung may be used to prepare compost manure instead of throwing them wastefully and polluting the soil.
4. **Ban of toxic chemicals**- Ban should be imposed on chemicals and pesticides like DDT, BHC etc which are fatal to plants and animals. Nuclear explosions and improper disposal of radioactive wastes should be banned.
5. **Public awareness**- Public awareness programs should be organized imparted to educate people for health hazards by environmental education. Ex. Educational institute and mass media.

9.6 Noise Pollution

The human ear is constantly being assailed by manmade sounds from all sides, and there remain few places in populous area where relative quietness prevails. The word noise (Latin- nausea) means unwanted or unpleasant sound that causes discomfort of the living being. Noise is also defined as wrong sound, in the wrong place at the wrong time.

9.6.1 Sources

Broadly speaking, the noise pollution has two sources, i.e. industrial and nonindustrial. The industrial source includes the noise from various industries and big machines working at a very high speed and high noise intensity. Non-industrial source of noise includes the noise created by transport, traffic and neighborhood noise generated by various ways.

The main source of traffic noise is the motors and exhaust system of autos, smaller trucks, buses and motorcycles. This type of noise can be augmented by narrow streets and tall buildings.

Aircraft is also a major source of the noise pollution. The problem of low flying military aircraft has added a new dimension to community annoyance, as the nation seeks to improve its aircraft operations.

The noise from locomotive engines, horns and whistles and switching and shutting operation in rail yards can impact neighboring communities and railroad workers.

The noise from the construction of highways, city, street and buildings is a major contributor to the urban area. Construction noise sources are hammers, air compressors, bulldozers, loaders and dump truck etc.

Industrial noise is one of the less prevalent community noise pollution. Neighbours' of noisy manufacture plants can be disturbed the sources such as fan, motors and compressors on the outside of buildings. Interior noise can also be transmitted to the community through windows and doors.

In the case of internal building noise from plumbing, boilers, generators, air conditioners and fans can be audible and annoying. Improper insulated walls and ceilings can reveal the sound of-amplified music, voices and noisy activity from neighbouring units.

Some house hold equipment, such as vacuum cleaner and some kitchen appliances have been and continue to be noise makers. Although there daily contribution is not too much.

9.6.2 Quality parameters

Different type of vehicles like motorcars, buses, trucks, aeroplane and tractors etc cause noise pollution. Sound waves cause metabolic disorders and and loud sound adversely affect the hearing and causes sleeplessness in man thus affecting nervous system sometimes leading to madness. Some sounds kill some microorganisms thus causing hindrance in decay. Noise meters have been designed for noise measurement from low to high frequencies, characteristic of human ear capacity. Meter record the dB scale for measurement of general noise. Noise in the range of 50 to 60 dB is sufficient to interfere with sleep and produce a feeling of fatigue on awakening.

Table- 9.4: The Maximum Permissible Noise Level (in decibel)

S.No.	Situation	dB
1.	Road traffic near residential area	70
2.	Ear protection required	85
3.	Hearing damage	90
4.	Stimulation in reception in skin	110
5.	Pain threshold	120
6.	Pain in ear	140
7.	Burning in skin	150
8.	Rupture of tymphanic membrane	160
9.	Major permanent damage in short time	180

9.6.3 Effects

Noise is part of our environment. The noise level has been rising continuously. Noise has been recognized as one of the dimensions of pollution which brings about degradation of the environment and creates health and communication hazards. The effect of noise pollution is multifaceted and inter related. The effect of noise pollution on human being, Animal and property are as follows.

1. Loss in working efficiency- By the noise pollution, the efficiency is increase with the noise reduction.

2. Low concentration – If we want the better work than there should be concentrate. But noise causes lack of concentration. Mostly, all the offices are on the main road, the noise of traffic or different type of horns, divert the attention of the people working in the offices.

3. Abortion- The unpleasant sound makes irritative nature. Sudden noise causes abortion in the females.

4. Blood pressure- The noise is recognized as major contributing factors in accelerating the already existing tension of modern living. This tension results in certain disease like blood pressure and mental illness.

5. Effects on plants- We know that plants are similar as human. There should be cool and peaceful environment for the better growth of the plants. But noise pollution cause poor quality of crops.

6. Physiological disorders- There develop a number of physiological disorders due to imbalance in functioning of the body. These are neurosis, anxiety, insomnia, hepatic disease, and increase in sweating, fatigue etc. Other effects are undesirable changes in respiration, circulation of blood in skin and gastrointestinal activity.

9.6.4 Control measures

Noise pollution is closely related to increase in industrialization and urbanization. It cannot be entirely eliminated but it can be kept at a safe level through adoption of some measures. There are following ways to control and reduce the noise pollution.

1. **Source control**- This can be done by the designing and fabricating silencing devices in air craft engines, automobiles, industrial machines and home appliances.
2. **Transmission control-** The coveringof room walls with sound absorbers as acoustic tiles and construction of enclosures around industrial machinery.

3. **Create vegetation cover-** The plants absorbed and dissipate sound energy and thus act as buffer zone. Tree should be planted along highways, streets and other places. Neem (*Azadirachta indica*) tree is good for this purpose.
4. **Noise pollution by law-** Silence zone must be declared near schools, hospitals and indiscriminate use of loudspeakers at public places should be checked by law. Motor vehicle act which provides restriction on truck using double sirens while passing through some localities. Should be implemented.
5. **Education-** Public must be made aware and educated about noise nuisance through adequate news media, lectures and other programmes.

9.7 Summary

Pollution is defined as a deviation from the natural composition of a part of the environment, resulting in adverse effects on life. The environment includes air, water, land and the interrelationship which exists among and between water, air and land and human beings, other living creatures, plants microorganisms and property. And the environmental pollutants means solid, liquid and gaseous substance present in such concentration may be injurious to the environment. Unlimited exploitation of nature by man disturbed the delicate ecological balance between living and non-living component of the biosphere. Pollution is a man-made problem, mainly the effluent countries.

9.8 Glossary

- **Atmosphere :** The gaseous envelop surrounding the planet.
- **Biodegradation :** Oxidative breakdown of synthetic or natural organic substances by microbial activity.
- **Biosphere :** The planet earth along with its living organisms and atmosphere which sustain life i.e. the earth and atmosphere in which organisms live.
- **Carcinogen :** Cancer inducing substances.
- **Chloro-fluoromethanes :** Compounds of carbon and halogens.
- **Climax :** The final, terminal, stable community that maintain itself for over longer period in equilibrium with the prevailing environmental conditions. This stage is known as **climax.**

- **Decomposers :** Microbes that obtain their nutrition form breakdown products of dead organic matter.
- **Disease :** Any malfunctioning of host cell and tissues that result from continuous irritation by a pathogenic agent or environmental factor and leads to development of symptoms.
- **Ecosystem :** An inclusive term for a living community and all the factors of its nonliving environment.
- **Environment :** The living and nonliving factors that surround a given organism or community or organisms.
- **Factor :** Any external force, substance and condition that affects an organism.
- **Fresh water :** Water with salinity less than 0.5 part per thousand.
- **Herbicide :** A chemical use to kill plants, frequently chemically related to a hormone.
- **Humidity :** The ratio of the weight of water vapour in a given quantity of air to the total weight of water vapour that quantity of air is capable of holding at the temperature.
- **Humus :** More or less decomposed finely divided amosphous organic matter in the soil.
- **Hydrosphere :** The part of the earth composed of water.
- **Leaching :** Removal of soluble components from soil or sludge deposits by percolating water etc.
- **Lithosphere :** The crust and mettle of earth.
- **Lysis :** A process of disintegration or soil destruction.
- **Misosphere :** Part of atmosphere extending from the ionosphere to exosphere.
- **Mineral :** A substance formed in nature by nonbiological process.
- **Non-renewable source :** A natural resource that is present in limited amount in nature, likely to be exhausted some day.

- **Ozone layer :** A layer of atmosphere which contain ozone produced by UV-radiation.
- **Pollutant :** A substance that is introduced into the environment may be gas, liquid or solid which is harmful to living being.
- **Population :** A group of interbreeding organism.
- **Reduction :** Any chemical reaction involving the removal of oxygen from or the addition hydrogen or an electron to a substance.
- **Smog :** Smoke arising from nitrogen oxide and hydrocarbon emitted by motor vehicle and photochemical action of sunlight.
- **Soil :** The uppermost stratum of the of the earth crust, which has been modified by weathering and organic activity into three zones.
- **Stratosphere :** The region of atmosphere above the troposphere in which temperature rises with height.
- **Toxin :** A poisonous secretion of plant and animal.
- **Troposphere :** The lowest level of atmosphere in which temperature decreases with height. This is about 20 km above the earth surface.

9.9 Self-Learning Excercise

Section- A (Very Short Answer type Question)

1. Gas released during Bhopal tragedy was- ---------------
2. Minamata diseases is a pollution related disease which result from- -----
3. Which is the major green house gas- ----------------
4. Ozone layer is destroyed by- ----------------
5. Biologists celebrate 5th June as- -----------------
6. Tajmahal is threatened due to the effect of- ---------------
7. A dental disease characterized by mottling of teeth due to presehce of certain chemical element in drinking water. Which is that element- ------
8. Which pollutant causes leaf curling- --------------
9. Noise pollution is measured in- ----------------
10. Mosses are indicator of which type of pollution- ------------------

Section- B (Short Answer type Question)

1- What do you understand by environmental pollution?

2- Write the short notes on sewage.

3- Write the short notes on weedicides and pesticides.

4- What effect pollution has on human beings?

5- How can we control different type of pollution?

6- Write down the sources of water pollution?

7- How can we control the soil pollution?

8- Write down the short notes on the depletion of ozone layer?

9- Write the short notes on the Acid rain?

10- How can we save the environment?

Section- C (Long Answer type Question)

1. What do you understand by pollution? Give causes of atmospheric pollution.
2. How can control the air pollution in the environment?
3. What is water pollution and write the cause of this type of pollution?
4. What is noise pollution and how can we control it?
5. Write the brief account of pollution and describe the all type of pollution?
6. Discuss the cause, effect and control of noise pollution?

Answer key of section A

1. Methyl isocynate
2. Industrial mercury waste in water
3. Carbon dioxide

4. Chlorofluorocarbons
5. World Environment Day
6. Sulphur Dioxide
7. Fluorine
8. Sulphur Dioxide
9. Decibels
10. Air pollution

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Unit-10

Ecological Management and Sustainable Development

Structure of the Unit:

10.0 Objectives

After studying this unit, you will able to understand about

- Ecological Management and EIA
- Environmental Appraisal Committee and Monitoring
- Sustainable Development , UNCED and UNCSD

It is in our best interest to help finance protection of our common future in some equitable way.

10.1 Introduction

We could begin to discuss the beginning of environment crisis as we reached to the end of 20th century .We are surrounded with curse of desertification , soil erosion, floods, droughts, extinct & threat to many plants and animals and hazardous pollutions. Yet the growth of population has been not arrested and demands for food, shelter, clothing, energy is increasing day by day. Therefore, Ecological Management is an approach to resource use & resource management. Development and environment are inseparable part, development process like agriculture, industry and mining had very harmful impacts on our environment. This leads to degradation of biological diversity .Sustainable development is going to act just like guiding principles.

It generates practical strategies that improve human well-being and prevent environmental degradation.

10.2 Basic Concepts

The human race is entirely dependent on the ecosystems that feed us, regulate our environment, and recycle our wastes. They provide all we need to survive. Over past 100 years, humans have changed ecosystems more rapidly. Now there have been net gains in human well-being and economic development, butthese gains have beenachieved at growing cost in the form of environmental degradation, loss of biodiversity.

Ecological management is focused on maintaining and enhancing the natural values of land to conserve biological diversity. With continuing alteration of the land by human activity, many ecosystems have become fragmented or reduced to isolated islands surrounded by agricultural fields or developed areas.

Ecological Management is the key to successful future and can be subdivided into five general categories: conservation, planning, restoration, prescribed management research and monitoring.

Ecological Management is an advanced approach to resource conservation and recycling and it acts as a regulatory force on human greed in resource exploitation and resource wasting. The main objectives of Ecological Management are:

- To equip students with the interdisciplinary knowledge and skills proceed with a career in natural resource management.
- To produce graduates capable of combining the scientific, economic and policy aspects of resource management and conservation, so that they can draw conclusions of strategic significance for government companies and NGO's.
- To provide students from natural science , life science, ecology and other disciplines with a broad understanding of issues , methods about natural resources and ecosystem management.

Therefore, it is high time we start working for ecological management i.e. proper resource use and resource management.

10.3 Environment Impact Assessment (EIA)

Analysis of any possible changes in environmental quality (adverse or beneficial) caused by a development project of Government or privatecompany is known as **Environment Impact Assessment (EIA).** As a matter of government policy, it is compulsory for any enterprise either it is government or private to include EIA in the planning stage of any development project and submit it to the Central Government for clearance. All major and minor irrigation projects and all highly polluting industries are subjected to EIA for their initiation.

The concept of Environmental Impact Assessment (EIA) involved in this period as a result of a fundamental change in the way of thinking about environment and development .Attempts were made to replace the economic growth approach by the concept of sustainable development.

Environmental Impact Assessment (EIA) is an important management tool for ensuring optimal use of natural resources for sustainable development. A beginning in this direction was made in our country with the impact assessment of river valley projects in 1978-79 and the scope has subsequently been enhanced to cover other developmental sectors such as industries, thermal power projects, mining schemes etc. To facilitate collection of environmental data and preparation of management plans, guidelines have been evolved and circulated to the concerned Central and State Government Departments.

10.3.1 Meaning of EIA

EIA is an evaluation procedure that helps planners and decision makers to understand the environmental impacts of a proposed project or activity. Definition of EIA depends also on the role of EIA in decision making process.

Environmental Impact Assessment (EIA) can broadly be defined as a study of the effects of a proposed project, plan or program on the environment.

The legal, methodological and procedural foundations of EIA were established in 1970 by the enactment of the **National Environmental Policy Act (NEPA**) in the USA. Most developing counties have also embraced and are in the process of formalizing EIA through legislation.

EIA is essentially a technique for drawing together, in a systematic way, expert qualitative assessment of a project's environment effect and presenting the results in a way which enables the importance of predicted effects, and the scope for modifying them, to be evaluated by the relevant decision-making body before a decision is given.

UNEP defines Environmental Impact Assessment (EIA) as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, by using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations.

10.3.2 Objectives of EIA

The objectives of EIA are to ensure that development is sustained with minimum environmental degradation. The Ministry of Environment and Forests, Govt. of India has been assigned the efforts for increasing EIA of developmental projects in various sectors such as multipurpose river valley projects , irrigation projects , thermal and atomic power plants , industries , mining , ports , transport. The Ministry initiated EIA with the river valley projects impact during 1978-79.Its scope was launched to other sectors. The notification of EIA of developmental projects was issued in 1994 and amended in 1997 and 2000.

To establish the impact of various developmental projects both on society as well as on land, water, air, flora and fauna etc .There is requirement for development projects to prepare an **Environment Impact Statement (EIS)** covering the following:

- Deforestation and afforestation
- Effect on land degradation.
- Air and Water, Noise pollution
- Loss of biological diversity including flora and fauna
- Socio-economic impact including human displacement, cultural lag, health aspects.
- Disaster management including flood, drought etc
- Recycling & reduction of waste

The **Ministry of Environment and Forests (MoEF)** of India has been in a great effort in Environmental Impact Assessment in India. The main laws in action are the **Water Act (1974)**, the **Indian Wildlife (Protection) Act (1972)**, the **Air Prevention and Control of Pollution Act (1981)** and the **Environment Protection Act (1986), Biological Diversity Act (2002).** The responsible body for this is the **Central Pollution Control Board**. Environmental Impact Assessment (EIA) studies need a significant amount of primary and secondary environmental data. Primary data are those collected in the field to define the status of the environment (like air quality data, water quality data etc.). Secondary data are those collected over the years that can be used to understand the existing environmental scenario of the study area. The environmental impact assessment (EIA) studies are conducted over a short period of time and therefore the understanding of the environmental trends, based on a few months of primary data, has limitations. Ideally, the primary data must be considered along with the secondary data for complete understanding of the existing environmental status of the area. In many EIA studies, the secondary data needs could be as high as 80% of the total data requirement. EIC is the repository of one stop secondary data source for environmental impact assessment in India.

The major aims of EIA are:

- Resource Conservation
- Waste minimization
- Recovery of by-product
- Efficient use of equipments
- Sustainable Development

10.3.3 Project Covered

EIA is intended to identify the impacts (both beneficial and adverse) of proposed public and private development activities. Often, the focus is dominantly environmental (biophysical); but good practice also addresses social and economic aspects. EIA is mainly used at the level of specific developments and projects such as dams, industrial plants, transport infrastructure (eg airport runways and roads), farm enterprises, and natural resource exploitation (eg sand extraction). EIA is most valuable when applied early in the planning process for a project as a support to decision-making.

The Environmental Impact Assessment (EIA) experience in India indicates thatthe lack of timely availability of reliable and authentic environmental data has been a major bottle neck in achieving the full benefits of EIA. The environment being a multi-disciplinary subject, a multitude of agencies is involved in collection of environmental data. However, no single organization in India tracks available data from these agencies and makes it available in one place in a form required by environmental impact assessment practitioners. Further, environmental data is not available in enhanced forms that improve the quality of the EIA. This makes it harder and more time-consuming to generate environmental impact assessments and receive timely environmental clearances from regulators. With this background, the **Environmental Information Centre (EIC)** has been set up to serve as a professionally managed clearing house of environmental information that can be used by MoEF, project proponents, consultants, NGOs and other stakeholders involved in the process of environmental impact assessment in India.

The projects in the following sectors are being assessed for environmental impact by the Ministry:

- Industry and Mining
- Irrigation and Power
- Transport and Communication

The coverage of the project includes:

- These requiring clearance from the Public Investment Board
- Requiring international funding
- Project referred by State Government or Administrative Ministries
- Project in sensitive areas
- Projects on which there are public complaints.

Projects in certain areas such as Doon valley, Agra- Mathura Trapezium and Tourism projects which fall under the guidelines of the Ministry and all projects being put up before **Cabinet Committee on EconomicAffairs (CCEA**) or **Public Investment Board** such as Ports, Communication Projects etc are considered.

A few problem areas such as the Doon Valley - an ecologically sensitive area, the National Capital Region (NCR) which is suffering from air and water pollution as well as congestion, Damodar River Basin which is very rich in natural resources and yet has extensive environmental degradation and Tapi estuary which represents the problems in the coastal region both for water and land development, have been selected for carrying out such studies.

A multi-disciplinary and multi-institutional approach has been adopted for conducting these studies. Draft reports are ready for Doon Valley and the NCR and are being discussed with the NGOs and the local people for finalising the same. Work relating to Damodar Basin and Tapi Estuary is continuing with respect to secondary data collection and analysis so as to identify the requirements of primary data collection and modification in the development scenarios.

The environmental impact assessment of development projects has so far been done on the basis of "Executive Order"issuing the provisions of the Environment Protection Act 1986.In order to bring all projects under the purview of environmental impact assessment, a draft notification has been prepared .A notification on Aravalli Range covering Gurgaon district of Haryana and Alwar District of Rajasthan was issued on January 9, 1992, with the intention to protect Aravalli Range.

10.3.4 Procedure for EIA

EIA is a procedure used to examine the environmental consequences or impacts, both beneficial and adverse, of a proposed development project and to ensure that these effects are taken into account in project design. The EIA is therefore based on predictions. These impacts can include all relevant aspects of the natural, social, economic and human environment. The study therefore requires a multidisciplinary approach and should be done very early at the feasibility stage of a project. EIA should therefore be viewed as an integral part of the project planning process. Unlike the environmental audit (EA), which is conducted on existing projects, the EIA is applied to new projects and the expansion aspects of existing projects.

The Ministry has developed guidelines for maintaining statement of environmental impact assessment along with questionnaires and checklist for the following:

- Industry and Mining
- Thermal Power
- River Valley
- Rail , Road Highway Projects
- Ports & Airports
- Communication Projects

The project authorities are requested to provide information as indicated in the guidelines along with the Environment Impact Assessment Statement (EIS) and Environment management Plan (EMP), an observation of the project proposals are made by the technical staff of the Ministry. After ensuring the structure assessment, it is placed before the Advisory Committee. The Advisory Committee discusses the impact of the project with the project authorities then site visits are made for on-the spot assessment of environmental aspects. Based on their examination, the Appraisal Committee makes their conclusions for approval or rejection of a particular project.

Although legislation and practice vary around the world, the fundamental components of an EIA would necessarily involve the following stages:

- **Screening** to determine which projects or developments require a full or partial impact assessment study;
- **Scoping** to identify which potential impacts are relevant to assess (based on legislative requirements, international conventions, expert knowledge and public involvement), to identify alternative solutions that avoid, mitigate or compensate adverse impacts on biodiversity (including the option of not proceeding with the development, finding alternative designs or sites which avoid the impacts, incorporating safeguards in the design of the project, or providing compensation for adverse impacts), and finally to derive terms of reference for the impact assessment;
- **Assessment and evaluation of impacts and development of alternatives**, to predict and identify the likely environmental impacts of a proposed project or development, including the detailed elaboration of alternatives.
- **Reporting the Environmental Impact Statement (EIS) or EIA report**, including an environmental management plan (EMP), and a non-technical summary for the general audience.
- **Decision** making on whether to approve the project or not, and under what conditions.
- **Monitoring, Compliance, Enforcement and Environmental Auditing** monitor whether the predicted impacts and proposed mitigation measures occur as defined in the EMP. Verify the compliance of proponent with the EMP, to ensure that unpredicted impacts or failed mitigation measures are identified and addressed in a timely fashion.

10.4 Environmental Appraisal Committee (EAC)

In order to extract multi-disciplinary inputs for appraisal of projects, the Ministry has constituted the EAC for the following sectors:

- River valley , multipurpose irrigation and hydro-electric projects
- Industrial projects
- Mining projects
- Thermal power projects
- Atomic power projects
- Nuclear fuel projects
- Infrastructure Development and Miscellaneous Projects

The EAC has experts for water resources management, pollution control, forestry, ecology, landscape planning etc. The project authorities have to provide the following documents for environmental appraisal of a development project:

1) Detailed Project Report (DPR)
2) Filled in questionnaire
3) Environmental impact statement (EIS)

EIS should provide possible impact of the project. Some of the issues to be included are:

a) Impact on soil , water and air quality
b) Impact on land use, forests , agriculture , fisheries , tourism etc
c) Socio-economic impacts on population.
d) Impact on health
e) Impact on flora and fauna especially on endemic and endangered species.

10.4.1 Environmental Appraisal Procedure

Once an application has been submitted by a project authority along with all the requisite documents specified in the EIA Notification, it is scrutinised by the technical staff of the Ministry prior to placing it before the Environmental Appraisal Committees. The Appraisal Committees evaluate the impact of the project based on the data furnished by the project authorities and if necessary, site visits or on-the-spot assessment of various environmental aspects are also undertaken. In case of site specific projects such as Mining, River Valley, Ports and Harbours etc., a two stage clearance procedure has been adopted whereby the project authorities have to obtain site clearance before applying for environmental clearance of their projects. This is to ensure avoiding areas which are ecologically fragile and environmentally sensitive. In case of projects where complete information has been submitted by the project proponents, a decision is taken within 90 days.

10.5 Environmental Management Plan (EMP)

EMP covers the following prospects:

a) Safeguards and control measures proposed to prevent the adverse environmental impacts.
b) Plans for rehabilitation of project outline
c) Eventual plans for dealing with accidents or disasters.
d) Monitoring the complete project or plan
e) Feedback mechanism on implementation of necessary safeguards.

There are numbers of guidelines and solutions for environmental clearance of different projects. For Industrial Projects, the guidelines provide a list of areas which may be avoided for set up of industries. These include coastal areas, National parks and Sanctuaries, wetlands, archeological monuments, flood plain of river system and major human settlements. For EIA, the guidelines maintain the factors. These are:

i. Meteorology and air quality
ii. Hydrology and water quality
iii. Occupational safety and health effects
iv. Impact on sensitive targets

There are some aspects for EMP. These include:

a) Treatment and disposal of liquid effluents
b) Emissions and solid wastes
c) Prevention and control of noise and vibrations
d) Precautions for safety and health

e) Preventive maintenance of control system
f) Recovery and reuse of waste products
g) Plantation and vegetation cover
h) Disaster planning
i) Environmental management plans foe ensuring implementation of necessary safeguards

These types of guidelines have also been prepared for transportation, tourism and communications. A number of projects have been detected by the Ministry and some have been cleared and some rejected. For example, Narmada Sagar (M.P.) and Sardar Sarovar Project (Gujarat) were accorded environmental clearance in 1987.

10.6 Environmental Monitoring

In order to assess the changes in the environment due to human activities, effective and reliable monitoring systems are required to monitor and predict such hazardous effects.

After considering all the facets of a project, environmental clearance is accorded subject to implementation of the stipulated environmental safeguards. Monitoring of cleared projects is undertaken by the six regional offices of the Ministry functioning at Shillong, Bhubaneshwar, Chandigarh, Bangalore, Lucknow and Bhopal. The primary objective of such a procedure is to ensure adequacy of the suggested safeguards and also to undertake mid-course corrections required, if any. The procedure adopted for monitoring is as follows:

1. Project authorities are required to report every six months on the progress of implementation of the conditions/safeguards stipulated, while according clearance to the project.
2. Field visits of officers and expert teams from the Ministry and/ or its Regional Offices are undertaken to collect and analyse performance data of development projects, so that difficulties encountered are discussed with the proponents with a view to finding solutions.
3. In case of substantial deviations and poor or no response, the matter is taken up with the concerned State Government.

4. Changes in scope of project are identified to check whether review of earlier decision is called for or not.

10.7 Sustainable Development

India is faced with many environmental problems.These problems are air and water pollution, loss of biodiversity & wildlife, carbon emissions, ozone layer depletion, global warming and climate change. Not only scientists, but every person of society becomes familiar with these environmental problems. We are now engaged to find the solutions of these problems and in a need to manage the relationship between environment and development in a way that development of every man on the planet improves with minimum damage to the environment. Such a co-ordinated process is referred to as **Sustainable Development.**

Sustainability is at the heart of many problems, a discussion relating to all aspects of natural resource management .A definition is important whether developing a framework or processes for ecosystem management. In defining sustainability, ecosystem health is tightly linked to the sustenance of humans and the quality of their lives. Sustainability is a relationship between dynamic cultural, economic, biophysical systems.

Sustainability is the ability of the earth's various system including human cultural systems and economics, to survive and adapt to changing environmental conditions.

Sustainability can be defined as the practice of maintaining processes of productivity indefinitely—natural or human made—by replacing resources used with resources of equal or greater value without degrading or endangering natural biotic system . Sustainable development ties together concern for the carrying capacity of natural systems with the social, political, and economic challenges faced by humanity. As early as the 1970s, the concept of sustainability was used to describe an economy in equilibrium with basic ecological support systems.

10.7.1 Definaitions

Sustainable Development refers to "the environment which maintains its homeostatis and wherein exploitation of natural resources, development of technology, population growth and such related aspects are managed and controlled carefully so that they do not adversely affect the environment. On the other hand, they enrich and strengthen various components of the environment.”

Sustainable Development follows “a form of growth and development in society that meets the current human needs conserving the natural resources for meeting the needs of future generation.”

Sustainable Development conceptually seeks to avoid environmental degradation while using the natural resources for economic development in a manner that ensures both, intra and inter generational equity. It consists of three pillars: economic development, social development and environmental protection.

Sustainable development (SD) is a process for achieving sustainability in any activity that uses resources and where immediate and inter generational replication is demanded. Sustainable development coincides with further economic growth and human development in the developed economy (and society) for finding the meansof continual development beyond economic development. As such, sustainable development is the organizing principle for sustaining finite resources necessary to provide for the needs of future generations of life on the planet. It is a process that envisions a desirable future state for human societies in which living conditions and resource-use continue to meet human needs without undermining the "integrity, stability and beauty" of natural biotic systems.

Sustainable development has been defined in many ways, but the most frequently quoted definition is from Our Common Future, also known as the **Brundtland**

Report:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

The concept of needs, in particular the essential needs of the world's poor, to which over riding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

10.7.2 Concept and Strategies

The concept of sustainable development is rooted in this sort of systems thinking. It helps us to understand ourselves and our world. The problems we face are complex and serious—and we can't address them in the same way we created them.

The concept of sustainable development can be interpreted in many different ways, but at its core is an approach to development that looks to balance different, and often competing, needs against an awareness of the environmental, social and economic limitations we face as a society.

Sustainable Development has been popular word throughout the world and adopted in all spheres of human life. The roots of sustainable development can be immersed in 1972 Stockholm Conference in Sweden where development was the first time linked to environment, emphasising the need for efforts at international level. The need of Social and Economic equity for achieving sustainable development was emphasised during this conference. This concept was followed up further which led to the creation of World Conservation Strategy in 1980 and then to UNCED in 1992 at **Rio de Janerio,** Brazil. It was the theme of the United Nations Conference of Sustainable Development (UNCSD) or Rio de Janerio to celebrate the 20th anniversary of the United Nations First Conference or Earth Summit in 1992 at the same place.

The sustainable development debate is based on the assumption that societies need to manage three types of capital (economic, social, and natural), which may be non-substitutable and whose consumption might be irreversible While it is possible that we can find ways to replace some natural resources, it is much more unlikely that they will ever be able to replace eco-system services, such as the protection provided by the ozone layer, or the climate stabilizing. In fact natural capital, social capital and economic capital are often complementarities. A further obstacle to substitutability lies also in the multi-functionality of many natural resources.

The world must quickly design strategies that will allow nations to move from their present, often destructive, processes of growth and development onto sustainable development paths. This will require policy changes in all countries, with respect both to their own development and to their impacts on other nation's development possibilities. Critical objectives for environment and development policies that follow from the concept of sustainable development include:

- reviving growth;
- changing the quality of growth;

- meeting essential needs for jobs, food, energy, water, and sanitation;
- ensuring a sustainable level of population;
- conserving and enhancing the resource base:
- reorienting technology and managing risk; and merging environment and economics in decision making.

10.7.3 Principles of Sustainable Development

Sustainable Development is the use of national resources judiciously for a more stable development and without impairing with the abilities of the future generation to use those resources, and without interfering into their living rights. Therefore, the development plans have to ensure:

- Sustainable and equitable use of resources for meeting the needs of present and future generations without causing damage to environment.
- To prevent further damage to our life support systems
- To conserve and nurture the biological diversity, gene pool and other resources for long term food security.

Conservationists and ecologists have long been aware of the significance of sustainability within natural environmental systems. However, it was not until the **Stockholm Conference of 1972**, the concept of "Sustainable Development"came to be known for the first time in the International sphere. Thereafter, in 1987 the concept was given a definite shape by the **World Commission on Environment and Development (WCED)** in its report called **"Our Common Future."**The commission was chaired by **G.H. Brundtland** as such the report is popularly known as **"Brundtland Report".** The WCED defined sustainable development as meeting the needs of the present without compromising the ability of future generation to meet their own needs , and this definition has since been widely adopted . In 1991 the**World ConservationUnion (WCU)**, **United Nations Environment Programme (UNEP)** and **World Wide Fund forNature (WWF)** came out with a document called "Caring for the Earth "", a strategy for sustainable living, which is based on the following nine key principles:

- Respect and care for the community of life
- Improve the quality of human life

- Conserve the earth’s vitality and diversity
- Minimize the depletion of non – renewable resources
- Keep within the Earth’s carrying capacity
- Change personal attitudes and practices
- Enable communities to care for their own environment
- Provide a national framework for integrating , development and conservation
- Create a global alliance

Some of the salient principles of “Sustainable Development” as culled –out from **Brundtland Report** and other international documents are;

- Inter generational equity
- Use and conservation of natural resources
- Environmental protection
- The precautionary principle
- Polluter pays principle
- Obligation to assist and co –operate
- Eradication of poverty
- Financial assistance to the developing countries.

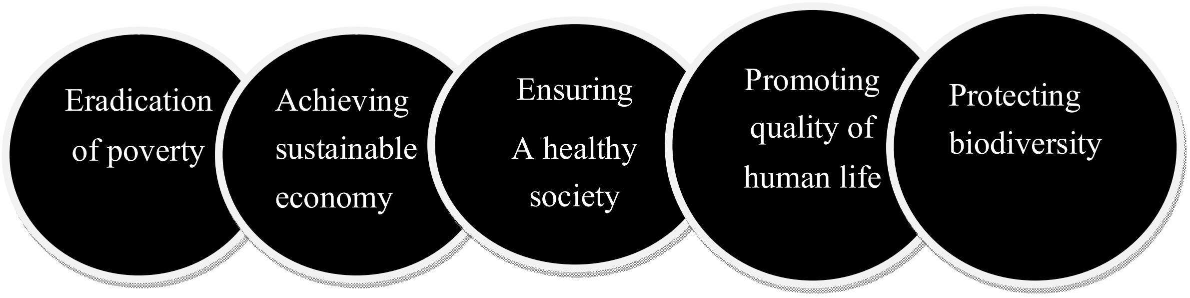

Fig 10.1: Principles of Sustainable Development

10.7.4 Goals of Sustainable Development

A goal of sustainable development may be used to help integrate diverse interests that would probably not otherwise co-operate. There are parallels with judges seeking justice, citizens wanting liberty, and philosophers and scientists pursuing truth– the goal may be elusive but efforts to reach it have to be maintained. There are a huge number of definitions of sustainable development. It is many things: a goal, a paradigm shift, above all difficult to achieve and often complex.

Sustainable development is widely held to have three goals: economic growth, environmental protection, and the health and happiness of people. Plenty of academics have noted the conflict within the concept of sustainable development – between wishing to remain within environmental limits and seeking growth or development. Supporters of sustainable development do not pursue environmental quality in isolation from addressing social disintegration and poverty. Sustainable development is a prime objective of environmental management, but it is a challenge to find effective and workable strategies. Such strategies will frequently overlap and interact, so it is vital to ensure that they do not interfere with each other and, if possible, are mutually supportive which necessitateboth a local knowledge and strategic co-ordination, ultimately at the global scale.

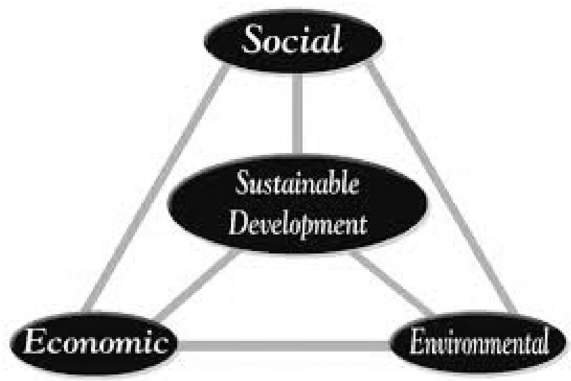

Fig. 10.2 : Goals of Sustainable Development

10.8 United Nations Conference on Environment and Development (UNCED)

In 1980, the **International Union for the Conservation of Nature** published a world conservation strategy that included one of the first references to sustainable development as a global priority.

In 1982, the **United Nations World Charter for Nature** raised five principles of conservation by which human conduct affecting nature is to be guided and judged.

In 1987, the **United Nations World Commission on Environment and Development** released the report ***Our Common Future***, commonly called the **Brundtland Report** on Sustainable Development as a key concept.

In 1992, a new global agenda UNCED or **Earth Summit** was held at **Rio deJanerio**, the capital of Brazil between 3-14 June , 1992 to ensure relationship between environment and development. It was historic largest assembly of world leaders in which more than 170 countries including 115 Heads of State and Government participated.There were discussions at ministerial and official levels and Heads of State and Government exchanged ideas and signed Declarations and conventions. On 14 June, The Brazilian President, UN Secretary – General and the UNCED Secretary –General, **Maurice F. Strong** delivered their speeches at Rio.

10.8.1 Earth Charter (Rio Declaration)

Rio Earth Summit marked 20th anniversary of the **Stockholm Conference** and the founding of UNEP. The Heads of State and Government assembled at Rio have an action plan, based on global partnership to save the Earth planet for future generations. The following four documents were adopted at the summit:

1) Rio Declaration or Earth Charter
2) Conventions on Climate change Biodiversity
3) Convention on Forestry
4) Agenda – 21 or Action Plan

Declaration with 27 guiding principles relates with the conservation, protection and restoration of health and integrity of the earth's ecosystem.The main stumbling blocks at the Earth Summit were differences between the U.S.A. and the Third world nations on preserving forests and money issues. There were many differences between the developed countries and U.S.A and the developing countries led by India over Conventions on climate change and biodiversity and on forestry. This Convention with 42 articles relates with global warming, ozone depletion and conservation of biodiversity. Agenda -21 or Action plan is concerned with action plan for 21st century in all areas of environment and economic growth in sustainable way.

In 1992, UNCED published in 1992 the **Earth Charter**, which outlines the building of a just, sustainable, and peaceful global society in the 21st century. The action plan **Agenda -21** for sustainable development identified information, integration, and participation as key building blocks to help countries achieve development that recognizes these interdependent pillars. It emphasises that in sustainable development everyone is a user and provider of information. Furthermore, **Agenda- 21** emphasises that broad public participation in decision making is a fundamental prerequisite for achieving sustainable development.

10.8.2 Commission on Sustainable Development (CSD)

The **Commission on Sustainable Development (CSD)** was suggested after the 1992 **Earth Summit** (UNCED) to carry out various programmes on Sustainable Development at national and international levels. CSD was given enormous potential to raise public and governmental concerns on development. The inequitable global economic order has hampered the effectiveness of CSD.

10.8.3 Clean Development Mechanism (CDM)

In Kyoto, 1997, nations of the world had agreed that the Clean Development Mechanism (CDM) was a process to assist developed countries in reducing their burden of excessive greenhouse gas emissions and the developing countries to move towards a less polluting growth.

CDM was designed for the following purposes:

a) to help developing countries in achieving sustainable development
b) assist industrialised countries meet emission reduction targets
c) to invest 'clean' projects in developing countries

CDM provides cheap emission reduction options to the rich world, with private companies to dominate.CDM design –"deliberate and purposeful".This has made CDM a cheap and corrupt development mechanism.

10.9 United Nations Conference on Sustainable Development (UNCSD)

In UNCSD , representatives of around 195 countries , 57 Heads of States ,490 ministers, 1200 UN staff ,12000 inter-governmental organisations,10000 NGO's and 63,000 delegates gathered at Rio + 20 for Sustainable Development and Eradication of poverty. The major theme was green economy, following three items were discussed:

- Equity and responsibility to reduce emissions.
- Sustainable Development Goals (SDGs)
- Green Economy

The United Nations Conference on Sustainable Development (**UNCSD),** also known as **Rio 2012**, **Rio+20, or Earth Summit 2012**, was the third international conference on sustainable development, which aimed at reconciling the economic and environmental goals of the global community. Few nations met the **World Wide Fund for Nature**'s definition of sustainable development criteria established in 2006.

One of the main outcomes of the Rio+20 Conference was the agreement by member of States to launch a process to develop a set of **Sustainable DevelopmentGoals (SDGs**), which will build upon the Millennium Development Goals and converge with the post 2015 development agenda.It was decided establish an "*inclusive and transparent intergovernmental process open to all stakeholders, with a view to developing global sustainable development goals to be agreed by the General Assembly*".

In the Rio+20 outcome document, member of States agreed that sustainable development goals (SDGs) must:

1. Be based on Agenda 21 and the Johannesburg Plan of Implementation.
2. Fully respect all the Rio Principles.
3. Be consistent with international law.
4. Build upon commitments already made.
5. Contribute to the full implementation of the outcomes of all major summits in the economic, social and environmental fields.
6. Focus on priority areas for the achievement of sustainable development, being guided by the outcome document.
7. Address and incorporate in a balanced way all three dimensions of sustainable development and their inter linkages.
8. Be coherent with and integrated into the United Nations development agenda beyond 2015.

9. Not divert focus or effort from the achievement of the Millennium Development Goals.
10. Include active involvement of all relevant stakeholders, as appropriate, in the process.It was further agreed that SDGs must be:
    - Action-oriented
    - Easy to communicate
    - Limited in number
    - Aspirational
    - Global in nature
    - Universally applicable to all countries while taking into account different national realities, capacities and levels of development and respecting national policies and priorities.
    - The outcome document further specifies
    - Be useful for pursuing focussed and coherent action on sustainable development
    - Contribute to the achievement of sustainable development
    - Serve as a driver for implementation and mainstreaming of sustainable development in the UN system as a whole Address and be focussed on priority areas for the achievement of sustainable development

The Rio+20 outcome documents *The Future We Want* resolved to establish an inclusive and transparent intergovernmental process on SDGs that is open to all stakeholders with a view to developing global sustainable development goals to be agreed by the UNGA. The outcome document mandated the creation of an inter-governmental Open Working Group that will submit a report to the 68th session of the General Assembly containing a proposal for sustainable development goals for consideration and appropriate action.

10.10 World Summit on Sustainable Development

WSSD Was held from August 26 to September 4.About 21,000 delegates including 104 Heads of State and Government worked together for 7 major issues. In May 2002, Kofi Annan, Secretary General of the UN drew attention at WSSD: Water, Energy, Health, Agriculture, Biodiversity.Highlights of seven major issues is:

1) Poverty eradication
2) Health
3) Water and sanitation
4) Agriculture
5) Energy
6) Biodiversity
7) Climate change

Keeping in view, the outcome of Earth Summit-1992, the WSSD failed to achieve much because of the lack of faith and trust between governments.No government was able to give money , technology , sovereignty.Compared to WSSD- 2002 , Earth Summit -1992 was successful as there was ability and will of government to work together and find solutions for global problems.

10.11 Sustainable Development in India

Environmental Sustainability has been the integral part of the Indian Culture. The need for conservation and sustainable use of natural resources has been reflected in our constitutional, legislative and policy framework .The various measures initiated for environmental protection by India included the following:

- Stockholm Declaration by Late Smt. Indira Gandhi visited and supported the idea of UN conference on Human Environment in Sweden in 1972.
- The Ninth five year plan (1997-2002) recognised a close relationship between environments, health, and development for enduring sustainability. Principles of sustainable development were followed in successive Tenth-five year plan (2002-2027) are:
    - Reduction of poverty
    - School education for all children
    - Reduction in gender gaps
    - Control of human population growth

  - Increase rate of literacy
  - Reduction in mortality rate of infants
  - Increase in forest cover
  - Cleaning of major polluted rivers
- Environment protection act 1986
- The National Conservation Strategy and Policy Statement on Environment and Development , 1992
- Convention on Biological Diversity (CBD)
- Biological Diversity Act 2002 with National Biological Diversity Authority for conservation of biodiversity, sustainable use of components.
- Acceded to Montreal Protocol and setting up Ozone Cell in MoEF.

10.12 International Effort on Sustainable Development

The various international programmes targeted for sustainable development are as follows:

- World Conservation Strategy
- World Commission on Environment and Development
- United Nations Conference on Environment and Development (UNCED) or Earth Summit
- Commission on Sustainable Development (CSD)
- World Summit on Sustainable Development (WSSD)
- United Nations Conference On Sustainable Development (UNCSD) or RIO+20
- Global Environmental Monitoring and Assessment

10.13 Summary

The Ecological Management option is designed to provide students with an understanding of how ecological principles can be applied to the management and conservation of natural resources and ecosystems. Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse. Sustainable development has three component goals: economic development (especially poverty reduction); social development; environmental protection. The Brundtland Report greatly boosted interest in sustainable development (World Commission on Environment and Development, 1987). Sustainable development is now a key goal for ecological management.

10.14 Glossary

- **Environment:** The sum of all physical, chemical, biotic and cultural factors that affect life of organism in any way.
- **Ecological management** : Various international, state and local measures which are directed at environmental conservation, the rational and sustainable allocation and utilisation of natural resources, the optimisation of interrelations between society and the environment, and the improvement of human welfare for present and future generations.
- **Sustainability**: It means ensuring that rate of use or consumption of any resource does not exceed the capacity of the natural systems to regenerate it. It also means that development meets their on needs.
- **Sustainable Development:** Development and or growth that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.
- **Afforestation:** Planting of trees in an area to provide a forest cover.
- **De-forestation:** Destruction of forest cover and the undergrowth.
- **Flora:** Species content of plants in an area.
- **Fauna:** Species content of animals present in an area.
- **Agenda 21:** a set of goals and proposals published following the 1992 Rio 'Earth Summit' which promotes sustainable development. All countries have been encouraged to adapt the proposals and incorporate them into governance and management
- **Earth Summit:** UN Conference on Environment and Development (UNCED) held at Rio de Janeiro in 1992. The second major UN environment and development conference (the first being at Stockholm in 1972).
- **CDM :** Clean Development Mechanism
- **CSD :** Commission on Sustainable Development

- **UNCED :** United Nations Conference on Environment and Development also called "Earth Summit 1992 ''
- **UNEP :** United Nations Environment Programme
- **WBCD :** World Business Council for Sustainable Development
- **WCED :** World Commission on Environment and Development

10.15 Self- Learning Excercise

Section- A : (Very Short Answer Type Questions)

1. In 1992 ... was held at Rio de Janerio.
2. UNEP defines…………as the tool used to identify the environment.
3. WSSD stands for World Summit on …………..
4. The main aim of EIA is…………
5. In 1987, UNCED released his report named as…………
6. The goals of sustainable development are social…. ……………. &……….
7. EIA stands for………
8. CSD means ………

Section- B : (Short Answer Type Questions)

1. Write short note on "Earth Charter".
2. What are the principles of Sustainable Development?
3. Write a short note on main objectives of ecological management?
4. What are the international efforts on Sustainable Development?
5. Explain Clean Development Mechanism (CDM).
6. Name the aspects of Environmental Management Plan (EMP).

Section- C : (Long Answer Type Questions)

1. Write a detailed note on United Nations Conference on Sustainable Development (UNCSD).
2. What do you understand by Environmental Appraisal Committee (EAC)?
3. Explain the procedure of Environment Impact Assessment (EIA).
4. Write short note on – a) Environmental Monitoring
   b) Sustainable Development in India

Answer Key of Section – A

1. Earth Summit
2. EIA
3. Sustainable Development
4. Resource conservation
5. Brundtland Report
6. Economic , Environmental
7. Environment Impact Assessment
8. Commission on Sustainable Development

10.16 References

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Unit-11

Origin of Agriculture and World Centers of Primary Diversity of Domestic Plants

Structure of the Unit:

11.0 Objectives

After studying this unit you will be understand the origin and introduction of cultivated plants in terms of-

- Origin of Agriculture
- Center of origin
- Plant introduction

11.1 Introduction

The cultivation of crop is one of the oldest occupations of men and began with the discovery of certain seeds spilled on disturbed ground, grew in some mysterious way into new plants. Men collected the seeds and spread it into different regions. This is how origin and introduction of crop plants started.

The term origin of crop plants mainly refers to the means by which the crop plants came into existence. The origin of a particular crop is directly related to the place or the site or the country where it was born and domesticated for the first time. The first attempt to develop the subject of origin of domesticated plant was done by Alphonse de Candolle (1883) in his book '**Origine des Plantes Cultivee**'. Nikolai Vavilov suggested the idea that many cultivated plants originated in the different regions of the world where these plants were domesticated and then dispersed and spread to other areas of the world. These centers are characterized by the presence of dominant genes. Often centers of diversity do not always occupy a limited area and there might be secondary centers of diversity due to long history of continuous cultivation and interaction with wild relatives or between different races of a crop.

11.2 Origin of Agriculture

Agriculture can be defined as the cultivation of plants, fungi and other life forms for food, fiber, biofuel, medicines and other products used to sustain and enhance human life. For most of the times in human history Men lived as hunters and gatherers. These people do not form permanent establishments and change their places according to availability of resources and changes in the climate. The cultivation of plants is one of the oldest occupations of Men. It began with the selection of plants for use. By the end of 18th century people started questioning about the origin of cultivated plants. The origin and evolution of agriculture represents a major shift in the adaptation of human populations. It had its impact on the evolution of culture too. However, sometimes agriculture is claimed as a mal-adaptation in human history (Manning, 2004).

Around 10,000 years ago in many areas of the world, there was a shift in human endeavour from foraging to farming. Most authorities agree that agriculture arose independently in different areas over several thousand years. Why this shift occurred can only be theorized, but the development of agriculture formed the basis of advanced civilization in both the Old and the New Worlds. Over the centuries, agricultural societies spread into those environments that could be easily adapted to agriculture, and foragers gradually became restricted to marginal areas. By the late twentieth century, foraging societies had largely disappeared, constituting only a tiny percentage of the human population and limited to a few tropical rain forests, deserts, savannas, tundras and boreal forests.A number of theories have been given for the origin of Agriculture. Any of the following or all causes can be assigned for the origin of Agriculture in different regions of the world (Aery, 2010). These are:

- A decrease in the number of wild species available due to overhunting resulting in the selection of certain animals for domestication.
- An increase in the cultivable wild plant species at the end of last glacial age.
- Advancement in the collection, processing and storage procedures of wild plant species.
- An increase in the population which forced to improve the production of more food.

Theories related to Origin of Agriculture

1. **Oasis Theory:** The Oasis hypothesiswas proposed by Raphael Pumpelly (1908) and supported byVere Gordon Childe who summarized the hypothesis in his book ***Man Makes Himself***. According to this hypothesis as the climate got drier, communities contracted to **oasis** where they were forced into close association with animals which were then domesticated together with planting of seeds. The hypothesis has little contemporary support, as the climate data for the time does not support the hypothesis.
2. **The Feasting Model:** TheFeasting model by Brian Hayden suggests that agriculture was driven by ostentatious displays of power such as throwing feasts to exert dominance. This required assembling large quantities of food which drove agricultural technology.
3. **TheHilly Flanks Hypothesis**: This hypothesis was proposed byBraidwood (1948). He suggesed that agriculture began in the hilly flanks of theTaurusand Zagros Mountains and that it developed from intensive focusedgraingathering in the region.
4. **The Demographic Theory:** TheDemographic theorywas proposed byCarl Sauer. They describe an increasingly sedentary population, expanding up to the carrying capacity of the local environment, and requiring more food than can be gathered. Various social and economic factors help drive the need for food.

5. **The Evolutionary/Intentionality Theory:** The evolutionary/intentionality hypothesis, advanced by scholars such as Rindos, is the idea that agriculture is a co-evolutionary adaptation of plants and humans. Starting with domestication by protection of wild plants, followed specialization of location and then domestication.
6. **The Innovation and Specialisation Model:** This model was given by Gerritsen, in *Australia and the Origins of Agriculture* (2008). This model considers the question in terms of economic development and treats agriculture as a form of specialisation arising from two factors, higher population densities and innovation in areas of higher net natural productivity and long-term advantageous information acquisition at nodal points in communication in long range scale-free networks.
7. **The Levantine Primacy Model**: This model was developed in the 1980s byOfer Bar-Yosefand colleagues. This model provides a cultural ecology explanation, based on the idea that some areas were better favoured with domesticable plants and animals than others.
8. **The domestication hypothesis:** This model put forth by Daniel Quinn and others states thatfirsthumans stayed in particular areas, giving up their nomadic ways, then developed agriculture and animal domestication.

Another hypothesis is that humans were prevented from staying in one place for much of their history, due to the risk of attacks from other tribes.

11.3 World Centers of Primary Diversity of Domestic Plants

Acenter of diversity is an area that has a high degree of genetic variation for a particular plant taxon (e.g. genus, species or family) that can also be thecenter of origin for that group. The center of origin is a geographical area where a group of organisms, either domesticated or wild, first developed its distinctive properties. Centers of origin are also consideredcenters of diversity. The center of origin allows one to locate wild relatives, related species and new genes (especially dominantgenes, 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 and increased urbanization.

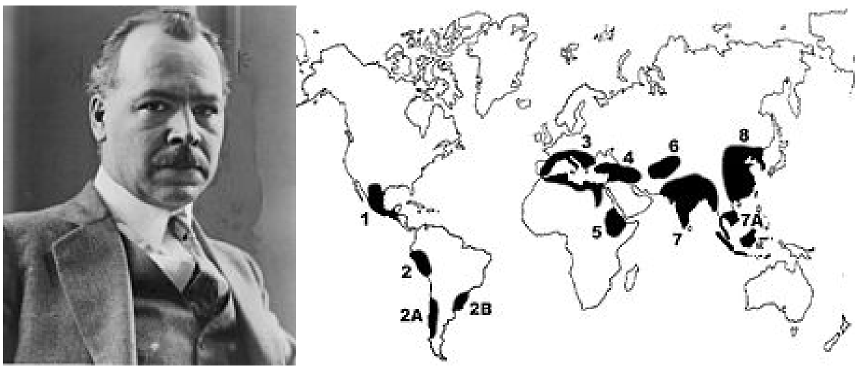
11.3.1 Concept of Candolle

Alphonse de Candolle (1863) a Swiss botanist first attempted to solve the mystery about evolution of crop plants. In his**'Origine des Plantes Cultivee'**he studied 247 plant species of cultivated plants.

Candolle classified the plants into six classes :

1. Plants cultivated 4000 years ago
2. Plants cultivated 2000 years ago
3. Plants cultivated less than 4000 years
4. Plants cultivated 2000 to 4000 years
5. Plants cultivated after the time of Columbus
6. Plants cultivated after the time of Columbus

11.3.2 Vavilov centers



Nikolai Vavilov

Fig. 11.1 : Vavilov's Center of Origin

Vavilov's Eight Center of Origin: (1) Southe Mexican and Central America, (2) South American, (2A) Chile Center, (2B) Southern Brazil, (3) Mediterranean, (4) Middle East, (5) Ethiopia, (6) Central Asia, (7) Indo-Burma, (7A) Siam-Malaya-Java, (8) Chinese

Vavilov Centers of origin are the regions of the world that are an original center for the domestication of plants. These are first described by Dr. Nikolai Ivanovich Vavilov in 1926. He proposed the concept based on his studies of a vast collection of plant at Institute of Plant Industry, Leningrad. Vavilov developed a theory on the centers of origin of cultivated plants. According to Vavilov plants were not domesticated somewhere in the world at random but there are regions where the domestication started. The center of origin is also considered the center of diversity. Until today Vavilov centers are regions where a high diversity of crop wild relatives can be found, representing the natural relatives of domesticated crop plants. The concept is that crop plants evolved from wild species in the area showing great diversity and that place is termed as primary center of origin. Later on from the primary center the crops moved to other places due to the activities of man. There are certain areas where some crops exhibit maximum diversity of forms but this may not be the center of origin for that particular crop. Such centers are known as **Secondary centers of origin.**

11.3.3 World Centers of Origin of Cultivated Plants

1) South Mexican and Central American Center

Distribution: Includes southern sections of Mexico, Guatemala, Honduras and Costa Rica.

Plants: Grains and Legumes: Maize, common bean, lima bean, tepary bean, jack bean.

Melon Plants: Malabar gourd, winter pumpkin, chayote.

Fiber Plants: Upland cotton, bourbon cotton, henequen (sisal).

2) South American Center

Distribution: This center includes the high mountainous regions of Peru, Bolivia, Ecuador, Colombia, parts of Chile and Brazil and whole of Paraguay.

Plants: Total 62 plants listed; three subcenters

i) Peruvian, Ecuadorean, Bolivian Center:

Root Tubers: Andean potato, other endemic cultivated potato species. Fourteen or more species with chromosome numbers varying from 24 to 60, Edible nasturtium.

Grains and Legumes: Starchy maize, lima bean, common bean.

Root Tubers: Edible canna, potato.

Vegetable Crops: Pepino, tomato, ground cherry, pumpkin, pepper.

Fiber Plants: Egyptian cotton.

Fruit and Miscellaneous: Cocoa, passion flower, guava, heilborn, quinine tree, tobacco, cherimoya.

ii) Chile Center

Plants: Common potato, Chilean strawberry

2B) Southern Brazil Center

Plants: Manioc, peanut, rubber tree, pineapple, Brazil nut, cashew, Erva-mate, purple granadilla.

iii) Mediterranean Center

Distribution Includes the borders of the Mediterranean Sea. 84 listed plants

Plants

Cereals and Legumes: Durum wheat, emmer, Polish wheat, spelt, Mediterranean oats, sand oats, canary grass, grass pea, pea, lupine

Forage Plants: Egyptian clover, white clover, crimson clover, serradella

Oil and Fiber Plants: Flax, rape, black mustard, olive

Vegetables: Garden beet, cabbage, turnip, lettuce, asparagus, celery, chicory, parsnip, rhubarb

Ethereal Oil and Spice Plants: Caraway, anise, thyme, peppermint, sage, hop

4) Middle East

Distribution: This is also known as the Near East or the Persian Centre of Origin. It includes the interior of Asia Minor, the whole of Transcaucasia, Iran and Highlands of Turkmenistan.

Plants Includes interior of Asia Minor, all of Transcaucasia, Iran and the highlands of Turkmenistan. Total 83 plant species are originated from this center.

Grains and Legumes: Einkorn wheat, durum wheat, popular wheat, common wheat, oriental wheat, Persian wheat, two-row barley, rye, Mediterranean oats, common oats, lentil, lupine

Forage Plants: Alfalfa, Persian clover, fenugreek, vetch, hairy vetch

Fruits: Fig, pomegranate, apple, pear, quince, cherry, hawthorn

5) Ethiopia

Distribution This center includes Abyssinia, hill country of Eritrea and part of Somaliland.

Plants

Total 38 species are originated from this center. This area is rich in wheat and barley.

Grains and Legumes: Abyssinian hard wheat, poulard wheat,emmer, Polish wheat,barley, grain sorghum,pearl millet,African millet, cowpea,flax, teff

Miscellaneous: Sesame, castor bean, garden cress, coffee, okra, myrrh, indigo

6) Central Asiatic Center

Distribution: It includes North West India, Afghanistan, Soviet Republics of Tajikistan and Tian Shan. It is also known as the Afghanistan center of origin.

Plants: Total 43 species are originated from this center.

Grains and Legumes: Common wheat, club wheat, shot wheat,peas,lentil,horse bean,chickpea,mung bean,mustard,flax,sesame

Fiber Plants: Hemp, cotton

Vegetables: Onion, garlic, spinach, carrot

Fruits: Pistacio, pear, almond, grape, apple

7) Indian Center

Distribution: This includes Burma, Assam, Malaya, Java Borneo, Sumatra and Philippines, but excludes North West India, Punjab and North Western parts of India.

This center is further divided in to two subcenters

7) Indo-Burma:

Distribution: Main Center (India): Includes Assam and Burma, but not Northwest India, Punjab, nor North West parts of India.

Plants: Total 117 species are originated from this center.

Cereals and Legumes: Rice, chickpea, pigeon pea, urd bean, mung bean, rice bean, cowpea,

Vegetables and Tubers: eggplant, cucumber, radish

Fruits: Mango, orange, tangerine, tamarind

Sugar, Oil, and Fiber Plants: Sugar cane, coconut, sesame, sunflower,tree cotton, oriental cotton,jute,crotalaria

Spices, Stimulants and Dyes: Hemp, black pepper, gum arabic, sandalwood, indigo, cinnamon tree.

7A) Siam-Malaya-Java:

Distribution

Siam-Malaya-Java includes Indo-China and the Malaya Archipelago.

Plants Total 55 species are originated from this center.

Cereals and Legumes: Job's tears, velvet bean

Fruits: Pummelo,banana,breadfruit,mango steen Oil, Sugar, Spice, and Fiber Plants: Candlenut, coconut palm,sugarcane,clove,nutmeg,black pepper,Manila hemp.

8) Chinese Center

Distribution: It consists of the mountainous regions of central and western China and the neighbouring low lands. It is the largest and oldest independent center.

Plants: A total of 136 plants are listed in this center.

Cereals and Legumes: Broomcorn millet, Italian millet, Japanese barnyard millet, Koaliang, buckwheat, hull-less barley, Soyabean, Adzuki bean, velvet bean

Roots, Tubers and Vegetables: Chinese yam, radish, Chinese cabbage, onion, cucumber

Fruits and Nuts: Pear, Chinese apple, peach, apricot, cherry, walnut, litchi

Sugar, Drug and Fiber Plants: Sugar cane, opium poppy, ginseng camphor, hemp.

11.4 The Indo-Burmese Centre

Distribution: The Indo-Burmese center is distributed on the Indo-chinese Peninsula, and comprises Cambodia, Lao, Myanmar, Thailand, Vietnam, Southern China and North Eastern India. The topography of the center is complex and is characterized by a series of north-south mountain ranges, which descend from the Himalayan chain and its south eastern extensions.

Plants: An estimate of total plant diversity in the area is about 13,500 vascular plant species, of which about 7,000 are endemic. Total 117 species are originated from this center. Among these plants some important crop plants are:

Cereals and Legumes: Rice, chickpea, pigeon pea, urd bean, mung bean, rice bean, cowpea,

Vegetables and Tubers: eggplant, cucumber, radish

Fruits: Mango, orange, tangerine, tamarind

Sugar, Oil, and Fiber Plants: Sugar cane, coconut, sesame, safflower, tree cotton, oriental cotton, jute, crotalaria

Spices, Stimulants and Dyes: Hemp, black pepper, gum arabic, sandalwood, indigo, cinnamon tree.

11.5 Plant Introduction and Secondary Centers

Plant introduction is thecintroductioncof plant species orvarieties into new places orregions. The term plant introduction has been used since these con dhal fof the19th century.

The under lying theory, first substan tiated in 1855 by A.de Candolle, wasel aborated by N.I. Vavilov (1926) on the basis of his theory of centers of origin of cultivated plants. The primary centers contain them aingene pool of wild related speciesand the mostancient form sofcul tivated plants, which are carriers of genes valuable for selection and breeding. The carriers of new characteristicst hatar epromising for breeding purposes (like yield capacity, high-quality production, early ripening) are often concentrated in these condary geographical centers of many cultivated plants (through hmutation sandhy bridization). Man's interventionled to the transferof plants from these centersto new regions and the concomitant broadening of the range of various species. Thus modern cultivated wheat, barley, rice, oats, corn, Soyabeans, cotton and sun flower are descendants of wild species that were frequently valuable in them selves.

The geography of the most important cultivated plants has changed; their ranges have been substantially broadened and asa result their connection with the primary centers has frequently been lost. For example, the native home of the coffee bean is Ethiopia, but today its production is concentrated chiefly in Latin America. The main production of peanuts, which originated in northern Argentina, is now concentrated in equatorial Africa.

According to Vavilov, there can be two sources for the introduction of plants:

(1) Gene centers, from which the dominant genes that determine resistance to diseases and pests and high- quality production can be drawn, and

(2) Remote areas of highly developed agriculture, where there isa concentration of the carriers of recessive genes that determine many valuable characteristics for breeding.

Material for the introduction of plants is primarily provided by the scientific expeditions that are sent by many countries to the primary and secondary centers of origin of cultivated plants. Botanical gardens and other botanical and breeding facilities perform the day-by-day work of introducing and acclimatizing wild species.

The process of importing new plants or cultivars of well-established plants from the area of their adaptation to another area where their potential is evaluated for suitability for agricultural or horticultural use is known as Plant Introduction.

Types of Plant Introduction

Plant introduction can be classified into types: primary introduction and secondary introduction. When the plant introduction is commercially usable as introduced without any modification, is known as **Primary introduction,** whereas when it need selections from the variable populations, or uses the plant introduction as a parent in crosses, is known as **Secondary introduction**.

11.6 Summary

The cultivation of crop is the oldest occupations of men. Agriculture isthe cultivation of plants for different products used to sustain and enhance human life. These plants are originated in different area of world. A geographical area where a group of plants, either domesticated or wild, first developed its distinctive properties is known as center of origin. It is also known ascenters of diversity. During the course of time the plants are spread in different areas. Introduction of plant species or varieties into new places or regions is known as plant introduction.

11.7 Glossary

- **Center of Origin**: It is a geographical area where a group of organisms, either domesticated or wild, first developed its distinctive properties.
- **Plant Introduction:** Plant introduction is the introduction of plants pecies or varieties into new places or regions.

11.8 Self-Learning Excercise

Section- A : (Very Short Answer Type Questions)

1. Name the Russian botanist who worked a lot on the origin of cultivated plants?
2. What is the origin of center of wheat?
3. Write the name of center of origin of cotton.
4. Write the name of center of origin of rice.

Section- B : (Short Answer Type Questions)

1. Explain domestication.
2. Describe primary center of origin.
3. Explain center of origin.
4. Write about the cultivation of berseem?
5. Describe primary center of origin.

Section- C : (Long Answer Type Questions)

1. Describe the Vavilov's concept of origin of cultivated plants.
2. Write an essay on origin of agriculture.
3. Describe the plant introduction.
4. Describe the eight centers of origin of cultivated plants recognised by vavilov.

Answer key of Section – A

1. Vavilov
2. South west Asia
3. Central America
4. Indo-Burma

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Unit - 12

Economic Botany of Food and Forage Crops

Structure of the Unit:

12.0 Objectives

After studying this unit you will understand the cultivation and importance of food and fodder plants in terms of-

- Origin, evolution, botany, cultivation of food plants
- Origin, evolution, botany, cultivation of millets
- Origin, evolution, botany, cultivation of fodder

12.1 Introduction

Food is the most important requirement of men as well as cattle. Food plants may be defined as plants that are used for human consumption. Although the angiosperms are the major source of human food but gymnosperms, pteridophytes, fungi and algae are also used as food. Human food differs from animal food in the sense that it usually undergoes some form of preparation prior to eating. Some foods, such as nuts, fruit and salad vegetables may be eaten raw, more often food is cooked. The use of plant food sources ranges from total dependence on wild plants by some peoples to almost total reliance on cultivated plants by people of developed countries. The range of foods eaten by man includes cereals, pseudo cereals, pulses, nuts, root and fruit vegetables etc.

12.2 Origin, Evolution, Botany, Cultivation and Uses of Food Crops

12.2.1 Wheat

Botanical name: ***Triticum aestivum***

Family: Gramineae

Common Name: Gehun

Origin and Evolution

The origin of wheat is believed at Hindukush mountainous regions adjoining to India and Afganistan. According to De Candolle Valley of Euphrates and Tigris was the origin of wheat. But Vavilov stated origin of Durum wheat is probably Abyssinia and soft wheat groups are in the region of Western Pakistan, South West Afghanistan and Southern parts of mountainous Babshara. Wheat has undergone domestication under selection pressures which changed it from a wild grass to a cultivated species with the present level of production.

Botanical characters

Wheat is an annual plant. Roots fibrous; stem erect (divided in long internodes and conspicuous nodes); leaves are alternate and with sheathing base, it can be divided into 2 parts, the sheath and the blade; inflorescence spike of spikelet; flowers axillary, zygomorphic, hypogynous, sessile and bisexual; tepals 2; stamens 3 and versatile; gynoecium tricarpellary showing pseudomonomery, unilocular, ovary superior, parietal placentation with one ovule; fruit caryopsis and seeds endospermic.

Cultivation

Wheat is one of the oldest and most important of the cereal crops. Though grown under a wide range of climates and soils, wheat is best adapted to temperate regions with rainfall between 30 and 90 cm. Winter and spring wheats are the two major types of the crop, with the severity of the winter determining whether a winter or spring type is cultivated. Winter wheat is always sown in the fall; spring wheat is generally sown in the spring but can be sown in the fall where winters are mild. Ideal sowing time is mid October to starting of November.

Uses

1. Wheat is eaten in various forms by more than 1000 million people in the world.
2. In India, it is second important staple food crop next to rice.
3. Soft wheat is used for making chapatee, bread, cake, biscuits, pastry and other bakery products.
4. In areas where rice is the staple cereal food, wheat is eaten in the form of ‘puris’ or in the form of ‘upma’.
5. In addition to this, wheat is also consumed in various other preparations such as ‘dalia’, ‘halwa’, ‘sweet meals’, etc.
6. In most of the urban areas of the country, the use of backed leavened bread, flakes, cakes, biscuits etc. is increasing at a fast rate.
7. Wheat straw is used as fooder, padding material and mulching material.
8. Wheat grain is used for preparing starch.

12.2.2 Rice

Botanical Name: ***Oryza sativa***

Family: Poaceae (Gramineae)

Common name: Chawal, dhan

Origin and Evolution

Rice is known to have been grown in China nearly 5000 years ago. Archeological studies also indicate that the remains of rice were found in yung shao excavations from China, of 2600 BC. According to de Candolle various wild relatives of rice such as *Oryza rufipogan* and *O. nivara* are available in India abundantly. Archaeological remains of rice available from Indus valley excavations also support the fact that rice was grown here before 2300 BC.

Nowadays there are two cultivated species of rice viz - *O. sativa* and *O. glaberrima* are widely grown in most of the regions. Their close resemblance and availability of their intermediate varieties is an indication of the fact that both the above mentioned species would have originated from a common ancestor *Oryza perennis.* It spread east ward from India, China and then gradually to Japan, and west ward to Iran, Iraq, turkey and Egypt.

Botanical Characters

Rice is a semi-aquatic annual grass. Plant body is having the height of 50-150 cm. Stem is cylindrical and differentiated into nodes and internodes. In the plant body tuft formation takes place due to the process of tillering. The inter nodes are hollow and of smaller size in the basal region of the plant body but gradually become elongated in the upper regions of the plant. Intercalary meristem is present above the each node. The basal leaf of each tiller and main stem is rudimentary and known as **protophyll**. Leaves are alternately arranged. Each leaf is differentiated into leaf sheath, lamina, ligule, and auricle. Node is partially or completely enclosed by leaf sheath. Lamina is 30-50 cm in length, and 1-2 cms broad. The margins of lamina are hairy.

Inflorescence of rice plant is panicle of spikelets. The spikelets are solitary and single flowered. Flowers are usually self-pollinated. The flowers are enclosed in lemma and palea and on maturity of plant, they form hull which is attached with grain. The grains of rice enclosed by hull are known as paddy or Dhann Lemma and palea are either owned or awnless. Each flower consists of six stamens (arranged in two whorls and a carpel) which are enclosed by lemma and palea.

Grain or fruit is one seeded caryopsis. The grains of rice show variability in size and shape. These are either white or yellow coloured. In the cereals maximum amount of starch is found in rice grains as reserve food after barley. Each rice grain contains 78% starch, 7.5% protein, along with 1.8% fat and vitamins.

Cultivation

About 90% of total rice production of the world comes from China, India, Bangladesh, Japan, Pakistan, Myanmar, Thailand, Vietnam, Korea, Philippines, Indonesia and Srilanka. However, the cultivation of rice is also common in Italy, Spain, Egypt and America. China is the country which provides maximum production of the world, India is next in number. India has the largest area under rice cultivation about 29% of the total world. More or less it is practically grown in all states of India. However the production of rice in our country is mainly concentrated in the river valleys, deltas and in low-lying coastal areas. The leading rice producing states of India are West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Orissa, Bihar, Madhya Pradesh and Assam.

Rice is an essentially the crop of tropical climate. However it is grown over extremely wide range of climatic conditions spread over throughout the world, but it is best suited to the regions which have high temperature, high humidity, prolonged sunshine and assured with continuous supply of water. An annual rainfall of 60-120 cm is favourable for upland varieties, and 180-240 cm for low land varieties.

Before the cultivation, field is thoroughly ploughed. Usually the field is having the soil of high water holding capacity and good water drainage. After the proper ploughing the field is flooded with water. However in the non irrigated areas the paddy cultivation process is started when these fields are filled by rain water. The sowing process of rice is undertaken at varied times in different parts of India depending on the climatic conditions. On the basis of harvesting period rice is placed under three categories. These are:

(1) Winter rice: This variety is sowed in the months of June-July and its harvesting is undertaken in November-December. This is mainly a crop of low lying areas and known as Aman.

(2) Autumn rice: This variety is sown in May-June and harvested by September-October. It is mostly cultivated in highlands.

(3) Spring rice: It is sown in December-January and harvested by March- April.

Two main systems for cultivation of rice are followed in India:

(a) Dry Cultivation: Similarly to other cereals in this system, the crop is raised on dry soil. The field is repeatedly ploughed and harrowed in the summer season to obtain the sufficient tilth. The field is ploughed five to seven times at an interval of seven days. Then the seeds are sown by broadcasting, dibbling or drilling in lines. The method of sowing in lines is mostly preferred as it ensures a uniform stand, requires a lower seed rate and facilitates inter culture operations. In this method line to line distance is kept 20-25 cm.

(b) Wet Cultivation: In this system of cultivation the crop is grown under an assured, sufficient and adequately regular supply of water and the plants remain flooded by water from the time of transplanting under harvesting. Wet cultivation system covers about 90% of rice cultivation in India. The land is thoroughly ploughed and puddled with 5-6 cm of standing water, under this system. The major aim of puddling is to get a soft soil so that transplanted seedlings can establish themselves adequately and quickly. Now this wet field is repeatedly ploughed 4-6 times with an interval of four to five days between two ploughing and then leveled up by planking. Here in this system, either the sprouted seeds are directly sown in a puddle or leveled field or alternatively seedlings are grown in a nursery and then transplanted. In the traditional rice growing areas where there is properly favourable rainfall, temperature and humidity are observed, the seedlings are grown on raised seed beds.

Besides the two above mentioned systems of paddy cultivations, there is yet another system, known as semi **dry system**, where in the beginning the rice is sown as dry crop but later on rain water is impounded in the field when the crop is 5-6 weeks old. This practice is known as "Bushening", and quite prevalent in Orissa and Madhya Pradesh. This process of ploughing the field with the standing crop serves three purposes weeding, thinning and inter-culturing of the crop.

The high yielding varieties of rice require sufficient amount of proper fertilizers. 30-45 days before sowing about 100-110 kg/hectare green manure is applied to the field. Then after sowing 100-110 kg super phosphate and 200 kg ammonium sulphate per hectare is applied.

Harvesting and Threshing

When culms of the crop plants turn brown or yellow, the crop is considered to be ready for harvesting. The premature harvesting decreases the crop yield and also affects the milling quality. On the other hand in the delayed harvesting, there are chances of loss of grains by shattering.

The task of harvesting is carried out by the help of hand sickles. After it, the harvested crop is dried immediately and threshed. Normally threshing is done by beating the sheaves or by trempling under the feet of bullocks. In some regions, the threshing is done by machines also, pedal and power threshers are used for this purpose. After the threshing grains are winnowed and properly dried before bagging. The rice grain covered by husk, as we know is known as paddy. This husk is separated from the grain by beating. After the separation from grain it is known as bran.

Uses

1. In various countries such as India, China, Japan, and Korea, rice is used as major or staple food. Since its bread or chapatti cannot be prepared because of glutinine deficiency in the grains hence it is taken directly as food after cooking or boiling.
2. Various food delicacies such as Idli, Dosa and Upma are prepared after fermentation generally in most of the parts of our country, but particularly in south India.
3. Rice is also used in the preparation of biscuits, ice-cream and pastry.
4. It is also used for making alcoholic beverages and as a source of starch.
5. Rice starch is widely used in cosmetic industry, as thickener in calico printing, in the finish of textiles.
6. Rice starch is also used for making dextrins, glucose and adhesives.
7. Paddy husk is used as a fuel and for making hard boards and as a raw material for alcohol and furfural.
8. Rice bran is used as cattle feed.
9. Edible fatty oil is also obtained from rice, bran, which is known as "bran oil".
10. It is used in soap industry and for making cosmetics.
11. Paddy straw is used as a fodder, in the manufacture of straw boards, and as soil mulch. Not only is this but also used for thatching, making hats, sacks, mats ropes and baskets.

12.2.3 Barley

Botanical Name: ***Hordium vulgare***

Family: Poaceae (Gramineae)

Common name: Jo

Origin and Evolution

Near-East region is known as place of origin for Barley. Abyssinia is believed as centre of origin for barley by one group and south East Asia (China, Tibet, Nepal) by another group of scientists.

Botanical Characters

The barley plant is approximately one meter in height. The stem of the plant has on average five to seven internodes separated by the nodes. The leaves are linear lanceolate. The leaves are formed of sheath, blade, auricles and ligule. It has two types of root systems. The first is where seedling roots develop to a tillering stage. The second type starts at the tillering stage and then grows deeper crown roots, which anchor the plant in the soil and help absorb water and nutrients.

Cultivation

Barley is tolerant to salinity and alkalinity but sensitive to acidity. Barley is being salt tolerant, best substitute for sodic soil. Drained, fertile deep loam soil with pH 7-8 is favourable for barley. Climate necessary for successful barley cultivation is similar to wheat. It performs well in cool climate. Warm and moist conditions are not conducive for barley growth. It can't tolerate to frost and frost and hail storm at flowering are more detrimental. Under rainfed, before end of October is optimum for sowing. In irrigated condition, first or second fortnight of November is optimum time of sowing. In Hilly zones barley is sown as summer crop in April-May.

Uses

1. Barley is important next to rice, wheat, maize in area and production.
2. It is more suitable than wheat in India. Due to hardy nature, it can withstand adverse agro-environments like, drought, salinity, alkalinity, varied topography like plain, hill, under rainfed and irrigated conditions etc.
3. It is a Rabi cereal crop and food for people of cooler and semi-arid part of the world.
4. In India, 90% of barley is used as human food.

5. It is also used for preparation of malt, beer, whisky, industrial alcohol and vinegar.
6. Energy rich drinks like bournvita, boost, horlicks and biscuit are form by barley malt.
7. Medicinal value of barley reduces cholesterol level in liver and also stimulates fatty acid synthesis in liver.
8. In USA as cattle feed and horse feed.
9. Barley has great demand to malting industry.

12.2.4 Maize

Botanical Name: ***Zea mays***

Family: Poaceae

Local Names: Makka, Makki

Origin and Evolution

Maize is an important cereal crop of the world. In some countries such as India and Argentina, it is cultivated as food crop while in other countries such as America it is grown as cattle feed crop. In terms of area under cultivation and production, it ranks next to wheat and rice. There is a controversial regarding the origin of maize. According to archeological and geological evidences, maize has originated in American continent. According to other workers there are sufficient evidences, that maize originated as a wild plant in Mexico and/or Andean low lands of central and south-west America. However, some other workers also stress the view of an Asiatic origin of maize, who considers that it was originated in South-East Asia, probably in India, and then from here it spread to American continent before Columbus.

The true or actual ancestor of maize is not yet known, because it does not exhibit similarity to any of the wild plant. Probably maize should have originated as a result of cross breeding between an unknown ancestor and a wild grass *Tripsacum.*

Botanical Characters

Maize is fast growing annual herbaceous plant attaining a height about 1.5 to 3 m. The stem (culm) is generally unbranched with tillering or without it. The culm is differentiated into nodes and internodes. Numerous adventitious stilt roots are developed from the lower nodes of culm. These fibrous adventitious roots are helpful in maintaining erect shoot system by providing support to the culm. Stilt/proproots produce branches, after entering in the soil. Inter nodes are of smaller size in the basal part of culm; however these become gradually longer or elongated and thin in the upper part of the plant. Leaves are long with a size of about 50-70 cm x 8- 15 cm, flat and distichous and differentiated into leaf base and lamina. A membranous ligule is present at the junction, of leaf sheath and lamina. The maize plants are monoecious. The male and female flowers are developed on the separate branchees. The tassel (male inflorescence) occupies the terminal position on the main axis. On the other hand the female inflorescences ear or cob are borne on modified lateral branches in the axils of the leaves. The cob or ear is a small branch which is called as **"Shank"** and it is surrounded by protective leaves. These leaves are known as **spathe or husk.**

Male inflorescence or tassel is in the form of a compact and much branched panicle with pairs of spikelets arranged in two rows on the lateral branches. Each spikelet consists of a pair of two glumes and two florets. Each male flower is having lemma, palea and three stamens. The ear producing branch or shrank has short internodes and bears a female spikes at the apex. These spikes are arranged in 8 or 16 or 24 vertical rows of spikelets and each of such spikelet has got two female flowers. Out of these two flowers one is sterile. However each fertile female flower consists of lemma, palea and a carpel. Feathery style is much longer and emerges out the cob. The two glumes of the female spikelet are membraneous and enclosing female florets. The longer feathery styles of female florets are collectively known as silk. The tip of the style has two short unequal stigmas. Anemophily or air pollination is observed in maize.

Cultivation

Maize is extensively cultivated in the most parts of the world. It has wonderful quality of acclimatization according to different ecological conditions. Basically maize is a plant of warm climate, therefore it grows favorably warms and humid sub tropical climate, or in the warm regions of temperate regions with a temperature range of 21°-27°C and annual rainfall of 60-120 cm. The crop can be grown on diverse soil types but alluvial and loam soils are mostly suited for its cultivation. It is a sun loving crop which require long, hot growing season with pIenty of sunshine from 100-120 days. The cold nights effect adversely to its growth, resulting into delayed maturity. The crop cannot tolerate frost.

Although the maize can be grown in diverse soil types, but well drained light to heavier alluvial and loamy soils with pH value ranging from 5-7 are most suitable for its cultivation. The Indogangetic plains of our country therefore are most suitable for the cultivation of maize. For better crop yield nitrogen, potash, magnesium, phosphorus and calcium fertilizers are added to the crop from time to time whenever required in the different stages of crop cultivation.

Today maize is one of the most widely cultivated in the world. However, its maximum yield comes from America (45%). Besides America it is extensively grown in some other countries such as Brazil, Mexico, New Zealand, Africa, France, Argentina Yugoslavia, Romania, Hungary and Itly.

In India maize is mostly grown as a kharif crop. The field is prepared before sowing. For this purpose field is ploughed several times, well harrowed and leveled, after this leveling, well organized harrowing is done. The process of sowing is started with the start of monsoon (June-July), because more water quantity is required for the adequate growth of the crop in the earlier stages. Seeds are usually sown by broadcasting, behind plough or by dibbling. The field requires irrigation at the intervals of 10-15 days. The crop matures in about 110-130 days. After the maturity of crop, the husk or spathe of the cob becomes yellow coloured and the grains turn dry and hard. In this stage, cobs are plucked from the plants or the crop plant is harvested with the cobs itself, then cobs are separated from crop plants. The dried crop plants are used as cattle feed. Threshing is done by machines of completely dried cobs; the grains are thus separated and stored in completely dried store houses.

Uses

1. Maize is extensively used for food, forage and cattle feed.
2. The grain of maize is quite nutritious with high percentage of easily digestable carbohydrates, fats and proteins. The grains of maize are ground into flour and baked into chapattis.
3. The grains of maize are roasted and eaten.
4. Pop corn and corn flakes are prepared from the grains of maize.

5. The oil obtained from maize is known as corn oil. It is used in making food and corn syrup also. The corn sugar is used in making jams and jellies and other confectionary sweets.
6. The grains are directly fed to milk producing and meat providing live stock.
7. The whole plant is used as cattle feed.
8. The maize starch is widely used as a sizing material in the textile and paper industry.
9. Corn oil, which is obtained from the embryo of maize, is used as lubricant and in soap industry.
10. The culm of maize plant is used for paper making raw material.
11. A specific protein **zein** remains present in maize which is used for the formation of artificial fibre.
12. By the fermentation of maize grains an alcoholic liquor **"chichi"** is prepared in Bolivia.

12.3 Origin, Evolution, Botany, Cultivation and Uses of Millets

Millets are the food crops of small grains which are basically used by the population of rural and tribal areas as staple feed, cattle feed and fodder. The production of millets is highest in India. Millets are generally different genera and species of family Poaceae. On the basis of their edible value millets are divided into two categories- major and minor millets.

Major millets are used for food crops as well as fodder. It includes Sorghum, Pearl millet, Finger millet *etc*. Minor millets are mainly used for fodder purposes. It includes Kodo millet, Little millet, Fox-tail millet and Barnyard millet etc.

The common names and botanical names of prominent millet crops are given in the table 12.1.

Table 12.1: Common and Botanical names of prominent Millet crops

S. No.	Common name	Botanical name
1.	Pearl millet (Bajra)	***Pennisetum typhoides***
2.	Sorghum (Jowar)	***Sorghum vulgare***
3.	Common millet	***Panicum miliaceum***
4.	Little millet	***Panicum miliare***
5.	Australian millet	***Echinochloa decompositum***
6.	Hungary rice	***Digitaria exilis***
7.	Finger millet (Ragi)	***Eleusine coracana***

12.3.1 Bajra

Botanical Name: ***Pennisetum typhoides***

Family: Poaceae

Local Names: Bajra, Bajri

Origin and Evolution

Pearl millet is the most widely grown type of millet. It has been grown in Africa and the Indian subcontinent since prehistoric times. The center of diversity and suggested area of domestication, for the crop is in the Sahel zone of West Africa. Recent archaeobotanical research has confirmed the presence of domesticated pearl millet on the Sahel zone of northern Mali between 2500 and 2000 BC. The earliest archaeological records in India is around 2000 BC and it spread rapidly through India reaching South India by 1500 BC, based on evidence from the site of Hallur.

Botanical characters

Bajra is an annual plant. The stem is known as culm and 15–75 cm in height. Leaf blades are linear or linear lanceolate, 5–30 cm long, 3–10 mm broad, glabrous or with some long white hairs toward base on upper surface. Spike erect, golden-brown in colour, 1–15 cm long, 6– 12 mm broad; spikelets broadly oblong, 3–3.5 mm long. Upper lemma rugose; spikelets subtended by 4–12 bristles in each involucre, these are 3–10 mm long.

Cultivation

Pearl millet is well adapted to growing areas characterized by drought, low soil fertility and high temperature. It performs well in soils with high salinity or low pH. Pearl millet is grown on over 260,000 km^2 of land worldwide. It accounts for approximately 50% of the total world production of millets.

12.3.2 Sorghum

Botanical Name: ***Sorghum vulgare***

Family: Poaceae

Local Names: Jowar

Origin and Evolution

Sorghum is native to Australia, with some extending to Africa, Asia, Mesoamerica and certain islands in the Indian and Pacific Oceans. *Sorghum bicolor* is grown for grain, while others species are used as fodder plants. The plants are cultivated in warm climates worldwide and naturalized in many places.

Botanical characters

Sorghum is an annual plant. Stem is tillers, fibrous root system, roots are finely branched, roots usually don't penetrate deeply, inflorescence panicle, spikelets occur in pairs (one is sessile while other is pedicellate). The sessile spikelet is fertile and the pedicellate spikelet is sterile Seed color is variable; grains are yellow, white or brown.

Cultivation

Sorghum bicolour is an important crop worldwide and used for food, fodder and biofuels. Most varieties are drought and heat tolerant, and are important for arid regions, where the grain is one of the staples for poor and rural people. These varieties form important components of pastures in many tropical regions. *S. bicolor* is an important food crop in Africa, Central America, and South Asia, and is the "fifth-most important cereal crop grown in the world".

12.4 Origin, Evolution, Botany, Cultivation and Uses of Forage Crops

Livestock feed includes all the food requirements of not only domesticated livestock, poultry and fishes, but also wild life. Three major food classes for livestock are recognized: forage, fodder and concentrates. Forage refers to all browse (the tender shoots and fruits of shrubs and trees) and herbaceous animal feed, including silage and green feed. The term forage utilization is used to define the proportion of the current year's forage production that is consumed or destroyed through soiling and trampling by grazing animals. Fodder refers to dried cured material, particularly dry cured roughage high in fibre, e.g. hay, straw and Stover (maize stems). The two terms are often confused, with fodder often being loosely applied to fodder. Concentrates have a high food value relative to volume; they are low in fibre and, depending on their origin, are usually rich in protein, carbohydrates or fat. They include the cereal grains and their by-products, pulses, oil seeds and their by-products or cake. Important fodder plants are:

12.4.1 Berseem

Botanical Name: ***Trifolium alexandrinum***

Family: Fabaceae

Berseem is an annual leguminous fodder crop. It is one of the most suitable fodders for areas below 1700 m altitude with irrigation facilities. It remains soft and succulent at all stages of growth. It can be grown without irrigation in areas with high water table and under water-logged conditions.

Botanical characters

Berseem is an annual plant. The stem is hollow and succulent. The roots do not extend far into the soil. The plant makes a dense growth of from 2-3.The leaves are large, numerous, slightly hairy, tender and succulent. Each leaf consists of three elliptical leaflets arranged in the trifoliate manner common to most clovers. Numerous yellowish white flowers form an elliptical dense head. Each floret in the head consists of a five-lobed calyx and a corolla consisting of a standard, two wings, and the keel; the typical flower of most members of the legume family.

Cultivation

Berseem grows well in medium to heavy soil and is tolerant to soil alkalinity. Before showing the land tilled and leveled. Mid September to first week of October is the best time of sowing. First time cultivation on any field requires inoculation with rhizobium culture. Sowing should be done by broadcasting the seed at the rate of 25 kg per hectare in standing water. Mixture of berseem and oats (50:50 ratios) also gives higher yield. The first cutting is obtained usually 60 days after sowing and subsequent cutting at the interval of 25 to 30 days. In the mid-hill zone during winter, interval between cuttings is about 50 to 60 days. In all, 5 to 6 cuttings may be obtained. On an average, nearly 550 qunitals of green fodder per hectare may be obtained.

12.4.2 Lucerne (Alfalfa)

Botanical Name: ***Medicago sativa***

Family: Fabaceae

Medicago sativa is a perennial leguminous fodder crop. It has a good vegetative growth almost throughout the year.

Botanical characters

Alfalfa is a perennial plant. It has a tap root system. On the roots are found the nodules, typical of the leguminous plants. The leaves are alternate, consist of three leaflets. The leaflets are rather narrow, two to three times as long as broad and sharply toothed in their upper part.

Cultivation

Deep and well drained loamy soil is best for this crop. It is very susceptible to acidic soil; therefore, it cannot be grown in soil with pH below 6.5 unless lime is applied. Best time of sowing is the start of October to end of November. First irrigation is applied about a month after sowing. The subsequent irrigations are given at an interval of 15-30 days depending upon weather conditions. The newly grown crop is usually ready for first cutting in about 2-4 months after the seeding depending upon the altitude. The subsequent cuttings may be taken at intervals of 30 to 40 days. If may give, on an average, 350 quintals green fodder per hectare per year.

12.5 Summary

Food is the most important requirement of the living organism. Food plants are defined as plants that are used for human consumption. Major source of human food is angiosperm plants especially members of family poaceae. The main food crops are wheat, rice, barley and maize. The population of rural and tribal areas use food crops of small grains as staple feed, cattle feed and fodder known as millets. The production of millets is highest in India. The main millets are bajra, sorghum *etc*.

12.6 Glossary

- **Protophyll:** The basal leaf of tiller and main stem is known as protophyll.
- **Millets**: Millets are the food crops of small grains. These are generally genera and species of family Poaceae.

12.7 Self-Learning Excercise

Section- A : (Very Short Answer Type Questions)

1. All cereals belong to which family of plants?
2. Write the botanical name of any two millets.
3. In India wheat is grown as ………crop.
4. What is the origin of center of wheat?
5. Wheat is a temperate crop whereas maize is a…………crop.
6. Paddy can thrive on ………………soil.
7. The botanical name of barley is………
8. The family of alfalfa is……………………
9. The botanical name of pearl millet is………

Section- B : (Short Answer Type Questions)

1. Write botanical characters of cereals.
2. Write economic importance of wheat.
3. Write the botanical characters of maize.
4. Write about the cultivation of berseem.
5. Write economic importance of maize.

Section- C : (Long Answer Type Questions)

1. What are millets? Describe the methods of cultivation of any two millets grown in your region.
2. Write notes on -

a. Berseem cultivation

b. Pearl millet cultivation

3. What are the major cereals of India? Mention the origin, cultivation and uses of any one of them.

5. Describe the economic importance and cultivation of rice.

Answer key of Section – A

1. Poaceae
2. *Pennisetum typhoides, Sorghum vulgare*
3. Rabi
4. South West Asia
5. Sub tropical
6. Alluvial
7. *Hordeum vulgare*
8. Fabaceae
9. *Pennisetum typhoides*

12.8 References

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Unit -13

Economic Botany of
Plant Fibers and Vegetable Oils

Structure of the Unit:

13.0 Objectives

After studying this unit you will understand the cultivation and importance of fibre and vegetable oil yielding plants in terms of-

- Origin, evolution, botany, cultivation of fibre
- Origin, evolution, botany, cultivation of vegetable oil

13.1 Inrtoduction

The use of plants for fibres is regarded as second to food in their usefulness. There are over 2000 species with usable fibre; more than 1000 of which are known from America, 750 from the Philippines and over 350 from East Africa (Hill, 1952). Plant fibres have been used by man for cordage, clothing, basketry and matting since time immemorial. Archaeological evidence of use of plants as fibre by early man is often inadequately represented because they do not preserve well.

13.2 Origin, Evolution, Botany, Cultivation and Uses of Plant Fibers

In the age of synthetic fibres, plant fibres are still of considerable economic and commercial importance. In order to compete commercially with animal (wool, hair, bristle, etc.) and synthetic fibres an adequate and regular supply must be guaranteed. Plant fibres, including wood pulp, are used for a wide range of products, including cardboard, fibreboard, non-wood board, paper, paper substitutes, cord/string/twine, thread/yard, woven material such as cloth and sacking, packing/stuffing, filling materials, matting, netting, basketry, thatch and tow, also for their cellulose derivatives such as *cellulose ethan oates (acetates),* cellophane, plastics, rayon *etc* (Cook, 1995).

Vegetable oil is defined as plant oils that are liquid at room temperature. Broadly it is defined without regard to a substance's state of matter at a given temperature. Vegetable oils are composed of triglycerides, as contrasted with waxes which lack glycerin in their structure. Although many plant parts may yield oil but primarily it is extracted from seeds.

Fibre Classifications and Characteristics

Fibres can be classified botanically according to their anatomical and morphological origins, or by their commercial use. The different type of botanically fibres is:

(1) Hairs: Cells known as *trichomes,* borne on the seeds or inner walls of the fruit and consist of elongated, unicellular or multicellular and nonconducting epidermal outgrowths. These are referred to as *ultimate fibres,* free of any extraneous plant tissue. Cotton, for example, from the seeds of *Gossypium* spp., consists of long and narrow unicellular hairs, two types of which occur in the cultivated cottons:

(a) Fuzz: Fuzz is Consist of short hairs which eventually become almost solid from internal cellulose deposits and are firmly attached to the seed; they cannot be spun.

(b) Lint: Lint is relatively long and readily detachable hairs with greatly reduced cellulose deposition, giving a hollow lumen so that the hairs collapse on drying to form a ribbon. The cellulose is deposited spirally, enabling the ribbon to twist and giving the characteristic convolutions that enable the cotton to be spun. Others examples are akund floss from the seeds of *Calotropis procera* and *C. gigantea,* and kapok from the inner capsule wall of *Ceiba pentandra* (silk cotton tree).

(2) Extra-xylary or bast fibres: Fibres of the cortex, pericycle and phloem is known as bast fibres. Among the more commercially important sources of bast fibres are *Boehmeria nivea* (ramie), *Broussonetia papyrifera* (paper mulberry), *Corchorus* spp., hemp, flax *etc*.

(3) Leaf fibres: Leaf fibers are obtained from the lamina and petioles of certain monocotyledons such as *Agave sisalana*, *A. fourcroydes, Furcraea foetida*, *Musa textilis*, *Phormium tenax*. There are three types of leaf fibre recognised:

(a) Crescent shaped median bundles running through the middle of the leaf and are consequently the longest.

(b) Fibre bundles from the periphery of the leaf.

(c) Fibres inbetween.

(4) Wood or xylary fibres: Obtained from trees and shrubs and include the fibre tracheids, i.e. xylary tracheids that resemble tracheids by the possession of bordered pits. Wood fibres are widely used in paper-making.

(5) Miscellaneous fibres: Obtained from other parts of the plant, such as piassaba or piassava fibre or bass from the leaf bases of *Attalea funifera*, coir fibre from the mesocarp or husk of *Cocos nucifera* (coconut), Italian whisk from millet stems, Mexican whisk from the roots of the grass *Muhlenbergia macroura,* raffia from the lower epidermis of young leaves of *Raphia farinifera.* According to Smartt (1990) a strong fibre from the erect peduncles of *Vigna unguiculata* cv. 'textilis' (these fibres are restricted to the peduncle).

Plant fibres, as distinct from hairs, consist of relatively long and tapering sclerenchymatous cells. They are usually formed directly from meristematic cells and often have inconspicuous simple pits. Such fibres may occur in nearly all parts of the plant, being most abundant in the cortex, pericycle, phloem and xylem. The presence of bordered pits distinguishes *xylary fibres* and fibre-tracheids from the simple pits of the *extra-xylary* or *bast fibres.* Short fibres, such as those of Manila hemp and species of *Agave* and *Sansevieria,* have all parts of the cell at the same stage of development. In longer fibres, such as those of *Cannabis sativa* subsp. *sativa* (hemp) and *Linum usitatissimum*, the cells elongate apically, keeping pace with the surrounding cells, with secondary thickening developing in part of the growing cell (Eames and MacDaniels, 1947; Tootill, 1984; Purseglove, 1987; McDougall *et al.,* 1993).

In dicotyledons, as a result of secondary growth, two age classes of fibres are produced. These are known as primary fibres and secondary fibres. The primary fibres are thicker and more compact, with thicker walls and narrower lumina than the secondary fibres; they are also coarse, hard and lustrous. Because the secondary fibres are produced by cambial activity after the herbaceous plants have reached maximum height, plants with thick stems will contain a higher proportion of secondary fibres than those with thin stems. The secondary fibres are finer, softer, weaker and less brittle than the primary fibres. Despite such important differences, it is virtually impracticable to separate the two fibres classes during retting.

13.2.1 Cotton

Botanical name: ***Gossypium*** spp.

Family: Malvaceae

Common Name: Kapas, Rui

Origin and Evolution

There were a number of centres located in Asia, Africa and the Western Hemisphere from which the species of *Gossypium* have originated and spread. Cotton is now grown in most of the countries in the tropical and subtropical parts of the world. The leading producers are the U.S.A., Mexico, Argentina, Brazil, Peru, China, India, Pakistan, Turkey, Sudan, Egypt and Uganda were other centres of cotton production. High-yielding, tender varieties are grown on irrigated land in Egypt and Peru, while in India the bulk of the area is planted with hardy but inferior types of cotton.

Hutchinson *et al.* (1947) have recognised 20 species of the genus *Gossypium*, taking into consideration the cytological, genetic, geographical and archaeological evidence of that time. The lint bearing species of *Gossypium*, which are the true cottons, can be classified as:

1. The American or New World cotton represented by *Gossypium hirsutum* and *Gossypium barbadense* of the section Hirsuta, and
2. The Asiatic or Old World cottons consisting of *Gossypium arboretum* and *Gossypium herbaceum* of the section Herbacea. The species of these two sections are genetically distinct and do not form natural hybrids.

Indian Cottons

Botanically, the cotton varieties of India belong to three distinct species, namely, *Gossypium arboretum, Gossypium herbaceum* and *Gossypium hirsutum. Gossypium arboretum* is supposed to be indigenous to India. Main areas of cultivation in India are Punjab, Uttar Pradesh, Rajasthan, Andhra Pradesh, Tamil Nadu and Maharashtra.

Botanical Characters

The plants of *Gossypium herbaceum* L. is shrubs usually 1-1.5 metre tall with few or no vegetative branches; stem thick and rigid, twigs and young; leaves-usually sparsely hairy, rarely glabrous, stipulate, bracteoles, rounded or broadly triangular; monodelphous stamens; anther filament short, styles short; stigma usually united throughout, rarely cleft at the top; capsules rounded, beaked, 2-3.5 cm long, surface smooth or very shallowly dented, with few oil glands, 3 or 4 locular, usually only opening slightly when ripe, sutures devoid of hair; seeds usually bearing two coats of hair, long lint hair and short fuzz hair, in rare types bearing lint only.

Cotton seed has three parts, namely, linters, hulls and kernel (meat). The linters consist mainly of cellulose. The minor constituents are pectins, minerals, waxes, resins, pigments, water soluble carbohydrates *etc*.

The hull or seed coat is black in colour. The main constituents of the hull are cellulose complexes, lignin, furfural and the minor constituents are tannins, mineral water, colouring matter and other substances. In between the inner surface of the hull (spermoderm) and the kernel (embryo), there is a thick membrane which forms the attachment to the cotton seed hull at the chalaza1 cap.

Cultivation

Cultivation of cotton requires a long frost-free period, long light periods and a moderate rainfall (600-1200 mm). A large proportion of the cotton grown today is cultivated in areas with less rainfall that obtain the water from irrigation. Production of the crop for a given year usually starts soon after harvesting the preceding autumn. Planting time of cotton is spring in the Northern hemisphere varies from the beginning of February to the beginning of June. Cotton is somewhat salt and drought tolerant, this makes it an attractive crop for arid and semiarid regions.

Before raw cotton is spun into yarn and woven into cloth, it must pass though a number of processes such as ginning, baling, picking, carding, combing and drawing.

1. **Ginning:** The raw cotton is conveying to the hopper of a gin of either roller or saw type. The roller gin cleans more slowly than the saw gin.
2. **Baling:** Ginned fibre is pressed hydraulically into bales which are partially wrapped in jute or hessian covers (bagging).
3. **Picking:** Baled cotton is at first broken and then the fibres are passed through a 'scutcher' where they are beaten, shaken and rolled to remove all the foreign matter and the strands are separated and delivered in a uniform layer
4. **Carding:** In this, fibres are placed in parallel which facilitates the removal of immature fibres and impurities.

5. **Combing and drawing:** Combing is a process where short fibres are removed, while drawing consists of straightening and aligning the fibres.

Uses

1. Innumerable commodities of cloths are made from cotton.
2. From the lint chiefly textile and yarn goods, cordage, automobile tire cord, and plastic reinforcing are prepared.
3. The linters are a valuable source of cellulose.
4. Cotton hulls are used for fertilizer, fuel and packing.
5. Fiber from the stalk is used for pressed paper and cardboard.
6. The seed which remains after the ginning is used to produce oil.
7. The cotton seed meal that is left generally is fed to ruminant livestock.

13.2.2 Jute

Botanical name: ***Corchorus*** Sp.

Family :Tiliaceae

Common Names: Jute

Origin and Evolution

About 40 species of jute distributed throughout the tropics of the world. Out of these, eight species occur in India. *Corchorus capsularis* is considered to have its origin in the Indo-Myanmar region while *Corchorus olitarius* is found wild both in Africa and India. It has been thought that the primary centre of origin of *Corchorus olitarius* was Africa and the secondary centre may be India or Indo-Myanmar. The crop is cultivated for fibre only in West Bengal of India, Bangladesh, Malaya and Sri Lanka.

Botanical Characters

The plant of *Corchorus* is herbaceous annuals, 1.5-4.5 m high; stem cylindrical, branched or unbranched; leaves glabrous, oblong, acuminate, coarsely toothed, lowermost pair of serration enlarged and end in filiform appendages; petiole 4-8 cm; stipule-usually 0.5-2 cm or more, foliaceous in some varieties of *Corchorus capsularis*; flowers small, in leaf opposed cymes in groups of 2-5 or more; sepals-**5, yellow, pale yellow or green;** petals 5-6, yellow, entire or split; stamens 30-60 (stamens 20-30 in *Corchorus capsularis*).

Species from which commercial jute fibre is obtained are similar in general appearance, the leaf of *Corchorus olitorius* has a shining upper surface and a rougher under surface and is almost tasteless when chewed. The leaves of *Corchorus capsularis* contain a bitter glucoside-corchorin and tastes bitter on chewing, hence it is often known as tita (bitter) pat, whereas *Corchorus olitorius* is niitlza (sweet) pat. The flowers of *Corchorus olitorius* are larger than those of *Corchorus capsularis*.

Cultivation

Jute needs a alluvial soil and standing soft water. The suitable climate for growing jute is warm and wet. Temperatures from 20-40˚C and relative humidity of 70-80% are favourable for successful cultivation. Generally jute requires 5-8 cm rainfall per week but at the time of sowing it requires more water.

Jute plants are harvested at 50% of fruiting. At this stage, both the yield and quality are good. In flooded areas, the crop may have to be harvested some time even before the appearance of the flower buds. The plants are cut close to the ground with sickles and tied in small bundles and left in the fields during which the leaves wilt and finally drop off.

The fibres occur in long wedge-shaped bundles outside the xylem. They are grouped in concentric rings alternating with the thin walled tissue of the phloem which disintegrates during retting. Each of the fibre bundles represents one strand or filament composed of 4-50 cells. The individual fibre cells are seldom longer than 2 or 3 mm.

Extraction of Fibre

Retting: Retting is a process by which fibres in the bark gets loosened and separated from the woody stalk due to the removal of pectins, gums and other mucilaginous substances. This is usually affected by the combined action of water and microorganisms. The tied bundles of jute stems are taken to the nearest pool or ditch for retting. The bundles are laid flat in the water, at least 0.6-0.9 m in depth and arranged side by side so as to form a regular platform, which is usually known as **'jak'.** The retting process is completed in 8-30 days. Fibre is extracted from the stalks of retted jute by hand or by decorticators.

Uses

1. Jute is used to make rugs, blankets, carpets, tarpaulins, cloth backing, carpets, linoleum and oilcloth, twine, rope, upholstery, curtains and coarse cloth.
2. The leaves of young shoots are an important source of vegetable food in Egypt, Sudan and Greece.
3. Jute butts are used for the manufacture of paper and paperboard.

13.2.3 Linen

Botanical name: ***Linum usitatissimum***

Family: Linaceae

Common Name: Flax

Origin and Evolution

The earliest evidence of humans using wild flax as a textile comes from the present day Republic of Georgia, where spun, dyed and knotted wild flax fibers were found in Dzudzuana Cave. Flax was first domesticated in the Fertile Crescent region. In China and India domesticated flax was cultivated by at least 5,000 years ago.

Flax was extensively cultivated in ancient Egypt, where temple walls had paintings of flowering flax and mummies were entombed in linen. Egyptian priests only wore linen, as flax was considered a symbol of purity. In North America, flax was introduced by the colonists and it flourished there. But by the early 20th century cheap cotton and rising farm wages had caused production of flax to become concentrated in northern Russia, which came to provide 90% of the world's output. Due to the easy availability of more durable fibers, flax has lost its importance as a commercial crop.

Botanical characters

Linum usitatissimum is an annual plant. The plants grow to 1.2 m tall, with slender stems. The leaves are glaucous green, slender lanceolate, 20-40 mm long and 3 mm broad. The flowers are pale blue, 15-25 mm diameter, with five petals. The fruits are round, dry capsule 5-9 mm diameter, containing several 4-7 mm long glossy brown seeds.

Cultivation

The most suitable soils for flax are alluvial and loams which contains a large proportion of organic matter. Flax is often found growing just above the waterline in cranberry bogs. Farming flax requires few fertilizers or pesticides. Within eight weeks of sowing, the plant will reach 10–15 cm in height and will grow several centimeters per day under its optimal growth conditions, reaching 70–80 cm within fifteen days.

Uses

1. Flax is grown for its oil, used as a nutritional supplement and as an ingredient in many wood-finishing products.
2. Flax is also grown as an ornamental plant.
3. Flax fibers are used to make linen.
4. Flax fibers are taken from the stem of the plant and are two to three times as strong as those of cotton.
5. Europe and North America depended on flax for vegetable-based cloth until the nineteenth century, when cotton overtook flax as the most common plant used for making rag-based paper.
6. Flax is grown on the Canadian Prairies for linseed oil, which is used as a drying oil in paints and varnish and in products such as linoleum and printing inks.

13.2.4 Sun Hemp

Botanical name: ***Crotalaria juncea***

Family: Fabaceae

Common Name: Sannai sunn, Bombay hemp

Origin and Evolution

Crotalaria juncea is not found as a wild plant but its ancient cultivation in India indicate that it originated here. India grows about 325,000 hectares of sunn hemp per year with an annual production of 80,000-100,000 tones, of which 20 to 30 per cent is exported mainly to the United Kingdom, Belgium and the United States. Though grown in nearly all parts of India, Uttar Pradesh alone contributes about 40 per cent of the total output.

Crotalaria is a large genus with many species native to the Asian tropics, but is mostly concentrated in Africa. Sun hemp is a bast fibre grown on a large scale in India, for local use and export, as a raw material for sacking and cordage. The plant is indigenous to India and is cultivated for fibre and for green manure in many states, such as Andhra Pradesh, Uttar Pradesh and Madhya Pradesh. It is also grown on a limited scale in Maharashtra, Punjab, West Bengal and Orissa. The fibre has a fair demand from overseas countries and a large proportion of it is exported out of India under 'Agmark'.

Botanical Characters

The plant of *Crotalaria* is erect, annual, grows to 1.2-1.5 metre or more; leaves-alternate, short, petiolate, lanceolate, obtuse with a small bristle like apex, stipulate; inflorescence terminal racemes; flowers bracteate, papilionaceous, bright yellow, calyx gamosepalous, of 5 lobes; corolla polypetalous, standard broad, wings, oblong, keel much pointed, lightly twisted at the apex; stamens 10, monadelphous, dimorphic with five short, versatile anthers on slender filaments alternating with long basifixed anthers with flattened filaments; seeds kidney shaped and exendospermous.

Cultivation

The harvesting of sun hemp can be done when it is in various stages of maturity like at the time of pod setting or when the pods dry up. Immature crops give clean white fibres, fine in texture and of little strength. The fibre from the mature crop is coarse and strong.

Uses

1. Sun hemp is essentially a cordage fibre and is used in the manufacture of ropes, twines, cords and marine cordage.
2. Also finds application in the manufacture of sailcloth, canvas, matting, sacking, and rope soles of shoes and sandals *etc*.
3. Besides, being resistant to deterioration in water, sum hemp is used for making fishing nets and marine cordage.
4. In India, it is largely used for ropes and cot stringing.
5. Because of high cellulose and low ash content, the fibre is particularly suitable for cigarette paper and high quality tissue paper.

13.2.5 Hemp

Botanical Name: ***Cannabis sativa*** L.

Family: Cannabinaceae

Common Name: Hemp, true hemp, ganja

Origin and Evolution

Cannabis sativa L. is a native of Central and Western Asia, but is extensively cultivated at present in both temperate and tropical regions. It has been grown as a fibre crop for centuries in cooler climates, while within the tropics it has long been known as the source of the narcotic resin, hashish (ganja, charas, bhang or marijuana).

Hemp fibre is the bast fibre and it is strong, lustrous and durable. Commercial fibre is 100-200 cm in length. Its fineness of staple is less than that of linen, though its tensile strength is appreciably greater. The fibre ends are blunt and rounded. The fibre is somewhat uneven in diameter and exhibits frequent joints, longitudinal fractures and swollen fissures. It is made up of a mixture of cellulose and lingo-cellulose.

Botanical Characters

The hemp plant is a stout, bushy, branching annual, varying from 5-15 feet in height. It is a dioecious species with hollow stems and palmate leaves. The best grade of fibre is obtained from the male plants. The crop is harvested as soon as the lower leaves are shed and the top of stalks and flowers turn yellow. Harvesting at the time of flowering gives the optimum yield of high quality fibre.

Cultivation

Hemp is usually planted between March and May in the northern hemisphere and between September and November in the southern hemisphere. Hemp grown for fiber is planted closely, resulting in tall, slender plants with long fibers. The seeds are sown from mid-April to mid-May with grain drills to 4–6 cm sowing depth. A total of 60–150 kg of nitrogen, 40–140 kg phosphorus (P_2O_5) and 75–200 kg of potassium per acre for hemp fiber made before sowing and again later, maybe three to four weeks.

The plants are harvested by hand or machine. Harvesting is done when the male flowers are beginning to shed pollen. Premature harvesting results in a lower yield and produce weaker but finer and softer fibre, while delayed harvesting gives a high and brittle fibre.

Hemp fibre is a white bast fibre which develops in the pericycle. Besides the primary pericyclic fibres, secondary fibres of smaller length are also produced by the activity of the vascular cambium. The fibre is extracted from the stalks, either by water-retting or dew-retting. The later method is common in Europe and America, while in Italy, and in some parts of Russia, Hungary, Yugoslavia and India, water-retting is the common practice. The stalks are tied in bundles and immersed in ponds or slow-running streams until the bark, including the fibre, separates due to the temperature of the water. In hot and damp weather, 3-4 days may be sufficient. In cool and dry weather 1-2 weeks are required. Dew-retted fibre is grey, while water-retted hemp is usually cream-white.

In India, the cultivation of the hemp plant is permitted in the districts of Almora, Garhwal and Nainital in Uttar Pradesh for its fibre but not for the production of hemp drugs. The plant is also cultivated to a small extent in Kashmir, Nepal and Travancore.

Uses

1. Hemp is used for making ropes, twine, carpets, sailcloth, yacht cordage, binder twine, sacks, bags and webbing. The finer grades of hemp can be woven into a cloth that looks like coarse linen.
2. Jeans, the famous working trousers are prepared from cloth made from hemp fibre. In the U.S.A., the famous denim jeans were first prepared from hemp cloth imported from Nimes, France.
3. In tropical regions, hemp is grown for its seed, and also for narcotics (bhang, ganja and charas) obtained from the flowering tops and leaves.
4. The seeds contain oil that is useful in soap, paint and varnish industries as a substitute for linseed oil. The drug, known as **"hashish"**, is a resinous substance that contains several powerful alkaloids.
5. Seeds are also used as bird feed.

13.2.6 Coir

Botanical name: ***Cocos nucifera*** L.

Family: Palmaceae

Common Names: Coconut palm, nariyal

Origin and evolution

There are some controversies regarding the origin of coconut. According to one opinion, it is native of Central and South America from where it reached to Asia through the, water currents and waves in marine waters. On the other hand it is believed that the northern end of Andes is its place of origin. Still other scientists believe south east Asia as its native home from where accidentally it spread to the sea coast of America (Persglov 1963). Nowadays coconut plant is extensively grown in the coastal areas of tropical and sub tropical countries such as Indonesia, Philippines, India, Mexica, New Guinea, Sri Lanka and Malayasia.

Botanical Characters

The plant of coconut is a tall and unbranched tree. The stem is either erect or may be slightly tilted to one side of 15-30 m height. The girth of stem is uniform from base to apex, having a diameter of 40-70 cm on which leaf scars are present in the form of rings. The basal part of stem is surrounded by adventitious roots and on its top stem is crowned by 20-30 large paripinnate leaves. The leaflets are 50-90 cm long with acute or acicular apices.

The flowering in the plant starts at the age of 5 or 6 years. The flowers are developed in spadix inflorescence. Spadix is developed in the axil of leaves and the plants are monoceious. On the upper part of spadix numerous male flowers are arranged while 10-50 female flowers are arranged on the basal part. There is a central axis in the spadix, from which upto 40 branches are developed.

Fruit is an ovoid and fibrous drupe, having a length about 20-30 cm and weight of 1-2 kg. Exocarp is hard, smooth and green coloured plus quite thick. Mesocarp is thick and fibrous; it is chief source of coir, while inner endocarp is stony and dark brown. In the basal region of endocarp there are three depressions are located, out of which one eye is large and soft below which the embryo is present. The inside of endocarp is lined with a fairly thick coating of milky white flesh. The cavity of nut is partially filled with coconut milk representing the liquid endosperm.

Cultivation

Coconut is mainly grown in coastal areas. It is preferably grown in sandy clay to loam of coastal areas or alluvial soil of river banks. It requires sufficient amount of sunlight, an average temperature between 27-32°C and 110-140 cm rainfall per year.

The fruits which are to be used for sowing should be healthy. The seedlings are carefully raised in nurseries, where well drained seed beds are prepared for this purpose. When the plantlets achieve the age of 6-8 months these are planted in the pits of 90 x 90 x 90 cm at the distance of 45 m from each other. The pits are prepared three months before the plantation and proper amount of manure along with insecticides is put in the pits. Properly fertilized plants grow at a rapid state and reach the flowering stage much earlier then unfertilized palms.

Fully ripe fruits are plucked from the coconut trees for oil production. After the harvesting of fruits husk is removed and the endocarp as well as fibrous mesocarp is separated, with the help of an upright steel bayonet fixed on a wooden past. After then these dehusked fruits are split across from the middle, and the dried endosperm of the fruit is separated. This dried endosperm contains about 3-5% moisture and 60-65% oil.

The extraction of oil from fruit is operated by hydraulic press or expeller or by rotary mill. Mostly, hot expression method is used for the oil extraction. The remaining oil contents which are left in the residue is taken out by solvent extraction method.

To obtain the best quality coir, the fruits are harvested when they are green. Husk usually forms 35-45 per cent of the weight of the whole nut. Husks from 10-11 months old nuts have been found to give superior quality fibre, possessing a golden yellow colour. The fibre from the husk is extracted on a commercial scale, either by natural retting process or by mechanical decortication.

Processing

1. Natural Retting: In this process, the husks soak in water (preferably saline water) for a certain period until the fibre becomes loose and soft. The soaking is done either in pits dug near lagoons or by the sides of backwaters where water flows in and out with the rise and fall of the tide.

During the retting process, the husk becomes soft and a number of substances like carbohydrates, glucosides, tannin and nitrogen compounds are acted upon by variety of anaerobic organisms which produce various organic acids and gases. When the process of fermentation progress, the temperature of the husk increases, water becomes turbid due to gas formation and frothing and the pectin in the middle lamella of the husk slowly dissolves. Subsequently, the rate of fermentation slows down and the water becomes clear without the evolution of gases and the consequent frothing and, at this stage, the husks are ready for removal. The period of retting is longer (8-10 months) in saline water and shorter (4-6 months) in fresh water.

2. Mechanical Methods: In this process dry or green husks are stored in cement tanks for a period of few hours to few weeks and the fibre extracted manually or mechanically. In one method, the husks are first crushed through a series of corrugated iron rollers, a machine called a **'husk crusher'.** Then, the husks are thrown into a retting tank where they undergo fermentation for a minimum period of 72 hours. This process, however, does not yield fibre of spinnable quality as in the case of natural retting, but yields only bristles and mattress fibres.

3. Chemical Methods: Various chemical methods have also been used for the retting of husk. The advantages claimed are of a higher yield of uniform quality fibre and saving of time.

Extraction of Fibre

After retting, the husks are taken out of water and washed and outer skin peeled off. They are placed on wooden blocks and beaten with a wooden mallet for separating the fibre from the pith. After the fibre is separated from the pith, it is cleaned and then spread in the shade for drying. The fibre spread for drying is occasionally beaten and tossed up with poles to remove the remnants of pith and impurities still adhering to the fibre.

Uses

1. Besides its main use as floor covering and in rope making, coir fibre extends extensive use as packaging material to protect goods against shock in transport.
2. Coir fibre finds its use in the production of activated carbon, artificial horse hair, paper pulp, roofing tiles, writing boards, thermal insulation, high stretch paper, manufacture of olive oil filters *etc*.
3. The coir is rubberised for making cushion seating for automobiles and railways.
4. Coir yarn has been found to be idea1 for hop wines, used in breweries in the U.S.A.
5. Coir bags are used in tea estates for collecting tea leaves and for transportation.

6. Coir yarn in used for making fenders which are attached to ships and boats for absorbing the shock of collision.
7. Coir mats are used for commercial packing purposes and circular mats are used for packing.
8. Coir matting, after bituminisation, offer possibilities of being used as floor covering in godowns to withstand moisture absorption by stored goods.
9. Rubber-backed coir mats are soil-proof, sound absorbent and do not scratch polished floors.
10. Heavy matting made out of thick coir rope is being used for transporting gas cylinders. It is used as a strainer in tube wells in place of wire mesh.
11. Hardboard made of coconut husk shorts and coir dust is durable, smooth, insect proof, fire retarding and water-repellent. It can be sawed, nailed, glued and finished for specific requirements.
12. Coir waste has been used in the manufacture of coirolite by incorporating it with resins and other ingredients by the usual techniques of plastic manufacture. The powder obtained is hot-pressed to obtain articles of any shape using appropriate moulds. It is a tough and hard material and possesses good strength and electrical resistance.

13.2.7 Silk Cotton/ Kapok

Botanical Name: ***Bombax cieba***

Family: Malvaceae

Common name: Kapok, White Silk-Cotton, Safed semal

Origin and Evolution

Bombax cieba is a tropical tree, native to Mexico, Central America and the Caribbean, northern South America and to tropical West Africa. The tree is cultivated for the seed fibre, particularly in south-east Asia, and is also known as the **Java cotton, Java kapok, Silk-cotton**. The commercial tree is most heavily cultivated in the rainforests of Asia, notably in Java, Philippines, Malaysia, China and South America.

Botanical characters

The tree grows to 70 m with a trunk up to 3 m in diameter with buttresses. The trunk and many of the larger branches are often crowded with large simple thorns. The palmate leaves are composed of 5 to 9 leaflets, each up to 20 cm long. The trees produce several hundred pods containing seeds surrounded by a fluffy and yellowish fibre.

Uses

1. The fibre of *Bombax cieba* is light, very buoyant, resilient, resistant to water, but it is very flammable.
2. It is used as an alternative to down as filling in mattresses, pillows, upholstery and stuffed toys such as teddy bears and for insulation.
3. Previously, it was much used in life jackets and similar devices until synthetic materials largely replaced the fibre.
4. The seeds produce oil that is used in soap industries.
5. The fibres create a seal that allows the pressure to force the dart through the tube.
6. The flowers are an important source of nectar and pollen for honey bees.

13.3 Origin, Evolution, Botany, Cultivation and Uses of Vegetable Oils

13.3.1 Mustard

Botanical Name: ***Brassica*** spp.

Family: Brassicaceae

Common name: Sarson

Approximately 150 species are included in this genus *Brassica*, out of which several species used as oil resources. The oil obtained from these various species is known as rape or mustard oil. Some important species used for the extraction of oil are:

(1) *Brassica campestris* var. *sarson* - Pili sarson

(2) *Brassica campestris* var. *dichotoma* - Bhuri sarson

(3) *Brassica campestris* var. *toria* - Kali sarson

(4) *Brassica juncea* - Rai

(5) *Brassica nigra* - Kali rai

(6) *Brassica alba* - Ujli sarson

Origin and Evolution

Members of *Brassicaceae* are mainly native to the north temperate parts of the old world. The three most basic centres of its genetic diversity are central and South Asia, China and Europe. The centre of origin of *B. nigra* is supposed at Asia minor from where it reached to Europe, Africa and India, *B. juncea* is said to be central Asia - Himalayas from where it spreaded to India and china. Another species *B. alba* is said to be originated in equatorial region. Indian mustard was introduced from China into North Eastern India. Mustard and rape are the crops of temperate climate and mainly grown in China, India, Pakistan, Canada, France, Poland and Germany. India is the highest mustard producing country of the world.

Botanical Characters

Plant of mustard is erect, slender and branched annual herb, attaining a normal height of 3-5 feet. Leaves are simple, alternate and lyrate with dissected margins. Numerous fine hairy structures are present on the surface of the leaf. Flowers are pale yellow, small and arranged in corymbose racemes. Corolla is cruciform in which four free and clawed petals are arranged in cross shaped manner. Stamens are tetradynamous and fruits are siliqua with short and stout beak. In each fruit usually 20-30 small, rounded, yellowish brown or black seeds are attached with replum.

The seeds have marked reticulation on their surface. They contain 20% protein and 30-45% oil. At the time of maturity of crop a pungent and repellent smell may be felt around the field. It is due to the presence of sulphur compounds in the crop plants.

Cultivation

Mustard is a plant of temperate climate and sown as Rabi crop. Comparatively lower temperature remains suitable for its favourable growth. The well drained light to medium sandy loam soil remains suitable for mustard crop. Usually fertilizers are not required for the crop. However the addition of nitrogen and phosphate fertilizers are said to be useful for higher yield in the irrigated crop. In most of the regions mustard is sown along with wheat as mixed crop.

Mustard is sown from mid-October to starting of November. But in 'baranill' areas the process of sowing its operated mid September to mid October. It is cultivated either as single crop or as mixed crop along with wheat or Barley.

The field is ploughed twice or thrice before sowing the seeds. For irrigated crop 8-10 tonnes/hectare compost is added. Gypsum powder is also sprayed in the field if there is saline soil.

The sowing is done by broad casting or by ploughs in linear rows. In mixed cropping, seeds are sown in the parallel rows 1.5-2m apart from each other, then the main crop (wheat or Barley) is sown between the two rows of mustard. On the other hand in single cropping, the seeds are although sown in the rows but the distance between the two parallel rows is kept 30-40 cm. In case of irrigated crop the field is first time irrigated after the one month of sowing after then the field is next time irrigated after 30-40 days of first sowing.

Generally the crop is harvested by means of hand sickles. After the harvesting stems are tied into bundles and kept under the sun for few days in large stacks. The fruits/pods then shelter and shed away seeds. The seeds are separated from husk by winnowing.

The mustard seeds contain about 30-45% oil depending upon the variety and the climatic conditions under which the crop is grown. At small level oil is extracted by Ghani, while at large level oil extraction is operated by expellers or hydraulic press. The crude oil which is obtained by the above process is now refined. Nowadays solvent extraction method is also being used for oil extraction.

Uses

1. The seeds of *Brassica juncea* are used as an ingredient in various pickles spices.
2. The mustard/rape oil is prominent edible oil which is used for food preparation and preparation of pickles and snacks.
3. Lower grade mustard oil may be used as illuminant and oiling of wooden articles.
4. Lower grade oil is also used as lubricant of machineries as well as in soap industry.

5. Massage of mustard oil provides relief in muscular pains and it is also useful for treatment of skin diseases.
6. Mustard/rape oil is also used as an ingredient in many Ayurvedic medicated oils used as liniment and for the massage in paralytic diseases of nervous system.
7. Mustard oil is also used in tanneries for making the leather soft and pliable.
8. The remaining residue of the seeds left after the extraction of oil is known as oil cake and it is used as cattle feed as well as for manure.
9. Leaves and unripe fruits are used for making delicious vegetable.
10. The stacks of dried stem are used as fuel.

13.3.2 Groundnut

Botanical Name: ***Arachis hypogaea***

Family: *Fabaceae*

Sub Family: *Papilionatae*

Origin and Evolution

Groundnut is a native to Brazil, where it is being cultivated since prehistoric times. Besides this the wild species of ground nut are found growing in natural conditions even today in that area. It was introduced in Senegal and Jambia by the portugese and from there the plant migrated to different parts of Africa and Europe later on. Groundnut was taken by Spainiyards after then to Philippines from where its cultivation gradually spread to China, Japan, Malayasia and India. The ground nut plant was introduced in Indian sub continent in 16th century and after then it spread rapidly in various regions.

Botanical Characters

Ground nut plant is an annual herb of 30-60 cm height. The main central stem is cylindrical and nearly erect or prostrate or lies in creeping condition. When the plant becomes mature then stem also becomes angular. The leaves are paripinnately compound and leaflets are arranged in two opposite pairs and known as quadrifoliate leaves.

Flowers are lemon yellow, sessile and born in the axils of the leaves located on basal short branches. Corolla is of papilionaceous type, hence self pollination is observed in groundnut flower, and however entomophily also occurs occasionally.

The flowers develop single or in clusters of 2-4. The flower bearing branches are pushed underground, at the depth of nearly 2.5 cm in the soil. This process takes place when the fertilization is over. The fruit formation also takes place below the soil surface (Geocarpic fruit). The fruit of groundnut is an elongated and indehiscent pod, containing 1-3 seeds, between the two seeds, the pods are slightly constricted. The seeds are obovate or cylindrical with a brick red or rush coloured and papery seed coat.

Proteins and fats are the major chemical constituents of ground nut seeds. It contains 25-28% protein (Arachin and Conorachin) and approximately 43-45% oil. Besides this vitamins (A1, B2 and B12) and phosphorus are also present in minor amounts.

Cultivation

Ground nut is cultivated in the tropical, sub tropical and warmer temperate regions. India, China, Sudan, America, Senegal, Nigeria, South Africa, Indonesia and Brazil are the prominent countries of ground nut cultivation. In India ground nut is mainly cultivated in Gujarat, Maharashtra, Andhra Pradesh and Tamil Nadu. However it is also cultivated in some parts of Uttar Pradesh, Madhya Pradesh, Punjab and Rajasthan.

Ground nut is a plant of tropical climate therefore commonly grown in the regions where annual rainfall is 50-77 cm and temperature remains comparatively higher. Higher rainfall is harmful for crop yield. Therefore in India groundnut is raised as kharif crop and sown from April-July. The sandy and well drained soil is considered suitable for the cultivation of ground nut, while clay soil is said unsuitable for its crop because it causes hindrance in the entrance of flowers in the soil during the formation of fruits.

The ground nut is cultivated between April and May to June and July. In south India it is sown from January to March as an irrigated crop. Generally ground nut is cultivated in rotation with wheat, Jawar and Bazra crops.

Field is ploughed twice or thrice before the sowing of seeds. The field is first ploughed just after the harvesting of Rabi crop of the field. The field is irrigated properly before the sowing. The one seeded fruits are either used directly for sowing or the fruit cover is first, removed and then healthy seeds are selected for sowing. The pods or seed are sown in the furrows. After then the field is made flat by planker. By this process, the humidity of the soil is preserved for comparatively long period. The distance between the two rows of the seeds is kept from 15-25 cm. The ground nut crop is mainly monsoon based, therefore less amount of irrigation is required for its cultivation, however, when rainfall is scare, then, the crop is irrigated twice or thrice at regular intervals. In the earlier phases of cultivation proper weeding is also required. It takes 4-5 months time for the maturation of crop.

On the maturity the harvesting is done usually by hand. Plants are either dug or pulled up and pods are removed by picking. Some pods remain in the soil itself during this process, which are also taken also by thorough and searchful digging. The picked pods after this process are dried under the sun soil is removed from their covering, and then stored or decorticated.

The oil contents of the seeds vary from 40- 50%. The oil extraction procedure is operated either by hydraulic pressure or expellers. Cold pressed oil is golden yellow coloured with mild smell while hot pressed oil is yellowish red coloured. Ground nut oil is a non-drying vegetable oil. The main fatty acids present in the oil are oleic acid (56%), linolenic acid (25%) and palmitic acid (6-12%). Besides this stearic, arachidic acids and some higher saturated acids are also present in minor amount. The oil is rich in phosphorus and vitamins including riboflavin, thiamin and niacin.

Uses

1. The oil of ground nut is predominantly used for culinary purposes.
2. Vegetable ghee is prepared from the hydrogenation of the oil which mainly used for cooking and other food purposes.
3. The lower grade oil is used in soap industries and as lubricant.
4. The oil is also used as emollinent and laxative.
5. The residue left after the oil extraction is known as oil cake or khali and used as cattle feed.
6. The superior quality oil cake is often mixed in wheat flour after milling and used for making chapattis, which are rich in proteins.
7. Seeds are commonly eaten raw or fried before use, these serve the purpose of food supplement because of richness in proteins and vitamins.
8. The crop plants left after the harvesting of crop are used as fodder.
9. The pericarp of pod is used as manure.

10. The peeled of kernels are used for making peanut butter.
11. The groundnut oil emulsion is used for the control of many insect pests of the plants. This emulsion further increases the toxicity of some common insecticides like **rotenine, nicotine and nicotine sulphate.**

13.3.3 Soyabean

Botanical Name: ***Glycine max***

Family: Fabaceae

Origin and Evolution

Soyabean is a globally important crop and provide oil and protein. Soyabean originated in South East Asia. It was firstly domesticated by Chinese farmers between 17th to 11th centuries BC. From about the first century AC Soyabean was introduced into several countries like Japan, Indonesia, Philippines, Vietnam, Thailand, Malaysia, Burma, Nepal and India.

Botanical characters

The pods, stem and leaves are covered with fine brown or grey hairs. The leaves are trifoliolate, having three to four leaflets per leaf. The leaflets are 6–15 cm long and 2–7 cm broad. The self fertile flowers are borne in the axil of the leaf and are white, pink or purple. The fruit is a hairy pod that grows in clusters of three to five, each pod is 3–8 cm long and usually contains two to four seeds 5–11 mm in diameter.

Cultivation

Cultivation of Soyabean is successful in climates with hot summers, with optimum growing conditions in mean temperatures of 20 to 30°C. They can grow in a wide range of soils, with optimum growth in moist alluvial soils with a good organic content. Modern crop cultivars generally reach a height of around 1 m (3.3 ft), and take 80–120 days from sowing to harvesting. The U.S., Argentina, Brazil, China and India are the world's largest Soyabean producers and represent more than 90% of global Soyabean production.

Uses

1. Approximately 85% of the world's Soyabean crop is processed into Soyabean meal and vegetable oil.
2. Soyabeans can be broadly classified as "vegetable" (garden) or field (oil) types.

3. Soyabean is most excellent for its high (38–45%) protein content as well as its high (approximately 20%) oil content.
4. The bulk of the Soyabean crop is grown for oil production, with the high-protein defatted and "toasted" soy meal used as livestock feed.
5. A smaller percentage of Soyabeans are used directly for human consumption.
6. Immature Soyabeans may be boiled whole in their green pods and served with salt, under the Japanese name **'edamame'.**

13.3.4 Coconut

Botanical Name: ***Cocos nucifera***

Family: Arecaceae (Palmae)

Local Name: Nariyal

Coconut is an important plant of which every plant part is useful. It is also said to be one of the greatest gift provided by nature to mankind. It is the chief source of coir fibres, timber wood and vegetable oil.

Origin

There are some controversies regarding the origin of coconut. According to one opinion it is the native of Central and South America from where it reached to Asia through the water currents and waves in marine waters. On the other hand it is believed that the northern end of Andes is its place of origin. Still other scientists believe South East Asia as its native home from where accidentally it spreaded to the sea coast of America (Persglov 1963). Nowadays coconut plant is extensively grown in the coastal areas of tropical and sub tropical countries such as Indonesia, Philippines, India, Mexicao, New Guinea, Sri Lanka and Malayasia.

Botanical Characters

The plant of coconut is a tall and unbranched tree. The stem is either erect or may be slightly tilted to one side of 15-30 m height. The girth of stem is uniform from base to apex, having a diameter of 40-70 cm on which leaf scars are present in the form of rings. The basal part of stem is surrounded by adventitious roots and on its top stem is crowned by 20-30 large paripinnate leaves. The leaflets are 50-90 cm long with acute or acicular apices.

The flowering in the plant starts at the age of 5 or 6 years. The flowers are developed in spadix inflorescence. Spadix is developed in the axil of leaves and the plants are monoceious. On the upper part of spadix numerous male flowers are arranged while 10-50 female flowers are arranged on the basal part. There is a central axis in the spadix, from which upto 40 branches are developed.

Fruit is an ovoid and fibrous drupe, having a length about 20-30 cm and weight of 1-2 kg. Exocarp is hard, smooth and green coloured plus quite thick. Mesocarp is thick and fibrous; it is the chief source of coir, while inner endocarp is stony and dark brown. In the basal region of endocarp, there are three depressions are located, out of which one eye is large and soft below which the embryo is present. The inside of endocarp is lined with a fairly thick coating of milky white flesh. The cavity of nut is partially filled with coconut milk representing the liquid endosperm.

Cultivation

Coconut is mainly grown in coastal areas. It is preferably grown in sandy clay to loam of coastal areas or alluvial soil of river banks. It requires sufficient amount of sunlight, an average temperature between 27-32°C and 110-140 cm rainfall per year.

The fruits which are to be used for sowing should be healthy. The seedlings are carefully raised in nurseries, where well drained seed beds are prepared for this purpose. When the plantlets achieve the age of 6-8 months these are planted in the pits of 90 x 90 x 90 cm at the distance of 45 m from each other. The pits are prepared three months before the plantation and proper amount of manure along with insecticides is put in the pits. Properly fertilized plants grow at a rapid state and reach the flowering stage much earlier than unfertilized palms.

Fully ripe fruits are plucked from the coconut trees for oil production. After the harvesting of fruits, husk is removed and the endocarp as well as fibrous mesocarp is separated, with the help of an upright steel bayonet fixed on a wooden past. After then these dehusked fruits are split across from the middle, and the dried endosperm of the fruit is separated. This dried endosperm contains about 3-5% moisture and 60-65% oil.

The extraction of oil from fruit is operated by hydraulic press or expeller or by rotary mill. Mostly hot extraction method is used for the oil extraction. The remaining oil contents which are left in the residue are taken out by solvent extraction method.

Uses

1. Coconut oil is used for culinary purposes.
2. It is also used as hair oil.
3. Coconut oil is popularly used for the manufacture of superior quality soaps, shampoo, shaving cream and other cosmetics.
4. Coconut oil is commonly used for candle sticks and making lubricants.
5. Endosperm is eaten raw and its powder is also used in the preparation of sweets, confectionary and other delicacies.
6. Growth hormones are present in liquid endosperm; therefore it is used as a component for making culture media, in plant tissue culture experiments. Besides this coconut milk is also taken as favourite drink.
7. Special type of sap or juice is obtained by making incision in closed spadix of coconut. It is boiled for making "Jaggery". Alocoholic liquor and vinegar is also prepared by its fermentation.
8. Fibrous mesocarp is an exclusive source of coir, which is used in the manufacture of various products.
9. Tree trunks of coconut are used as girdles for making huts and leaves are used for thatching, or for making mats, baskets and brooms.
10. The dried coconut fruits are used in various religious purposes and offerings in temples, exclusively in Hindus.

13.3.5 Sunflower

Botanical Name: ***Helianthus annuus***

Family: Asteraceae

Local Name: Sunflowers

Origin

Sunflower is a genus of plant comprising about 70 species of family Asteraceae, all of which are native to North America except three species in South America. The common name, "sunflower," also applies to the popular annual species *Helianthus annuus*, the common sunflower. The genus is one of many in the Asteraceae that are known as sunflowers.

Botanical Characters

Sunflowers are tall annuals that grow to a height of 50–400 cm. The rough and hairy stem is branched in the upper part in wild plants but is usually unbranched in domesticated cultivars. The petiolate leaves are dentate and often sticky. It bears one or several terminal capitula (flower heads), with bright yellow ray florets at the outside and yellow or maroon disc florets inside. During growth, sunflowers tilt during the day to face the sun, but stop once they begin blooming.

Cultivation

Sunflower is propagated by seed. In the conventional systems of seedbed formation, seedbed consists of mould board plowing or chisels plowing. The field free of weeds, hardpans, stones and water logged conditions is suitable for sunflower cultivation. Ridges, field waterways, terraces and water harvesting basins are prepared. The density for sunflower ranges from 25 000 to 35 000 plants per hectare, depending on the yield potential of the area. Row width range from 90 to 100 cm. Sunflower seeds are planted at relatively shallow depths. In soil with high clay content, seeds are planted at a depth of 25 mm. In sandy soils, seeds can be planted at a depth of up to 50 mm.

Uses

1. The seeds of sunflower are edible. They can be eaten raw, cooked, roasted or dried. They are a popular, nutritious snack containing a good source of protein, vitamins A, B and E, Ca, N and Fe.
2. The petals are also edible; they can be cooked and eaten like artichokes.
3. The seed heads are also a source of food for birds and animals.
4. Sunflower seeds are a major ingredient in commercial birdseed.
5. Sunflower leaves are used as feed for livestock.
6. Sunflower oil is a popular vegetable oil known for its light colour, mild flavour, low levels of saturated fats and ability to withstand high cooking temperatures.
7. The oil can also be added to soap, lubricants and candles.
8. Sunflower oil can help relieve skin conditions, haemorrhoids and ulcers.
9. Sunflower roots can remove radiation from soils and water. They were used to clean up the Chernobyl disaster.

10. The flowers can be used to make an all natural dye.
11. The stalks are used to make paper and clothes.

13.4 Summary

The use of plants for fibres is regarded as second to food in their usefulness. Plant fibres, including wood pulp, are used for a wide range of products, including cardboard, fibreboard, non-wood board, paper, paper substitutes etc. The chief fiber yielding plants are cotton, jute, sunhemp, hemp, coir. Vegetable oils are composed of triglycerides, as contrasted with waxes which lack glycerin in their structure. It is primarily extracted from seeds. Mustard, ground nut, Soyabean, coconut, sunflower are the main producers of vegetable oil.

13.5 Glossary

- **Fuzz:** Fuzz Consist of short hairs which eventually become almost solid from internal cellulose deposits and are firmly attached to the seed; they cannot be spun.
- **Lint:** Lint are relatively long and readily detachable hairs with greatly reduced cellulose deposition, giving a hollow lumen so that the hairs collapse on drying to form a ribbon.
- **Retting:** Retting is a process by which the fibres in the bark get loosened and separated from the woody stalk due to the removal of pectins, gums and other mucilaginous substances.
- **Geocarpic fruit:** The fruit form below the soil surface is known as geocarpic fruit.

13.6 Self-Learning Exercises

Section- A : (Very Short Answer Type Questions)

1. Give the botanical name of any two fibre yielding plants.
2. Give the botanical name of any two vegetable oil yielding plants.
3. Sunflower belongs to which family of plants?
4. Write the botanical name of any hemp.
5. Write the family of cotton.

Section- B : (Short Answer Type Questions)

1. Write the botanical characters of coconut.
2. Write economic importance of jute.
3. Write the botanical characters of cotton?
4. What are fuzz and lint?
5. Write economic importance of sunflower.

Section- C : (Long Answer Type Questions)

1. Describe the methods of cultivation and uses of any two oil yielding plants.
2. Describe the methods of cultivation and uses of any two fibre yielding plants.

Answer key of Section – A

1. *Cocos nucifera, Crotalaria juncea*
2. *Arachis hypogeea, Helianthus annuus*
3. Asteraceae
4. *Cannabis sativa*
5. Malvaceae

13.7 References

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Unit - 14

Economic Botany of Medicinal & Aromatic Plants

Structure of the Unit:

14.0 Objectives

The objective of this unit is to summarise the

- economic botany and ethnobotany of important medicinal and aromatic

14.1 Introduction

Medicinal and aromatic plants occupy an important place in the life of mankind. There are about 1,500 medicinal plants in India.Traditional societies use native wild plants for medicinal purposes.

Prominent species

(a) Tropical

Brahmi, somraj, amla, anantmul, kurchi, tulsi, piplamul, babchi, sarpagandha, bahera, amaltas, jasmine, khas-khas and ashwagandha.

(b) Temperate

Indian belladonna, Indian berberry, kutki, Indian henbane, jatamansi, papri, rubarb, chirayata and kuth are found.

Forest Trees: There are 16 forest types in India based on climate and vegetation. The forests have a wide variety of hard and soft-wood indigenous tree species.

10. These are as follows:

(a) Tropical

Babul, banteak, gurjan, haldu, hollock, khair, khejri, laurel, maharukh, mango, neem, phaduk, rosewood, sal, sandalwood (Santalum album), semul, shisham, teak, toon, white cedar and bamboo types.

(b) Temperate

Chir, kail, chilgoza, deodar, Himalayan fir, spnice and the Indian birch.

Wild Forage Plants

About 400 species of wild herbage legumes occur in the different phyto-geographical regions of India. Some of these taxa possess a large number of species. The grasses are represented by about 245 genera and 1256 species, of which 21 genera and 139 species are endemic. The diversity of herbage legumes and grasses is largely found in the Western Ghats, Eastern Ghats, the north-eastern region and the Himalayas.

Native Ornamental Plants

There is a rich diversity that occurs in the Indian subcontinent where ornamental trees, shrubs, climbers, herbs and succulents are concerned.

Some prominent examples of trees are as follows:

Neem (Azadirachta indica), kadam, kachnar, dhak, amaltas, peepal (Ficus religiosa), ber, banteak, siris, semul, kanak champa, imii (Tamarindus indica), arjuna, ashoka (Saraca indica), Champaka, raga champa, Gardenia latifolia, Ficus elastica, Crataeva religiosa, Pongamica pinnata, Dalbergia sissoo and Millingtonia hortensis.

Medicinal and aromatic plants constitute a major segment of the flora, which provides raw materials for use in the pharmaceuticals, cosmetics, and drug industries. The indigenous systems of medicines, developed in India for centuries, make use of many medicinal herbs. These systems include Ayurveda, Siddha, Unani, and many other indigenous practices. More than 9,000 native plants have established and recorded curative properties and about 1500 species are known for their aroma and flavour.

In one of the studies by the World Health Organization, it is estimated that 80 per cent of the population of developing countries relies on traditional plant based medicines for their health requirements (WHO, 1991). Even in many of the modern medicines, the basic composition is derived from medicinal plants and these have become acceptable medicines for many reasons that include easy availability, least side effects, low prices, environmental friendliness and lasting curative property.

India and China are the two major producing countries, having 40 per cent of the global biodiversity and availability of rare species. These are well known as the home of medicinal and aromatic crops that constitute a segment of the flora, and provide raw materials to the pharmaceutical, cosmetic, fragrance, flavour etc. industries. The aromatic plants are the important economical source of a number of well established and important drugs; in addition, they are the source of some chemical intermediates needed for the production of a number of drugs.

India has been considered a treasure house of valuable medicinal and aromatic plant species. The Indian System of Medicine uses over 1,100 medicinal plants and most of them are collected from forests regularly, and over 60 species among them are particularly in demands. On account of the fact that derivatives of medicinal and aromatic plants have no side effects and deal curatively, the demand for these plants is on the increase in both developing and developed countries. As a result, the trade of medicinal plants is increasing fast.

From the trade data available, it is clear that the global market for medicinal plants has always been large and has been on increase in the recent past. In the report commissioned by the World Wide Fund for Nature, it is pointed out that, the total import in 1980 of "vegetable materials used in pharmacy" by the European Economic Community was 80,738 tons. India was the largest supplier with 10.05 tons of plants and 14 tons of vegetable alkaloid and their derivatives. India, Brazil and China are the largest exporters of medicinal plants. Trade of medicinal plants from India is estimated to be worth Rs. 550 crore.

Cosmetics and aromatherapy products are two important areas where Indian medicinal plants and their extracts like essential oils can contribute globally. Medicinal and aromatic plants have a high market potential with the world demand for herbal products growing of the rate of seven per cent per annum. Aromatic plants provide products with are extensively used as spices, flavouring agents and in perfumes and medicine. In addition, they also provide raw materials for the production of many important industrial chemicals.

The spices and essential oil industry traditionally was only a cottage industry in India. Since 1947 a number of industrial organizations have been established for large scale processing and production of spices, oleoresins, essential oils, their pure constituents and perfumes. The essential oils which are being produced in India are oils of ajwain, cedar wood, celery seed, citronella, eucalyptus, lemon grass, mentha, spearmints, Palmarosa, patchouli, terpertine and votive.

14.2 Description of Important Medicinal Plants

14.2.1 Aonla

Table 14.1

1.	Botanical Name of Plant	***Emblica officinalis*** Gaertn	
2.	Family	Euphorbiaceae A deciduous tree, found in deciduous forests of the country upto 1350 m. on hills. Often cultivated.	
3.	Area	1300 ha	
4.	Production	88200 t	
5.	Important States	UP, Gujarat, Rajasthan, Maharashtra	
6.	Cultural Practices i.Varieties/Types/Clones released/identified	Banarasi, Chakaiya, Francis, Kanchan, Krishna, Balwant, NA-6, NA-7, NA-9, Anand-2 and BS-1.	
	ii. Propagation methods and planting time	Modified ring, patch and shield budding as well as soft wood grafting. June to August	
	iii.Fertilizer dozes	1000 gm N, 500 gm P2O2 and 750 gm K 2O per plant/year. The fertilizer should be given in two split doses viz. Sep – Oct and April – May.	
	iv.Irrigation schedule	Irrigation to young plantation at 10 days interval during the summer. To fruit bearing plantations, first irrigation should be given just after manuring and fertilization and then at 15 days intervals after fruit set (April) till onset of monsoon. Avoid irrigation during flowering period.	
	v. Diseases, pests and	Diseases/causitive/	Control measures

	their control:	Organism/agent ------------------------- Aonla rust (Ravenellia emblica) Fruit rot (Pencillum islandlium) Necrosis (Boron Deficiency) Bark eating caterpillar (Inderbela tetraonis) Shoot gall maker (Betousa stylophora) Aphid (Cerciaphis emblica) Scale insect Anar butterfly (Virachola isocrates)	--------------------------- Spray (twice) Dithane Z 78(0.2%) during July-September. Treating the fruits with Nacl solutions. Spray of 0.5% - 0.6% borax in Sept–October Months. Injecting kerosene oil/ Dichlorovols or Endo-Sulfan (0.05%) in holes and plugging with mud Galled twigs should be pruned. Spray of 0.05% monocrotophos during rainy season Spraying of dimethoate @ 0.03% Application of mono-Crotophos @ 0.05% Remove and destroy all the affected fruits.
7.	Planting time i) Rainy season ii) Spring season	July to September Mid of January to March	
8.	Biochemical analysis (Active ingredients)	The fruit is rich source of vitamins and minerals. High vitamin C content (750-850 mg/100 gram pulp)	
9.	Post Harvest Management	Different varieties mature at different period e.g	

		Chakaiya (January), Banarasi (October end), Krishna (December) and Francis (mid November – December). Large size fruits (4 cm. & above) free from blemishes are used for preserve, candy and pickle. Small sized fruits are used for chavanprash making and defective fruits are used for Trifala making. Generally, basket for pigeon pea stem and gunny bag of 40-50 kg capacity with newspaper as liners are used for packing of aonla fruits. However, wooden crate with polythene lines is most suitable for packing and long distance transportation. Aonla fruits can be stored upto 15-20 days at low temperature (10-15o C). However Chakaiya can be stored upto 45 and 75 days in 10% and 15% salt solution respectively without any decay.
10.	Cost of Cultivation	Cost benefit ratio is 1:4. Pay back period is six years.
11.	Internal consumption and export potential	Export potential yet to be exploited. Huge internal demand in ISM.
12.	Action and uses	Aperient, aphrodisiac, astringent, digestive, diuretic, laxative, refrigerant and tonic. Useful in anaemia, jaundice, dyspepcia, haemorrhagic disorders, bilionsness, diabetes, asthma, bronchitis. An Ayurvedic preparation Chyavanprasha is very much valued for its restorative action
13.	Compound Preparations	Chyavanprasha, Dhatri Lauha, Amalki Rasayana.

14.2. 2 Aswahagandha

Table : 14.2

1.	Botanical Name of Plant	***Withania somnifera*** Dunal
2.	Family	Solanaceae
3.	Yield Plant Part	300-400 kg roots/ha + 50-75 kg seeds/ ha
4.	Actual Ingredients	Withaferin, Anaferin, Tropine and many other Alkaloides and Steriodes
5.	Important States	Madhya Pradesh and Rajasthan
6.	Cultural Practices i)Varieties/Types/Clones released/identified	Jawahar Asgandh – 20, Jawahar Asgandh 134 and Rakshita
	ii)Propagation methods and planting time	Direct sowing of seeds (Broadcasting) Planting time in 3rd week of August to September.
	iii) Fertilizer doses	The crop is mainly grown on residual fertility. Hence, no fertilizers applied
	iv) Irrigation schedule	Rainfed
	iv) Diseases, pests and their control	Major disease is damping off, seedling rotting, seedling blight. Seed treatment with Captan 3 g/kg seed is recommended.
7.	Biochemical analysis (Active ingredients)	Alkaloids and Steroids
8.	Post Harvest Management	The crop is ready in six month, harvesting starts from January and continues upto March.

		Average yield 400-500 kg of root and 50 kg seed/ha. Cleaning, drying and grading of roots.
9.	Cost of cultivation (Cost : benefit ratio)	About Rs.1000/ha and gross return about Rs.2800 (CB ratio 1:2:8)
10.	Internal consumption and export potential	Huge internal consumption also being exported.
11.	Any other remarks	Immunomodulator/Rasayan drug, general tonic in arthritis.
12.	Action and uses	Alterative, aphrodisiac, tonic, deobstruent, diuretic, narcotic, abortifacient. Used in rheumatism, consumption , debility from old age.
13.	Parts used	Root
14.	Compound preparation	Ashwagandhadi churna, Ashwagandha rasayana, Ashwagandha Ghrit, Ashwagandharishta

14.2.3 Ashoka

Table : 14.3

1.	Botanical Name of Plant	***Saraca asoca*** (roxb.) Dc Wild.
2.	Family	Leguminosae
3.	Local Name	Ashoka
4.	Habit and Habitat	A small evergreen tree 6-9 m. high, found wild along steams or in the shade of evergreen forests. It occurs almost throughout India up to an altitude of 720 m in the Centre

		and Eastern Himalayas & khasi, Garo & Lushai hills. It is also found in the Andaman islands. Leaves pari-pinnate, 15-20 cm long, leaflets 6-12, oblong, lanceolate, flowers organe or orange-yellow, very fragrant, pods flat, leathery, seeds 4-8, ellipsoid-oblong.
5.	Important Habitat	Himalayas, Bengal and Western Peninsula.
6.	Cultural Practices i.Propagation methods and planting time ii.Irrigation Schedule	Seeds. Seedlings are raised and planted in rainy season Rainfed
7.	Biochemical analysis (Active Ingredients)	Haematoxylin, tannins and glycoside, leucopelargonidin and leucoeyanidin have been extracted from the barks
8.	Post Harvest Management	Bark is removed and sun dried for use in preparation of various herbal medicines.
9.	Utilisation	The bark is reported to stimulate the uterus, making the contractions more frequent and prolonged without producing tonic contraction as in the case of pituitary ergot. It is also reported to cure biliousness dyspepsia, dysentery, colic, piles and pimples. Leaves possess blood purifying properties. Flowers used in dysentery and diabetes.
10.	Plant part used	Bark
11.	Actual Ingredients	Tannin and Catechol
12.	Internal consumption and export potential	Internal consumption is quite high in pharmaceutical industries. Good export

		potential
13.	Action and uses	Astringent, used in menorrhagia and uterine affections, internal bleeding, bleeding haemorrhoids and haemorrhagic dysentry.
14.	Compound Preparations	Ashokarishta, Ashokaghrita

14.2.4 Bael

Table : 14.4

1.	Botanical Name of Plant	***Aegle marmelos*** L.Corr.
2.	Family	Rutaceae
3.	Habit and Habitat	A small or medium sized tree, distributed throughout the country.
4.	Yield	7500 t
	Plant Part used	Fruits and leaves (200-400 fruits/tree)
	Actual Ingredients	Non-reducing sugars, essential oil, abscisic acid and marmelosin.
5.	Cultural Practices i.Varieties/Types/Clones Released/identified	Some well known types have been named according to fruit shape and locality e.g Mirzapuri, Darogaji, Ojha, Rampuri etc. Some improved selections are: NB-4, NB-5, NB-9.
	ii.Propagation methods and and planting time	Vegetative propagation by Patch budding in June-July.
	iii.Fertilizer dose	For 8 years old and onwards trees, 80 kg FYM, 480 g N, 320 g P and 480 g K/

		tree/year is recommended.
	iv.Irrigation	In the initial years, plants require frequent irrigation. Once established, light irrigation should be given after manuring and fertilization and proper soil moisture may be maintained after fruit set.
	v.Diseases, pests and their control	Name Control Measures -- Bacterial shot Spray of streptomycin Hole sulphate @ 500 ppm. (Xanthomonas controls this disease. Bilvae) Fruit canker Precaution should be taken so that fruit is Not hurt during plucking Also during transporta- tion, the fruit should Be packed tightly.
6.	Biochemical analysis (Active ingredients)	Protein (1.8%), Fat (0.39%), minerals (1.7%), Carbohydrate (31.8%), Carotena (55 mg/100 fruit), thiamine (0.13 mg/100g), riboflavin (1.190 mg/100).
7.	Post Harvest Management	At the time of harvest, tree become leafless and fruits get completely exposed. The fruits are picked individually from the tree keeping a portion of fruit stalk. Fruits are usually packed in gunny bags, baskets or wooden crates using newspaper as cushioning material. Fruits are quite hardy and they can be stored well at ambient temperature.

		However, fruits can be stored for 12 weeks at 9oC.
8.	Internal consumption and export potential	Fruits are mostly consumed in our country. Export potential to be explored.
9.	Cost of cultivation	Cost-benefit ratio is 1:3 and pay back period is six years.
10.	Action and uses	Aromatic, astringent, carminative, cooling, laxative, febrifuge, stomachic; used in colitis, diarrhoea, dysentery and flatulence. Root is also an ingredient of Dashmoola.
11.	Parts used	Fruits, root bark, leaves, rind of the ripe fruit, flowers.
12.	Compound Preparations	Bilwapanchaka Kwath, Bilwandi Churna, Dashmoola rishta, Dashmools Kwath.
13.	Any other remarks	Presence of marmelosin in fruits has anthelminitic activity.

14.2.5 Brahmi

Table : 14.5

1.	Botanical Name of Plant	***Bacopa monnieri*** L
2.	Family	Scrophulariaceae
3.	Yield Plant part Actual Ingredients	Whole plant especially leaves (100 kg dry herb/ha) Alkaloid, brahmine
4.	Habit & Habitat	A small herb found throughout India upto 4000 feet. Plant an annual, creeper is mostly found near water-logged place.

5.	Cultural Practices i. Varieties/Types/Clones Released/identified	Subodhak and Pragyashakti
	ii. Propagation methods and planting time	By runners and by seeds, In rainy season
	iii.Fertilizer doses	100 kg N/ha in three splits; 60 kg P205 60 kg K2O/ha at the time of planting
	iv.Irrigation	After sowing/transplating
6.	Biochemical analysis (Active ingredients)	Plant contains bacosides A & B, bacogenins, stigmasterol, stigmaotanol B-sitosterol. Leaves give herpestine. Monnierin is also isolated from the plant.
7.	Post Harvest Management	Harvesting in October-November
8.	Cost of cultivation Gross return Net return	Rs.35,000 / ha Rs.2,00,000 / ha Rs. 1,65,000 / ha
9.	Internal consumption and export potential	Having internal and external demand.
10.	Uses	Used as nervine tonic/memory enhancer
11.	Compound Preparations	Brahmighrit, Sarasvatarisht, Brahmivati.

14.2.6 Chandan

Table : 14.6

1.	Botanical Name of Plant	***Santalum album*** Linn
2.	Family	Santalaceae

3.	Actual Ingredients	Essential oil (1.5-6%)
4.	Distribution	A small evergreen tree, distributed in dry scrub forests of Salem, Mysore, Coorg, Coimbatore, Nilgiris upto 900 m. altitude. Also reported to be found in Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamilnadu.
5.	Cultural Practices i.Varieties/Types/Clones released/identified	Local type
	ii.Propagation methods and planting time	By seed and grafting. Seedlings are raised in polythene bags and plants during rainy season.
	iii.Ferilizer dozes	20t FYM/ha. Fertilizer requirement not yet worked out.
	iv. Irrigation schedule	Rainfed
	v.Diseases, pests and their control	Spike disease is common which is caused by mycoplasma. Under severe infection, the whole plant dies. Jassids (Pentacephala nigrilines), Fulgoroides and sandal wood beetle are important insects reported to cause considerable loss.
6.	Biochemical analysis (Active ingredients)	Alphasantalal, beta santalol and alpha and beta santalene are the main constituents in the oil.
7.	Post Harvest Management	Sandal wood trees are harvested at the age of 30-60 years. The soft wood is first removed, the hard wood is chipped and then converted into powder in a mill. The powder is soaked

		in water for 48 hours and then distilled. Distillation takes place in 48 hours. The oil is rectified by redistillation and filtration.
8.	Internal consumption and export potential	Export of sandal wood chips and oil and dust was 552.2 and 29.5 t respectively during 1995-96. Besides our internal consumption in cosmetics and perfumery industries is also high.
9.	Action and use	Antiphlogistic, antiseptic, cooling and styptic. The wood round up with water into a fine parts is commonly applied to local inflammations, to the temples in fever and to skin diseases to allay heat and pruritus. It is internally administered in cystitis, gonorrhoea, haemorrhagia, urinary disorders and gleet.
10.	Compound Preparations	Chandanasava.

14.2.7 Chirata

Table : 14.7

1.	Botanical Name of Plant	***Swertia chirata*** syn. S.Chirata Buch – Ham.
2.	Family	Gentianaceae
3.	Use Plant part Actual Ingredients	Whole plant used Alkaloids
4.	Habit and Habitat	An erect herb, found in temperate Himalayas between 1300-3000 m. from Kashmir to Bhutan and Khasia hills. It is scarcely

		available in the market and generally substituted by Andrograpis paniculata Nees or other species of Swertia.
5.	Cultural Practices i. Propagation methods and planting time	Propagated by seeds. The seeds are sown in the nursery and then seedlings are transplanted in the field.
	ii.Fertilizer doses	FYM is ideal for these plants
	iii.Disease	Some species of this genus are reported to serve as alternate host of blister rust of Pinus.
6.	Biochemical analysis (Active ingradients)	Plant contains alkaloids – gentianine, gentiocrucine, enicoflaving, swer – chirin. Plant is antiinflammatory, swerchirin – antimalarial, hypoglycaemic.
7.	Post Harvest Management	Drying of plants
8.	Internal consumption and export potential	Huge demand in ISM and was imported at a tune of 58.22 t valued at Rs.14.61 lakhs in 1995-96.
9.	Action and uses	Bitter, tonic, stomachic, laxative, febrifuge. Used in anorexia, biliary disorders, cough, constipation, fevers, skin diseases, worms.
10.	Compound Preparation	Kiratadi Kwath, Sudarshan Churna.

14.2.8 Giloe

Table : 14.8

1.	Botanical Name of Plant	***Tinospora cordifolia*** wild miers, ex hook
2.	Family	Meninspermaceae

3.	Local Name	Giloe
4.	Habit & Habitat	A large, glabrous, deciduous climbing shrub found throughout tropical India. Ascending to an altitude of 300 m. Stem rather succulent with long filiform flesh aerial roots from the branches. Bark graey-brown or creamy white. Leaves membranous, cordate with a broad sinus. Flowers small, yellow or greenish yellow, appearing when the plant is leafless. Drupes ovoid, glossy, succulent, red. Seed curved.
5.	Propagation	The Plant is sometimes cultivated as ornamental & propagated by cuttings.
6.	Utilisation	The plant is used in general debilities, dyspepsia, fever & urinary disease. The leaves are good as fodder for cattle and rich in proteins and fairly in calcium and phosphorous. A decoction of the leaves is used for the treatment of gout. The young leaves bruised in milk, are used as a liniment in erysipeals. The leaves are beaten with honey and applied to ulcers. Dried & powdered fruit mixed with ghee or honey is used as a tonic and also in the treatment of Jaundice and rheumatism. The root is a powerful emetic and used for visceral obstructions. Its watery extract is used in leprosy.
7.	Plant part used	Stem and Leaves
8.	Active Ingredients	Alkaloid

9.	Cultural Practices i.Varieties/Types/Clones Released/identified ii.Propagation methods and planting time	Locally grown Stem cuttings. Planting time is rainy season.
	iii.Crop duration	Perennial
10.	Biochemical analysis (Active ingredients)	Tinosporon, Tinosporic acid, Tinosporol, Giloin, gilonin, berberine, cordifol, Tinosporidine.
11.	Post Harvest Management	The stem and leaves are harvested and dried in sun.
12.	Internal consumption & export potential	Mostly consumed by Ayurvedic pharmaceuticals
13.	Action	Rejuvinator, astringent, antipyretic, blood purifier and curative of dermatosis.
14.	Uses	General debility, pyrexia, skin diseases, gout, rheumatic arthrites and spure.

14.2.9 Guggal

Table : 14.9

1.	Botanical Name of Plant	***Commiphora wightii***(Arn) Bhandari
2.	Family	Burseraceae
3.	Yield Plant Part Actual Ingredients	700-900 g gum per plant Tree yield an oliogum-resin-guggulipid
4.	Habit and Habitat	A shrub or small tree, reported to be found in

		Karnataka, Rajasthan, Deccan and Gujarat.
5.	Cultural Practices i.Varieties/Types/Clones released/identified ii.Propagation methods iii.Fertilizer doses iv.Irrigation Schedule v.Diseases, pests and their control	Local types Plants raised (about 80% success) by cutting. Application of 5 kg FYM and 25-50 gm urea per bush per year. Require moderate irrigation Plants are affected by white ants, Cercospora leaf spot and bacterial leaf blight. Control: Pits are filled with FYM and treated with BHC or aldrin to protect the new plants from white ants.
6.	Harvesting and yield	Plants attain normal height and girth after 8-10 years of growth when they are ready for tapping of the gum by shallow incision on the bark between December and March.
7.	Biochemical analysis (Active ingredients)	Gum resin contains guggulsteraes Z and E guggulsterols, two diterpenoids – a terpene, hydrocarbon named cembrne A and B, a cliterpene – alcohol – mukulol 3 camphorone and cambrene
8.	Action and uses	Carminative, antispasmodic, disphoretic, ecbolic, antisuppurative, aphrodisiac, emmenagogue. Gum resin is commonly used for the treatment of rheumatoid arthritis.
9.	Compound Preparations	Yogarajaguggulu, Kaishoreguggulu, Chandraprabha vati
10.	Marketing	Gum – resin is in great demand.

14.2.10 Indian Barbery

Table : 14.10

1.	Botanical Name of Plant	***Berberis aristata*** DC
2.	Family	Berberidaceae
3.	Local Name	Chitra, Rasaut
4.	Habit & Habitat	An erect spinous shrub, 2 – 6 m. high, often forming gregarious patches, pale yellowish-brown bark, closely and rather deeply furrowed. Flowers are golden-yellow. It occurs in the Himalayas between 2000 – 3000 m & also in Nilgiri Hills.
5.	Plant part used	Root bark, stem, and wood fruit
6.	Actual Ingradients	Barberine
7.	Important States	Assam, Bihar and Himalayan Region
8.	Cultural Practices i.Varieties/Types/Clones Released/identified	Local clones
9.	Propagotion	Propogation is from seeds, self sown in nature. Seedlings or cuttings can be taken during spring season after the berries are over. Layering is also recommended since the cuttings present some difficulties.
10.	Biochemical analysis (Active ingredients)	Barberine (alkaloid)
11.	Post Harvest Management	Drying of barks
12.	Utilisation	The use of the roots as a source of Rasaut has

		been referred to. The dried berries are edible. The root bark is rich in alkaloidal content. Berberine, the principal alkaloid can be easily obtained from the roots in the form of its salts. Rasaut, mixed with butter and alum, or with opium & lime-juice & painted over the eyelids as a useful house-hold remedy in acute conjuctivities and in chronic ophthalkmia. A yellow dye is obtained from root and the stem. The berberry dye has been largely used in tanning & colouring of leather.
13.	Action and uses	Stomachic, astringent, tonic, antiperiodic, diaphoretic, antiphyretic, alerative, purgative. Used in menorrhagia, diarrhoea, jaundice, skin diseases, malarial fever.
14.	Compound Preparations	Darvyadi Kwath, Darvyadi leha, Darvyadi taila.

14.2.11 Isabgol

Table : 14.11

1.	Botanical Name of Plant	***Plantago Ovata*** Forsk
2.	Family	Plantaginaceae
3.	Habit and Habitat	A herb found in Punjab plains and low hills from Sutlej westwards, Sindh and Baluchistan.
4.	Area under cultivation	50000 ha

5.	Production in tonnes	48000 t of seeds
6.	Yield Plant part	Seeds 900-1500 kg/ha, Husk-225-375 kg/ha
7.	Cultural Practices	
	i.Varieties/Types/Clones released/identified	RI-87, RI-89, AMB-2, GI-1, GI-2, MI-4, MIB-121, HI-34, HI-2, HI-1, HI-5, NIHARIKA
	ii. Propagation methods and planting time	By seeds Mid October to Mid December
	iii. Fertilizer,s dose or dosage	N:P 50:25 kg/ha (25 kg of N + full P as basal dose 25 Kg N as top dressing 35 DAS)
	iv.Irrigation schedule	3 to 6 irrigations, Presowing, after sowing, Seedling stage, Spike formation stage, Flowering stage, Seed development stage depending upon the soil type and agro climatic condition.
	v. Diseases, pests and their control	Downy mildew and Powdery mildew: Dithane M-45 or Dithane Z-78 @ 2.0 to 2.5 g/lit or Bordeaux mixture 6:3:100 for downy mildew and Karathane W.D. (0.2%) for Powdery mildew 6:3:100 for downy mildew, Karathane W.D (0.2%) for Powdery mildew. Wilt : Wilt disease is also observed which can be controlled by seed treatment with Bavistin or Benlate 2.5g/kg of seed. Sucking type of pests (Aphid) attach the crop. Spraying with Endosulfan @ 0.5% or Dimethodate @ 0.2% at fortnighty interval

		can control the aphids.
8.	Biochemical analysis (Active ingredients)	Protein, polysaccharides, cellulose, pectin, oil, muscilage.
9.	Post Harvest Management	Crop matures during March-April (110-130 days). It should be harvested when atmosphere is dry. Harvested plants spread over and after 2 days they are threshed with tractor/bullocks. Pinkish type husk are removed from the seed coat by processing through a series of grinding in mills to separate husk.
10.	Cost of cultivation	Cost of Cultivation = Rs.19320/ha
11	Internal consumption and export potential	Isabgol seed 17,680.63 tonnes valued at Rs.14,069.78 lakhs and husk 2580.29 tonnes valued at Rs.1663.73 lakhs exported during the period from April – October, 1997-98. Besides our internal consumption is also quite high.
12.	Action and uses	Demulcent, cooling, diuretic; used in inflammatory conditions of the mucous membrane of gastro intestinal and genitourinary tracts, in chronic dysentery, diarrhoea and constipation.
13.	Parts used	Seeds and seek husk. Used as single drug for cure of constipation and Dysentery.
14.	Any other remarks	This crop has good export potential and can be exploited commercially

14.2.12 Jatamansi

Table : 14.12

1.	Botanical Name of Plant	***Nardostachys jatamansi De***
2.	Family	Valerianaceae
3.	Habit and Habitat	An erect perennial herb with long, stout, woody rootstock; found in alpine Himalayas at 3500-5000 m. extending eastwards to Sikkim and Bhutan. The species is vulnerable.
4.	Yield Plant part Actual Ingredients	Rhizome (1290 kg/ha) Valeopotriate and Essential Oil
5.	Cultural Practices i.Varieties/Types/Clones released/identified	Dalhouse clones
	ii.Propagation methods and planting time	Seeds and Roots. Seed nursery preparation in July/Aug. Transplating after 6 – 8 weeks (April/May)
	iii.Fertilizer doses	60:20:40 NPK
	iv.Irringation schedule	One irrigation soon after sowing and 2-3 irrigations during rain free condition.
	v.Dieseases, pests and their control	No serious pests and diseases.
5.	Biochemical analysis (Active ingredients)	Volatile essential oil 0.5% (Valeopotriates and Valerian oil)
6.	Post Harvest Management	Harvested roots washed and dried in shade condition.

7.	Cost of cultivation (Cost : benefit ratio)	Not commercially cultivated
8.	Action and uses	Aromatic, bitter, tonic, antispasmodic, deobstruent, stimulant, antiseptic, diuretic, emmenagogue. Used in epilepsy, hysteria, chorea, convulsions, palpitation of heart, mental disorders, insomnia.
9.	Parts used	Root-stock
10.	Compound Preparations	Mansyadi Kwath
11.	Any other remarks	Crop is not under regular cultivation, so there is a rapid depletion of the plant from its natural sources. Quality degradation under storage is reported.

14.2.13 Kalmegh

Table : 14.13

1.	Botanical Name of Plant	***Andrographis paniculata***
2.	Family	Acanthaceae
3.	Yield Plant part Actual Ingredients	Panchang (Stem, leaf, flower, seed and root) Kalmeghin Andrographolide (0.8-2.%%). Leaves contains maximum while stem contains minimum amount.
4.	Habit and Habitat	A small herb found throughout India in plains of Himachal Pradesh to Assam, Mizoram, Gujrat, Bihar and South India.
5.	Cultural Practices	Local clones. There is no named variety.

	i.Varieties/Types/Clones released/identified	
	ii.Propagation methods and Planting timed	Propagated by seed and cuttings. Seedlings/plantlets raised in nursery in Iast week of July.
	iii.Fertilizer doses	Poultry manure or FYM 10 t/ha, Castor cake 2 t/ha, 75 Kg N, 75 Kg P2O5.
	iv.Irrigation schedule	Kharif season crop. If rain is inadequate then 2-9 irrigations are given.
6.	Post Harvest Management	Crop duration 90-100 days. Harvesting is done in end of October and 1st week of November. Harvest should be spread over on the floor and it should be covered at night to protect from dew. One week drying under shade is required. Average yield 2-2.5 t/ha dry herb.
7.	Cost of cultivation Gross return Net return	Rs.10,000/ha Rs.43,000/ha Rs.33,000/ha
8.	Internal consumption and export potential	Ayurvedic formulations for debility, chronic malaria, jaundice, anaemia and loss of apetite. Andrographis preparations in different potencies for Homeopathic medicines.

14.2.14 Katki

Table : 14.14

1.	Botanical Name of Plant	***Picrohiza kurroa*** Royle ex Benth
2.	Family	Scrophulariacae

3.	Habit and Habitat	A perennial herb, found in Alpine Himalayas from Kashmir to Sikkim at altitudes of 2700 – 4500 m.
4.	Cultural Practices Propagation methods	Through seeds and rhizome
5.	Biochemical analysis (Active ingredients)	Bitter glucoside Kutkin (3.4%), Kurrin, (0.5%), Vanillic acid (0.1%).
6.	Post Harvest Management	Drying
7.	Action and uses	Bitter tonic, antiperiodic, cholagogue, stomachic. Used in dyspepsia, fever, diseases of liver & spleen including jaundice, anaemia, scorpion stings and in purgative preparations.
8.	Parts used	Root and rhizome
9.	Compound Preparations	Arogyavardhani, Katukadya lauha, Tikkadi Kwath, Tiktadighrita
10.	Internal consumption and export potential	Limited internal consumption
11.	Any other remarks	Threatened perennial herb but can be domesticated and cultivated

14.2.15 Madhunashini

Table : 14.15

1.	Botanical Name of Plant	***Gymnema sylvestre*** R. Br
2.	Family	Asclepiadaceae
3.	Plant parts used	Leave and roots

4.	Habit and Habitat	A perennial climber found in Western Ghats, Konkan, Tamilnadu, Karnataka and Uttar Pradesh.
5.	Cultural Practices i. Varieties/Types/Clones released/identified	Local clones
	ii.Propagation methods and planting time	By cutting in rainy season
	iii.Fertilizer doses	10 g Nitrogen 6 5 g Phosphorous/vine
6.	Biochemical Analysis (Active ingredients)	Gymnemic acid, Quercitol, Lupeol, B-amyrin, Stigmasterol
7.	Harvesting	After one year leaves are ready for harvesting
8.	Harvesting period	September to February
9.	Post Harvest Management	Drying of leaves and roots
10.	Action and uses	Astringent, stomachic, tonic, refrigerant, antidiabetic. Leaves have a peculiar property neutralising temporarily the taste sensation for sugar and used in diabetiss.
11.	Uses	Diabetes, Liver disorders, cardiac Amenorrhoea, Sec. Amenorrhoea, Cough and Asthma
12.	Compound Preparations	Sarivadyasava, Sarivadyavaleha, Sarivadi Kwath, Sarivadi vati.

14.2.16 Satavari

Table : 14.16

1.	Botanical Name of Plant	***Asparagus racemosus Willd***
2.	Family	Liliaceae
3.	Habit and Habitat	A climber found almost all over India
4.	Yield Plant Actual Ingredients	Tuberous roots (100-150 q/ha 3rd year). Saponin
5.	Cultural Practices i. Varieties/Types/Clones ii.Propagation methods and planting time	Local clones By seeds/adventitious roots March-April (Sowing) July-August (Transplanting)
6.	Biochemical analysis (Active ingredients)	Shatavarin I, II, III and IV (Roots) Quercetin, rutin and Hyperoside (Flowers and fruits) Diosgenin and Quercetin – 3 Glucuronide (Leaves)
7.	Post Harvest Management	Tuberious roots are ready for harvesting in 3rdyear. After harvesting, roots (tuberous) are washed and dried in sun for making of powder.
8.	Action and uses	Antidiarrhoetic, refrigerant, antidysenteric, diuretic, demulcent, nutritive tonic, galactagogue, aphrodisiac, antispasmodic. Used in consumption, epilepsy, diarrhoea, blood dysentery, haemophilic disorders, and swellings
9.	Parts used	Root

10.	Compound Preparations	Shatavari ghrita, Naraina taila, Vishnu Tails, Shatmulyadi lauha, Shatavari panaka.

14.2.17 Shankapushpi

Table : 14.17

1.	Botanical Name of Plant	***Convolvulus pluricaulis***
2.	Family	Convolvulaceae
3.	Distribution	A prostrate perennial herb found all over India, in Lalitpur district found in Talbehat, Meharauni and Lalitpur forest ranges. Present day availability is very low, approximately 50 – 60 quintal per year.
4.	Part used	Whole plant
5.	Soil type	Sandy loams, Block cotton soils Red sandy soils; PH 5.5 to 7. It is also grown in marginal lands with good drainage and some organic matter applied to the soil.
6.	Rainfall	800 mm – 1200 mm
7.	Field preparation	Deep ploughing in the month of May and is allowed to weather. 15 tons per hectare farm yard manure is spread out in the field during June before rains. After FYM applied and after on set of monsoons second ploughing is done followed by two cross harrowing. The land is finally divided in to small blocks.
8.	Sowing	The seeds are broadcast mixing with sand or Line sowing 30 cm x 30 cm also done. After

		sowing light top dressing of FYM is given. Very light watering is done. Seedlings appear within 30 days.
9.	Weeding & Hoeing	Generally two weedings & hoeing are given within 40 – 50 days.l
10.	Harvesting	Plants get flowers in October and seeds developed in December. Crop harvesting period is January to May. Whole plant is dried in shade and is stored for marketing.
11.	Biochemical analysis (active ingredients	Alkaloids, Sankhpuspine
12.	Action	Intellect promoting, nervine tonic, Expectrorant, Anti-leprotic, Refrigerant
13.	Uses	Insomnia, Insanity and Epilepsy, Cough, Skin disorders, Hyperpyrexia, General debility

14.2.18 Safed Musli

Table : 14.18

1.	Botanical Name of Plant	***Chlorophytum borivillanum***
2.	Family	Liliaceae
3.	Yield Plant part Actual Ingredients	Tuberous roots (1000 kg/ha) Saponin 2-4%
4.	Distribution	Southern Rajasthan, Western M.P and North Gujarat

5.	Cultural Practices i.Varieties/Types/Clones released/identified	Selections viz. RC-2, RC-16, RC-36, RC-20, RC-23. RC-37 have been collected and maintained at RAU, Udaipur
	ii.Propagationn methods and planting time	By seed and by tuberous roots, second week of June
	iii.Fertilizer doses	No chemical fertilizer tested on thier crop. 10-15 t FYM/ha provides good nutrient status for heatlhy growth.
	iv. Irrigation schedule	First irrigation immediately after planting. If there is no rainfall, then irrigation may be done after 10-15 days interval.
	v.Diseases, pests and their control a)Rotting of root during storage b) Chlorosis in foilage	Infection of Aspergillus sps and Fusarium sps. Control : Treatment with thiram and captan at 4.0 g/kg of roots reduced rotting during storage. This may be due to Iron deficincy.
	vi.Crop duration	90-110 days
6.	Biochemical analysis (Active ingredients)	Carbohydrates 39.10% - 42% Protein 0.5% Saponin 2% - 4% Root fiber 3% - 5%
7.	Post Harvest Management	Harvested roots are spread in the shade for about 4-7 days. Later, fleshy roots separated from the bunches. Slight pressure exerted by thumb and finger on the skin of root so that they

		get separated and milky white root come out. It should be cleaned and dried for 7-10 days.
8.	Cost of cultivation (Cost : benefit ratio)	Cost of cultivation = Rs.22,000/- Gross return = Rs.65,000/- Cost benefit ratio = 1:2:95
9.	Internal consumption and export potential	Mainly consumed in herbal based pharmaceutical industries. It has large and consistent market demand in the country and current projection of the annual demand is estimated between 300-500 t.
10.	Any other remarks	Safed musli is a well known tonic and a aphrodisiac drug given to cure general debility and extensively used in Ayurvedic medicines. Still major requirements of the pharmaceutical industries is fulfilled through collection from the forest, thus it has become threatened species in India. Effort should be made for its regular cultivation to fulfil the growing demand.

14.3 Summary

Plants produce thousands of specialized metabolites, many of which have medicinal uses. More than half of the top 150 prescribed drugs in the US have at least one compound derived from plants, and about 80% of the world population depends on plants or plant extracts as a major source of healthcare. This unit looks at the history of medicinal plants, herbal remedies in traditional and contemporary medicine, and ongoing efforts to identify novel medicinal compounds from plants.

New approaches, such as metabolomics, metabolic engineering and systems and synthetic biology, are contributing towards the identification, characterization and production of plant-derived medicines.

14.4 Glossary

- **Acetylcholine :** A neurotransmitter released at neuromuscular junctions. Has empirical formula $C_7H_{17}NO_3$.
- **Ague :** A fever marked by chills and shivering.
- **Alzheimers :** A degenerative brain disorder characterized by premature senility and dementia.
- **Analgesic :** A drug characterized by its ability to relieve pain.
- **Annual :** Completing the life cycle in one growing season.Asthma - Disease of the respiratory tract characterized by difficult breathing, cough, and a sense of constriction in the chest.
- **Astringent :** A drug characterized by its ability to draw together skin or mucous membranes.
- **Biennial :** A biennial plant is one whose life cycle takes two years or growing seasons to complete.
- **Bronchitis :** Inflammation of the bronchial mucous membranes.
- Bronchodilation- Dilation, or opening, of the bronchial tubes.
- **Carcinogenic :** A substance with the property of causing cancer
- **Catkin :** An inflorescence bearing scaly bracts and apetalous flowers
- **Cholera :** A bacterial disease contracted through contaminated drinking water. Symptoms include severe gastrointestinal problems such as acute diarrhea and infection of the small intestine.
- **Colic :** Disease characterized by severe pain in the gut due to various affections of the gastrointestinal tract.
- **Cystitis :** Inflammation of the bladder.
- **Delirium :** A mental disturbance characterized by hallucinations, confusion, and disturbed speech.
- **Dermatitis :** General term for inflammation of the skin.

14. 5 Self -Learning Exercises

Section- A : (Very Short Answer Type Questions)

1. Up to _____ percent of all medicine comes from chemicals found in plants.
   25
   50
   75
   100
2. Botany is the branch of biology that studies _______.
   plants
   herbs
   lichens
   all of these are studied by botanists
3. Some call this plant a weed, but it can be used to stimulate the digestion system and work as a diuretic.
   Cranberry
   Curare
   Dandelion
   Willow
4. A malaria fighting plant used by the Chinese.
   Willow
   Artemisia Annua
   Curare
   Cranberry
5. Drug stores have been around for about _______ years.
   100
   200
   300
   400
6. The World Health Organization estimates _____ percent of people in the world use traditional remedies instead of pharmaceuticals
   20

40

60

80

7. Used with blow-gun darts, chemicals from this plant were used in early medical operations to relax patients.

Sweet Annie

Willow

Dandelion

Curare

8. Acetylsalicylic acid is found in ______

Aspirin

Willow Bark

Both of these.

Neither of these.

9. Which of one these was not likely how early humans learned about medicinal plants.

Trial and error

Local doctor

Watching animals

10. Where are medicinal plants found

mountain tops

jungles

oceans

your back yard

everywhere

Section- B : (Short Answer Type Questions)

1. Describe the importance of “Aonla”
2. Write short note on “sarpagandha”.
3. Write names of five medicinally important plants.

Section- C : (Long Answer Type Questions)

1. Describe in detail the medicinal importance of “Ashwagandha”.
2. List the medicinal importance of any three medicinal plants?
3. Give examples each of medicinal and aromatic plants.

Answers key of Section A

1. 50
2. All of these are studied by botanists
3. Dandelion
4. Artemisia Annua
5. 300
6. 80
7. Curare
8. Both of these
9. Local doctor
10. Everywhere

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Unit -15

Economic Botany of Fire- wood, Timber yielding Plants and Non-Wood Forest Products (NWFP)

Structure of the Unit:

15.0 Objectives

The objectives of the unit is to provide detailed knowledge of

- economic botany of Fire-wood, timber yielding plants and Non wood forest products.

15.1 Introduction

Firewood is any wooden material that is gathered and used for fuel. Generally, firewood is not highly processed and is in some sort of recognizable log or branch form, compared to other forms of wood fuel like pellets or chips. Firewood can either be seasoned (dry) or unseasoned (fresh/wet). It can be classified as hardwood or softwood.

Firewood is a renewable resource. However, demand for this fuel can outpace its ability to regenerate on local and regional level. Good forestry practices and improvements in devices that use firewood can improve the local wood supplies.

15.2 Harvesting

Harvesting or collecting firewood varies by the region and culture. Some places have specific areas for firewood collection. Other places may integrate the collection of firewood in the cycle of preparing a plot of land to grow food as part of a field rotation process. Collection can be a group, family or an individual activity. The tools and methods for harvesting firewood are diverse.

15.3 Economic Botany of Bamboo

Bamboo

Botanical Name: *Bambusa vulgaris*

Common Names:

English Name: Bamboo

Hawaiian Name: 'Ohe

Japanese Name: Take

Chinese Name: Chu

Classification:

Bambusa vulgaris Schrad. ex J.C. Wendl.

Kingdom: Plantae-Plants

Subkingdom: Tracheobionta-Vascular plants

Superdivision: Spermatophyta-Seed plants

Division: Magnoliophyta-Flowering plants

Class: Liliopsida-Monocotyledons

Subclass: Commelinidae

Order: Cyperales

Family: Poaceae-Grass family

Genus: Bambusa Schreb.- Bamboo

Species: *Bambusa vulgaris* Schrad. ex J.C. Wendl.- Common Bamboo

Bamboos are a group of woody perennial evergreen plants in the true grass family Poaceae.

Some of its members are giants, forming by far the largest members of the grass family.

There are 91 genera and about 1,000 species of bamboo.They are found in diverse climates, from cold mountains to hot tropical regions. Although bamboo is a grass, many of the larger bamboos are tree-like in appearance and they are sometimes called ***"bamboo trees".***

The stems, or ***'culms',*** can range in height from a few centimetres to 40 metres, with stem diameters ranging from 1 mm to 30 cm.The stems are jointed, with regular nodes.Many bamboos are popular in cultivation as garden plants.In cultivation, care needs to be taken of their potential for invasive behaviour.They spread mainly through their roots and/or rhizomes, which can spread widelyunderground and send off new culms to break through the surface

Gramineae, the grass family, has provided civilization throughout history with a bounty of food and many other uses. The top three economically important plants of the world are grasses: wheat corn, and rice. Human kind probably would not have survived if not for the grasses. The sub-family Bambusoideae, is certainly no exception. These are the bamboos. Consisting of 75 genera and over 1000 species, these unique plants have played a diverse and important role in the development of society, as we know it today.

Morphology

The tall bamboo plant shows the regular internodal lengths and prominent nodes. They resemble telescoping antennas, but at a constant diameter.

The culm is the above ground stem, this is what is used for most all for many applications. The culm is woody and either hollow or solid, however most species exhibit some degree of hollowness. The length and thickness of the culm varies greatly between species. Some species can get as tall as 130 feet and be more than a foot in diameter--these have been reported to grow at nearly two inches each hour.

Branches, also segmented arise from the culm. Upon the branches are to be found leaves, with petioles. The fact that the leaves have petioles helps to set the bamboos apart from the other grasses. The leaves and young shoots are the parts eaten by Pandas. The Panda subsists on no other plant or food source. Bamboos alone keep them going strong.

New culms, or shoots, are produced from an extensive rhizome system. Simply, rhizomes are modified stems, usually growing underground (Fig. 1). The rhizomes cause the "clump habit" of growth exhibited by the bamboos. "Clump habit" refers to the culms growing in close proximity to each other, such as a "tuft of grass". There are basically two types of rhizomes'. pachymorph and leptomorph. Most species exhibit both, to a greater or lesser degree. Pachymorph rhizomes are very compact. They are associated with autumnal growth and produce a dense clump of culms. Leptomorph rhizomes, associated with spring growth, spread a little more. Than pachymorph, in some cases a lot more. In other words they are responsible for the lateral growth of a given stand, or clump, of a bamboo species.

Knowledge of rhizomes is also necessary for species identification. The keys in McClure's book, to North American species, use rhizome types as the first step toward identifying bamboo species.

Reproduction

In addition to asexual reproduction through rhizomes, bamboos also flower and produce seed, sexually. Most bamboos produce a panicle inflorescence with a varying number of spikelets. Each spikelet contains one or several florets. Unlike other members of the grass family, bamboo florets contain six stamens.

Aside from structure, the bamboos are most unique because of when they flower. Some species flower every year, some every 15 or 30 years, and some species only flower every 120 years! When bamboos flower, all of the plants of a particular stand flower simultaneously, from the small new shoots to the tall 15, 30 or 120 year old culms. The whole stand then dies, leaving behind a bed of seeds a foot deep. It is believed that the bamboo developed this method of reproduction to protect itself from its primary natural predator, the panda. Since pandas eat only bamboo, the panda population will naturally be thinned out when a species of bamboo flowers, even though the pandas will switch to another species--now civilization has started to encroach on the panda's habitat pushing the panda into smaller and smaller areas. The pandas are facing famine, and possibly extinction, unheard of before. The pandas now do not have as many species of bamboo to choose from when one dies off. But help may be on the way.

Most of the economically important species flower every 30 years. But, this is a long time and the reason little research can be done toward improving the plant. However, breeders may soon be able to bring the "king of the grasses" to a level of importance unknown before. A group of Indian scientists recently were able to cause tissue culture of bamboo to bloom in less then a year. The cultures were grown in a medium of cytokinin and coconut milk, for some reason flowering is quickened (Blooming, 79-80). If these experiments hold up under further testing, we may begin to enter a new age of bamboo agriculture.

It was recently discovered that some extracts from bamboo bark inhibit bacterial growth, especially a species of ***Staphylococcus***. This could have a profound impact on the food industry as a natural preservative.

Also, with bamboo, wells can be drilled. Some third world countries have been able to get water from wells drilled with bamboo. Some wells have been drilled to 1,600 feet deep. It requires no electricity and no drilling rig one place has put 494 acres of land under irrigation with bamboo pipes and bamboo drilled wells.

The uses for bamboo are unlimited. From fishing rods to food preservatives to scaffolding on skyscrapers, bamboo is truly "king of the grasses".

Indigenous Practices

Bamboo, as well as niu, coconut, is one of the most useful and practical plants for humankind, providing water storage, food, raw materials for household, garden use, musical instruments and more.

Bamboo wood has silica in its cell walls and is hard, straight, strong, flexible, light and easily can be split. Split bamboo can be made into mats, hats, screens, baskets, fans, umbrellas, brushes, paper, ropes, roofing tiles, wall mats, or as a part of the sleds of old Hawai'i, called ***holua***.

The stem of bamboo has been carbonized for use as electric lamp filaments, in goldsmithery, and tabashir, a fine powder used as a chemical catalyst.

15.4 Economics Botany of Teak

Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Magnoliopsida
Order	:	Lamiales
Family	:	Verbenaceae
Genus	:	Tectona
Botanical Name	**:**	***Tectona grandis***

Other names : Saka, Burma teak, Rangoon teak, moulmein teak, giathi, jatisak, kyun, maisak, rosawa and tekka are the other names used for the Teak tree.

Description : Teak is tall evergreen tree. It has yellowish blonde to reddish brown wood. It attains the height of about 30 meter. The fruit is a drupe. It has bluish to white flowers. It produces the large leaf similar to the tobacco leaf. The bark is whitish gray in colour. It is generally grown straightwith the uneven texture, medium lusture and the oily feel. The upper surface of the tree is rough to touch and the inner surface has hairs. The fruit is enclosed by the bladder like calyx, which is light brown, ribbed and papery.

Other species : Tectonagrandias, Tectonahamiltoniana, and Tectonaphilippinensis are the other related species of the Teak tree.

Location : Teak is well grown in all the parts of India. It is also found in the Gir National Park, Satpura National Park, Pench Tiger Reserve in India.

Cultivation methods : The new plants can also be propagated from cuttings. It is usually planted when the four to six weeks old. Plough the land thoroughly and level it. The best season to plant the teak is monsoon, most probably after the first shower. Carry out weeding operations regularly. Teak requires loamy soil rich in humus and having the right content of moisture with good drainage. It grows well in hilly and dry areas. It requires a dry tropical climate for its growth. It flowers in february and March.

Medicinal uses : Teak also holds the medicinal value. The bark is bitter tonic and is considered useful in fever. It is also useful in headache and stomach problems. Digestion may be enhanced by the teak wood or bark.

Other uses : It is used in the furniture making, boat decks and for indoor flooring. It is widely used to make the doors and house windows. It is resistant to the attack of termites. Its wood contains scented oil which is the repellent to insects. The leaves yield the dye which is used to colour the clothes and edible. Teak is probably the best protected commercial species in the world.

Wood suitable for carpentary and building is known as timber. It is of two types, hardwood (most dicots) and soft wood (gymnosperms and some dicots like Salix; Salmalia and Morus). Heaviest wood is that of *Guaiacum officinale* but in India it is *Acacia sundra*

Some common timber yielding trees are:

(1) **Teak:** (Sagwan) *Tectona grandis*.Most durable wood.

(2) **Sal:** *Shorea robusta*.

(3) **Sissoo:** (Shisham).*Dalbergia sisso* (Indian Red wood) *Dalbergia latifolia* is Indian Rose wood.

(4) **Sins:** *Albizzia lebbeck*.

(5) **Arjun:** *Terminalia arjuna.*

(6) **Indian Almond:** *Terminalia catappa.*

(7) **Harir:** *Terminalia chebula.*

(8) **Hollock:** *Terminalia myriocarpa.*

(9) **Deodar:** *Cedrus deodara.*

(10) **Ironwood:** Mesuaferra (Nagkesar, Nagchampa).

Trees are also planted under social forestry programme on village common land, vacant land along roads and railway embankment. The plants should be fast growing, capable of giving fodder and fuel besides some timber, e.g. Leucaena, Allanthus, Anogeissus. Certain woods are used for specific purposes. For example; wood of Salix alba and *Salix purpurea* is useful for making cricketbats. Hockey sticks are prepared from wood of Morus alba.

(1) Plants Used as a Source of Resin

Resin is Alcohol soluble sticky exudation. Pine resin *(Pinus roxburghii* and other species, gymnosperm) yields turpentine and rosin Damar is obtained from *Shorea robusta* or Sal.

(2) Plants Used as a Source of Gums

Gums are sticky exudation of bark which are insoluble in alcohol but form colloidal solution in water.

(1) Kuteera gum-*Sterculia urens.*

(2) Bengal Kingo gum-*Butea monosperma.*

(3) Salai-*Boswellia serrata*.

(4) Dhaora-*Anogeissus latifolia*.

(5) Gum Arabic-Acasiasapota.

(6) Milky latex of Achrassapota forms chickle gum from which chewing gum is produced.

(3) Plants Used as a Source of Tannins

These are astringent acidic substances used in preparation of dyes, inks and leather. Acacia nilotica, Walnut Juglansregia, Cesalpinia, Uncania (leaves and young branches).

(4) Plants Used as a Source of Dyes

(1) Cutch (Kattha): Heart wood of Acacia catechu in betel leaves and colouring textiles.

(2) Henna (Mehndi): Leaves of Lawsonia inermis.

(5) Plants Used as a source for Insecticides

Insecticide kill or repel insects. Natural insecticides include

(1) Azadirachta indica (Magosa/Neem)

(2) Boenighauscniaalhiflora.

(3) Peganum harmala.

(4) Derris (rotenone)

(5) Chrysanthemum (Pyrethrum).

15.5 Name and Uses of Important Forest Plants

S. No.	Botanical Name	Common Name	Uses
1	***Leaucaena leucocephala***	Subabul	Timber, fodder, poles, fuel, soil conservation
2	***Salix spp.***	Willow	Timber, basket making
3	***Sapindus mukorosis***	Ritha or Soapnut Tree	Fuel, soap nut for washing cloth
4	***Swietania mahgoni***	Mahogoni	Poles, gum, tannin, industrial timber, ornamental and soil conservation.
5	***Dendrocalmus strictus***	Solid bamboo	Fodder, poles, industrial use, paper, soil conservation
6	***Bambusa arundinicae***	Hallow	Fodder, paper, poles,

		bamboo	industrial use, soil conservation
7	***Acacia conciana***	Shikekai	Medicinal, fuel, timber, soap
8	***Prosopis guliflora***	Vilayati Babhul	Medicinal, fuel, timber, fencing
9	***Prosopis cinerarie***	Khejadi	Fodder, fuel, timber, fencing
10	***Terminalia chibula***	Hirda	Timber, dye, fuel, medicinal
11	***Terminalia paniculata***	Kingal	Timber, fuel
12	***Terminalia bellerica***	Baheda	Medicinal, timber, fuel
13	***Polyalthia longifolia***	Drooping Ashok	Ornamental, road avenue
14	***Semicarpus anacardiuin***	Biba	Medicinal, fuel
15	***Cassia renigera***	Pink cassia	Ornamental
16	***Cassia fistula***	Bahaya / Amaltas	Ornamental, medicinal
17	***Diospyros melanoxylon***	Tendu	Beedi leaves
18	***Plantanus orientalis***	Chinar	Timber, fuel
19	***Diosypros tomentosa***	Temburni	Ornamental, medicinal, fruits
20	***Kigelia piñata***	Monkey Plant	Ornamental
21	***Shorea robusta***	Sal	Timber, fuel
22	***Ailanthus excels***	Maharukh	Fodder, match industries
23	***Quercus spp.***	Indian oak	Fodder, fuel, sericulture
24	***Lagerstroemia parviflora***	Sidhabenteak	Fodder, fuel, gum, tannin, pole, timber, ornamental
25	***Hardwickia binata***	Anjan	Fodder, fuel, agricultural

			implements
26	***Erythrina indica***	Pangara	Fuel and soil conservation
27	***Grewia spp.***	Dhaman	Fibre
28	***Pinus roxburghii***	Chir-pine	Resin, gum, tannin, oil, pole, soil conservation
29	***Jacaranda mimosaefolia***	Neel-mohar	Ornamental and soil conservation
30	***Grevillea robusta***	Silver oak	Ornamental, avenue tree
31	***Pithecolobium saman***	Rain tree	Ornamental, shade tree, fuel
32	***Spathodia campanulata***	Fountain Tree	Ornamental. shade tree, fuel
33	***Millingtonia hortansis***	Indian cork tree	Ornamental, cork industry
34	***Mimusopselengi***	Bakul	Shade tree, scented flower, rootstock for sapota, avenue
35	***Feronia elephant***	Wood apple	Fruits, medicine, timber
36	***Anona suatimosa***	Sitaphal	Fruits, fuel
37	***Cedrus deodara***	Debdar	Timber, furniture, flanks
38	***Glyricidia maculata***	Giripushpa	Fodder, leaf manures
39	***Butea monosperma***	Palas	Ornamental, Cottage industry, lack industry
40	***Thespeti apapulnea***	Ran Bhendi	Timber, fuel, rural ornamental
41	***Garcinia indica***	Kokam	Fruit, oil industry, squish, oil seed, medicine
42	***Tarminalia catappa***	Wild Almond	Ornamental, oil seed
43	***Manilkaria hexandra***	Khirani	Fruits, fuel, root stock for sapota

44	***Adina cordiolia***	Haldu	Timber, fuel
45	***Gmnelia arborea***	Shivan	Timber, fuel
46	***Lagesrromea lanciolata***	Nana	Timber
47	***Callistemon lanceolate***	Bottle Brush	Ornamental road avenue, parks
48	***Agave American***	Agave /' Ghaipath	Live fencing, rope making
49	***Peltophorum ferroginum***	Peltophooru m	Ornamental road avenue tree, parks
50	***Anona reticulate***	Ramphal	Fruits, soil reclamation
51	***Buchanamia latifolia***	Charoli	Fruits, soil conservation
52	***Anacardium occidentale***	Cashewnut	Cashewnut Fruits, soil conservation

15.6 Non-timber Forest Product

Non-timber forest products (NTFPs), also special, non-wood, minor, alternative and secondary forest products, are useful substances, materials and/or commodities obtained from forests which do not require harvesting (logging) trees. They include game animals, fur bearers, nuts, seeds, berries, mushrooms, oils, foliage, medicinal plants, peat, fuelwood, and forage.

Research on NTFPs have focused on their commodifiability for rural incomes and markets, as an expression of traditional knowledge or as a livelihood option for rural household needs, and, as a key component of sustainable forest management and conservation strategies. All research promotes forest products as valuable commodities and tools that can promote the conservation of forests.

Definitions

There is a wide variety of NTFPs, including mushrooms, huckleberries, ferns, transplants, seed cones, piñon seeds, tree nuts, moss, maple syrup, cork, cinnamon, rubber, tree oils and resins, and ginseng. The United Kingdom's Forestry Commission defines NTFPs as "any biological resources found in woodlands except timber,"and Forest Harvest, part of the Reforesting Scotland project, defines them as "materials supplied by woodlands - except the conventional harvest of timber." These definitions include wild and managed game, fish and insects. NTFPs are commonly grouped into categories such as floral greens, decoratives, medicinal plants, foods, flavors and fragrances, fibers, and saps and resins.

Other terms similar to NTFPs include special, non-wood, minor, alternative and secondary forest products. NTFPs in particular highlight forest products which are of value to local people and communities but have been overlooked in the wake of forest management priorities (for example, timber production and animal forage). In recent decades, interest has grown in using NTFPs as alternatives or supplements to forest management practices. In some forest types, under the right political and social conditions, forests can be managed to increase NTFP diversity and, consequently, to increase biodiversity and potentially economic diversity.

Uses

The harvest of NTFPs remains widespread throughout the world. People from a wide range of socio-economic, geographical and cultural contexts harvest NTFPs for a number of purposes, including but not limited to: household subsistence, maintenance of cultural and familial traditions, spiritual fulfillment as well as physical and emotional well-being, scientific learning and income. Other terms synonymous with harvesting include wild-crafting, gathering, collecting and foraging. NTFPs also serve as raw materials for industries ranging from large-scale floral greens suppliers and pharmaceutical companies to micro-enterprises centred upon a wide variety of activities (such as basket-making, woodcarving and the harvest and processing of various medicinal plants).

Economic importance

It is difficult to estimate the contribution of NTFPs to national or regional economies as there is a lack of broad-based systems for tracking the combined value of the hundreds of products that make up various NTFP industries. One exception to this is the maple syrup industry, which in 2002 in the US alone yielded 1.4 million US gallons (5,300 m3) worth USD$38.3 million.In temperate forests such as in the US, wild edible mushrooms such as matsutake, medicinal plants such as ginseng, and floral greens such as salal and sword fern are multimillion dollar industries. While these high-value species may attract the most attention, a diversity of NTFPs can be found in most forests of the world.

In tropical forests, for example, NTFPs can be an important source of income that can supplement farming and/or other activities. A value-analysis of the Amazon rainforest in Peru found that exploitation of NTFPs could yield higher net revenue per hectare than would timber harvest of the same area, while still conserving vital ecogical serviloces. Their economic, cultural and ecological value, when considered in aggregate, makes managing NTFPs an important component of sustainable forest management and the conservation of biological and cultural diversity.

Research

Researches on NTFPs have focused on three perspectives: NTFPs as a commodity with a focus on rural incomes and markets, as an expression of traditional knowledge or as a livelihood option for rural household needs, and, finally, as a key component of sustainable forest management and conservation strategies. These perspectives promote forest products as valuable commodities and important tools that can promote the conservation of forests. In some contexts, the gathering and use of NTFPs can be a mechanism for poverty alleviation and local development.

15.7 Summary

Our country is seriously threatened by desertification, soil erosion, and consequent siltation of lakes and rivers that result in floods and droughts. To combat these problems, we need to reforest fallow lands and hilltops with a wide range of trees and shrubs. While choosing trees to plant, the following factors must be taken into consideration:

a) **Utility:** Used as a source of food, fodder, firewood etc.; used for rearing insects for producing honey, silk, and lac; used for cultural reasons, for instance in festivals.

b) **Site limitations:** Quality of soil, availability of light; risk of fire, water logging, damage caused by grazing, risk of interference with overhead electrical/phone wires, etc.

c) **Life cycle and characteristics of the tree:** How fast it grows, how tall and wide it will grow, whether it sheds leaves and whether the tree branches break easily.

d) **Functions it can perform:** Shade, windbreak, bee-forage, adding beauty (foliage, flower, shape), habitat for wildlife, etc.

15.8 Glossary

- **Adaptation :** Modifications in living organisms over time that allow them to function better in their environment.
- **Agriculture :** The practice of farming, including cultivation of land for growing crops and livestock production.
- **Agroforestry :** Combination of timber production & agriculture on the same land. Farming activities are undertaken between widely spaced trees usually cultivated for timber, firewood and/or fodder.
- **Angiosperms :** Flowering plants. These plants produce seeds enclosed in an ovary.
- **Association :** A grouping of plants that have similar growing requirements, and are often dominated by one or more species for which they are characterised.
- **Backburning :** A bushfire preventative technique that involves lighting a controlled fire at a safe point to burn back towards the front of the bushfire.
- **Basal area (BA) :** The cross-sectional area of a tree at breast height (1.3m) expressed in square metres (m2). It's a tool used to calculate sustainable timber yield.
- **Biodegradable :** Material capable of being decomposed e.g. wood.
- **Biodiversity :** The genetic variety of life forms and their ecosystems.Comprises genetic diversity (within species), species diversity (between species) and ecosystem diversity.
- **Bole :** The tree trunk from the ground to the crown break. The bole doesn't include major branches supporting the tree crown, and may/not be straight.
- **Bolewood :** Section of the bole that is utilizable for a commercial product and is cut square at both ends to be made ready for delivery for processing.
- **Breast height :** 1.3m above the ground. This is the standard height at which a tree diameter is measured.

- **Broadleaf forests :** The general description of forests composed principally of trees and shrubs of the botanical group of flowering species which is in contrast to conifers or pines.
- **Bushfire :** A wildfire burning through bushland such as a State forest.
- **Cable logging :** Logging method based on a skyline wire cable system, used where slopes are too steep for conventional logging machinery.
- **Canopy :** The uppermost level of foliage formed by the branches and leaves of a tree.
- **Capacity :** The ability to apply knowledge in problem solving processes and innovate to create change

15.9 Self -Learning Exercises

Section- A : (Very Short Answer Type Questions)

1. Give one example of firewood yielding plant.
2. Give one example of timber yielding plant.

Section- B : (Short Answer Type Questions)

1. What does weathering do to teak?
2. What are those dark brown or black spots on firewood of?
3. What do the changes to the "firewood" definition mean?

Section- C : (Long Answer Type Questions)

1. What species of firewood are regulated?
2. Describe in detail Non wood fire produce.

15.10 References

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Unit - 16

Green Revolution

Structure of the Unit:

16.0 Objectives

After studying this chapter you will be understand about -

- green revolution
- the benefits of green revolution

- the adverse consequences of green revolution

16.1 Introduction

After the World War Second, the world was facing shortage of food. It became difficult to meet food demands of the world population. The scientists & farmers from all over the world had one common aim to appease hunger of people and make available food to poor. This collective effort led to the rise of new era with revolutionary changes with the aim to increase agricultural input. It was a period which initiated the use of mechanized means and new agro-technologies which began from Mexico and later spread to Asia. The revolution better known as green revolution was experimental within developing countries like India. The term was generally associated with wheat and rice crops but high yielding varieties for other crops have also been developed. When India got independent after 1947, food security and the production of enough food for the increasing population was one of the main challenges that our country faced. India is basically a agricultural based country who mainly depends on monsoons. The country has faced the situations of droughts and food shortages many times before independence. There was a need for a solution to food shortages. Because of the limited land available under cultivation and expanding population, India has to make tough efforts to increase the food production by increasing yield per unit area from existing land. Thus Green revolution contributed in increase in agricultural productivity and proved a huge success in terms of increased food production for the world population but it had its criticism too. This unit deals with the green revolution and the impacts of the green revolution**.**

16.2 Green Revolution

16.2.1 Definition

The increase in population resulted in increase poverty and shortage of food. The green revolution was a technological response to world food shortage. The development of several high yielding varieties of wheat and rice in the mid 1950s as a result of various plant breeding techniques led to dramatic increase in food production. This phase is often referred to as ‘Green Revolution’.

16.2.2 Historical Background

The green revolution began in Mexico. Traditional farming can only yield a limited biomass, as food for humans and animals. Plant Breeding as a technology has helped increase yields to a very large extent. The revolution was dependent to a large extent on plant breeding techniques by crossing unrelated plants and not the genetic engineering for the development of high yielding varieties (HYVs) & disease resistant varieties in wheat, rice, maize etc. Green revolution was not only because of introduction of HYVs but due to cumulative use of chemical fertilizers, pesticides, mechanized methods of farming such as tractors, pump sets, threshers etc. from the time of sowing to harvesting of crops using miracle seeds. It is said that the term ***'Green Revolution'*** was coined by William S. Gaud, director of the US Agency for International Development (USAID) in March 1968 for the revolutionary changes in agriculture. The revolution was 'green' to symbolize the revolution related to agricultural inputs and technologies.

16.2.3 Success of Green Revolution

International scientists and Institutes with experts were the driving force behind this innovative idea which took the form of a revolution. The introduction & production of HYVs of rice & wheat has contributed in the success of green revolution as these were semi dwarf varieties which were not susceptible to lodging as tall varieties are. The success must also be credited to use of nitrogenous fertilizers & pesticides which gave higher yields per unit of land area.

There were two waves of green revolution which prevailed in India. One in 1960s to 1970s which was prevalent in northern India specially Punjab but confined to wheat crop. The second wave prevailed during 1970s to 1980s and included rice and other crops covering the whole country. The Green Revolution successfully found its application in tropical or 'less developed' countries such as India, Pakistan, Bangladesh, Indonesia and China. With the use of HYVs there increased the production of food grains but the problem of poverty was not solved.

Fig. 16.1 : Mechanized tractor in a agricultural land

16.3 Innovation for Meeting World Food Demands

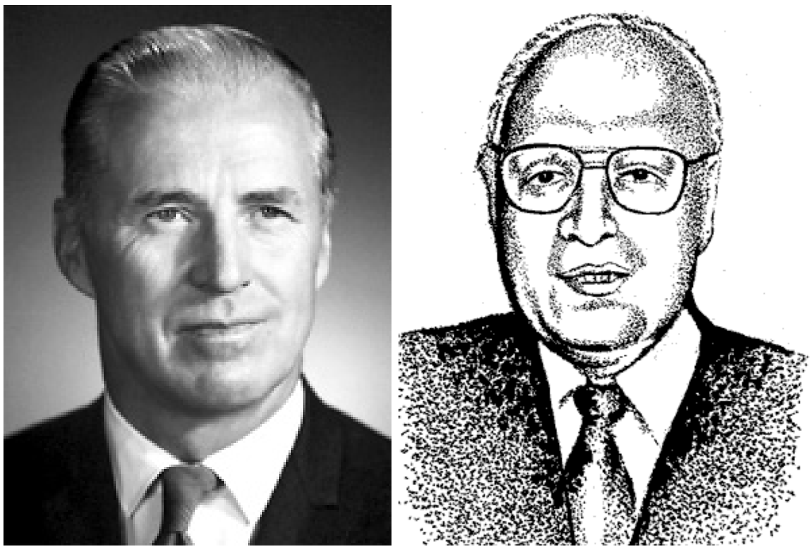
Different improvements have been made in food crops to meet the food demands of increasing population of the world. The revolutionary changes starting from Mexico spread to countries like Philippines, India, China, Pakistan, Bangladesh etc. The various international research institutes & organizations have been the centers of new innovations with food crops using breeding techniques. Whether it be IRRI, Rockefellar and Ford Foundations, IARI, CIMMYT etc. aimed to develop new varieties which were more responsive, more resistant and had promising higher yield. The Rockefellar & Ford Foundations aimed to develop international agriculture research system to transfer new trends and researches in developing countries. The work done at these international institutes were then co-operated and collaborated by Indian scientists at Indian Institutes like IARI to benefit farmers. These innovations will be discussed as improvements in cereals and millets as follows-

16.3.1 Improvement in Wheat

In early fifties, after the independence India various measures such as land reforms, irrigation facilities, and fertilizer production were introduced to increase food production in India. The capacity of our country to produce wheat increased from 6 million tons to 12 million tons in 1964. But still there was something missing which could help in increased production. In 1966, High Yielding Variety Programme (HYVP) was introduced by the Government of India which rose wheat production to about 17 million tons in 1968. Dr. B.P. Pal is one name who initiated the wheat improvement programme at the Indian Agricultural Research Institute (IARI), New Delhi. He developed rust resistant variety of wheat NP 809 which was resistant to all three types of rust & other variety NP 824 which has the ability to respond to about 50 kg of nitrogen. Later on even many non – lodging and fertilizer responsive varieties of wheat also developed. But there felt some need of some dwarf or short varieties to get economic response.

It was at CIMMYT (International Centre for Wheat and Maize Improvement) in Mexico during the year 1954, where increase in yield was seen when many improved varieties of wheat were used after several tests in test plots. This was done by Dr. Norman E. Borlaug and his colleagues. Dr. Borlaug was a Mexican wheat breeder. He developed many dwarf wheat varieties like Sonara – 64 and Lerma Rojo – 64A which contained *Norin -10* dwarfing gene from a Japanese variety. Japan is actually originating centre of semi dwarf varieties. It was during late 19th century when Japanese breeders crossed 'Daruma' variety of wheat with some American wheat varieties. These hybridizations resulted in a new Japanese variety called as Norin 10. Dr. Borlaug was awarded Nobel Prize for peace in 1970 for his contributions for humanity and is widely known as 'Father of Green Revolution'. The HYV seeds can also be called as 'miracle seeds' as they created a kind of miracle by boosting the yield of crops. The miracle seeds spread to Asia and other developing countries. The introduction of HYVs to be grown in India was a joint collaboration of Government of India & Ford Foundation through import from CIMMYT, Mexico. For which Punjab was selected as the centre of introduction of miracle seeds. Using Mexican varieties, Dr. M.S. Swaminathan at IARI, New Delhi developed "**Sharbati Sonara** variety of wheat through mutation breeding in India. Varieties like **Kalyan Sona** and **Sonalika** are some other examples of semi dwarf varieties developed in India. These semi dwarf wheat varieties are high yielding, fertilizer responsive and lodging resistant. Plant breeding consists of the principles and the methods required for favorably changing the genetic constitution of crop plants by crossing two different unrelated plants. Mutation breeding is utilization of induced mutations for crop improvement. Dr. Swaminathan is responsible for green revolution in India and is known as 'Father of Green Revolution in India'. In India, Punjab state was chosen by the Government of India for first use of these HYV seeds.

A postage stamp entitled 'Wheat Revolution' was released in July 1968 by then Prime Minister Indira Gandhi at the Indian Agricultural Research Institute (IARI), New Delhi to commemorate the big leap in production of wheat. Within 10 years of Green Revolution, India became self-suficient in food production and her dependency on other countries for food came to an end. The introduction of HYVs brought a 'boom' in grain production. These HYV varieties were developed with qualities like disease resistance and edible qualities in form of 'chapati' making keeping in mind. The green revolution was able to avert deaths caused by hunger & famines.



A B

Fig. 16.2 A: Dr. Norman E. Borlaug- Father of Green Revolution;

B: Dr. M.S. Swaminathan - Father of Green Revolution in India

16.3.2 Improvement in Rice

The development of semi dwarf rice varieties went in pace with development of semi dwarf wheat varieties. The improvement programme in rice started at Central Rice Research Institute (CRRI), Cuttack in 1952 by Dr. K. Ramiah through hybridization of temperate japonica rice varieties from Japan with Indian Strains (*Indica- Japonica* hybridization programme). The main aim of this programme was to make Indian rice varieties more respondent to fertilizer application by transferring this ability from japonica varieties. There was a big leap in yield of rice from 3 tons/hectare to 7 tons/hectare when a dwarfing gene from a Chinese variety known as '*Dee-Geo- Woo-Gen'* was introduced into Indian rice species. This gene was used to develop a semi dwarf rice variety *Taichung Native* 1(TN1) in Taiwan. Varieties like IR8 & IR36 were developed by International Rice Research Institute (IRRI), Los Banos, Philippines and introduced in India in 1966. Subsequently many semi dwarf varieties have been developed using TN-1 & IR-8 varieties with various crosses among different rice plants. IR-8 variety was produced by crossing *Dee-Geo- Woo-Gen* and an Indonesian variety 'Peta' at IRRI. Initially these varieties were grown extensively in larger areas in India but were replaced later by varieties like Jaya and Ratna which were superior semi dwarf varieties. Besides being high yielding, fertilizer responsive and lodging resistant, semi dwarf varieties of rice were photoinsensitive which made rice cultivation possible in nontraditional areas like Punjab.

Fig. 16.3 Indian Postage Stamp on Wheat Revolution

To commercialize hybrid rice technology, India is the second country in the world. The rice cultivation was revolutionized with the development of semi dwarf rice varieties.

16.3.3 Improvement in Maize

Over four decades ago, the hybrid programme for maize started in India in collaboration with Rockefellar & Ford Foundations. Ganga Safed 2 & Deccan was the major hybrid varieties released in India.

16.3.4 Improvement in Millets

Millets are small seeded cereals which are used as forage and as a food for both man & domestic animals. They include jowar, bajra, oats etc. Various hybrids in jowar have been released in India eg. CSH 1, CSH 2, CSH 3, CSH 4 etc. Hybrid varieties of bajra released in India include PHB 10, PHB 14, BJ 104, BK 560. India is the first country to develop hybrids of bajra. The hybrids of millets are in particular appropriate to grow in dry conditions of Rajasthan state. As the hybrid crops were susceptible to downy mildew diseases, they didn't become very popular.

16.4 Impacts of Green Revolution

The green revolution had mixed impacts on food production, agriculture, economy, environment and lives of people. For instance, if on one hand it made India self sufficient in food grains then on other hand it was not in reach for every poor. Various impacts can be discussed as positive impacts or benefits and as negative impacts as follows.

16.4.1 Benefits

The Green Revolution was based on HYVs. So the advantages of HYVs can be summarized as benefits of green revolution. The advantages of HYVs are-

1. These HYVs were more responsive to controlled irrigation.
2. They were more responsive to fertilizers.
3. They have higher productivity through higher yields.
4. These 'modern varieties' were disease resistant.
5. As a whole, green revolution reduced dependency of countries for food imports imparting national food security.
6. The revolution raised rural income.
7. It led to rapid agricultural and economic growth.
8. The green revolution increased crop production.
9. It also created plenty of jobs as greater employment generated in rural economy.
10. It contributed in better nutrition by providing more diversified diet with increased calories availability.

16.4.2 Adverse Consequences

Though the revolution was a big success all over the world but it too had some disadvantages-

1. HYVs require heavy amount of water. The irrigation became the necessity with use of these HYVs. Water facility was provided through tube wells, dams & canals.
2. The green revolution caused soil degradation disturbing the soil quality- It created depletion in soil's micronutrient content. Use of HYVs on same land year after year required heavy amounts of water making water logging conditions. This caused salinisation of soil thereby accelerating the salinity of soil.
3. These miracle seeds required more amount of pesticides.
4. Heavy fertilizer requirement was also an adverse effect of green revolution.
5. The use of 'modern varieties' require high cost of farming.
6. It increased the number of resistant pests.
7. The green revolution was confined to food grains only.
8. It resulted in decreasing genetic diversity.
9. The products (grains obtained) had poisoning from biocides (pesticides & herbicides) which affected health of people consuming these products.
10. It increased income inequality and inequitable asset distribution.
11. It spread in only well irrigated & high potential rain-fed areas while areas without access to sufficient water were left out.
12. It resulted in loss of biodiversity as the use of pesticides killed many soil organisms & insects.
13. It affected health of people by contaminating underground water through seepage of chemical fertilizers used on agricultural lands.

16.5 Present Status

The green revolution helped India in transforming into producer of food grains from an importer. It aided India in becoming self- sufficient in food grains production along with raising economic standards by alleviating poverty. On 27th November, 2015, Golden Jubilee of green revolution in India was commemorated.

It has been suggested to replace the term high yielding varieties (HYVs) with high responsive varieties (HRVs) as HYV seeds besides large quantities of nitrogenous fertilizers and water, they require control for disease, pests & weeds and increased mechanization (use of tractors, diesel pump sets, energized tube wells, automatic threshers)

Green Revolution is gradually being replaced by 'Biorevolution' which is based on genetic engineering and include molecular & cell biology expertise along with conventional plant breeding skills.

16.6 Summary

After the World War Second, the world was facing shortage of food. It became difficult to meet food demands of the world population. It was a period which initiated the use of new agro-technologies which began from Mexico and later spread to Asia, the revolution known as green revolution. Green revolution contributed in increase in agricultural productivity and proved a huge success in increased food production.

The green revolution began in Mexico. Dr. Borlaug was awarded Nobel Prize for peace in 1970 for his contributions for humanity and is widely known as 'Father of Green Revolution'.

Using Mexican varieties, Dr. M.S. Swaminathan at IARI, New Delhi developed Sharbati Sonara variety of wheat through mutation breeding in India. The hybrid programme performed for maize, rice, wheat, millets in India.

The green revolution had mixed impacts on food production, agriculture, economy, environment and lives of people. For instance, if on one hand it made India self sufficient in food grains then on other hand it was not in reach for every poor. Green Revolution is gradually being replaced by 'Bio-revolution' which is based on genetic engineering and include molecular & cellbiology expertise along with conventional plant breeding skills.

16.7 Glossary

- **Green Revolution:** a large increase in crop production in developing countries achieved by the use of artificial fertilizers, pesticides, and high-yield crop varieties.
- **Bio-revolution**: the genetic engineering of plants and animals with the potential to greatly exceed the productivity improvements.

- **Mutation:** the changing of the structure of a gene, resulting in a variant form which may be transmitted to subsequent generations, caused by the alteration of single base units in DNA, or the deletion, insertion, or rearrangement of larger sections of genes or chromosomes.
- **High Yielding Varieties:** High-yielding varieties (HYVs**)** are any of a group of genetically enhanced cultivars of crops such as rice, maize and wheatthat have an increased growth rate, an increased percentage of usable plant parts or an increased resistance against crop diseases.
- **Fertilizers:** Substances or mixtures that are added to the soil to supply nutrients or to make available nutrients already present in the soil, in order to increase plant growth and productivity.
- **Plant Breeding:** Plant breeding is the art and science of changing the genetics of plants in order to produce desired characteristics.

16.8 Self - Learning Exercise

Section- A : (Very Short Answer Type Questions)

1. The Green Revolution began in _________.
2. The high yielding varieties were _______ responsive to fertilizers.
3. In _________ a postage stamp on wheat revolution was released at ______ by_____________.
4. The dwarfing gene which was incorporated into Indian rice strains is known as ___________.
5. ________________is known as Father of green revolution in India.
6. The greatest contribution in success of green revolution is of _______.
7. Who is father of green revolution and awarded Nobel Prize for his contribution?
8. Name the improved variety of wheat played important role in green revolution in India.
9. The full form of CIMMYT is

   a) Centre for International Maize Management and Test

   b) International Centre for Wheat & Maize Improvement

c) International Centre for Maize & Millets Test

d) Centre for Indian Millets & Wheat Improvement

10. The term ‘green revolution’ was coined by

a) Norman Borlaug

b) M.S. Swaminathan

c) William S. Gaud

d) Dr. K. Ramiah

11. Golden Jubilee of green revolution in India was commemorated on

a) 27^{th} October 2014

b) 27^{th} November 2015

c) 27^{th} December 2015

d) 27^{th} November 2014

12. The variety of wheat produced by M.S. Swaminathan in India are

a) Sona

b) Sharbati Sonara

c) Kanchan Sona

d) Lerma Rojo

13. Varieties of rice like IR-8 & IR-36 were developed at

a) IRRI

b) CIMMYT

c) IARI

d) CRRI

14. PHB 10 is a hybrid variety released in India is of

a) wheat

b) rice

c) bajra

d) jowar

15. HYVP was started in India in the year

a) 1961

b) 1963

c) 1962

d) 1966

Section- B : (Short Answer Type Questions)

1. Who is known as Father of green revolution in the world? Name the place from where it started.
2. What were the main institutes all over the world that contributed in development of hybrid varieties of different crops?
3. What are the benefits of high yielding varieties?
4. What were the improvements in millets which were beneficial to Rajasthan state?
5. What are the major contributions of Dr. Norman E. Borlaug in Green Revolution?
6. What is biorevolution?

Section- C : (Long Answer Type Questions)

1. Describe the impacts of green revolution.
2. What are the major improvements in wheat during green revolution?
3. Discuss from where the green revolution originated and how it spread all over the world.
4. Write a short note on green revolution & explain the main improvements done in wheat.
5. Discuss how the green revolution changed the lives of people of India.

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Unit-17

Plant Diversity

Structure of the Unit:

17.0 Objectives

After going through this unit you will understand the basics of biodiversity and able to know about

- biodiversity
- levels of biodiversity
- maintainance of biodiversity
- reasons behind biodiversity loss
- endemic species and hot spots
- importance of biodiversity in ecosystem functions and stability

17.1 Introduction

Each and every species has a particular function in an ecosystem. The more varied the ecosystem is, i.e. the greater the biodiversity, the greater its resistance to environmental stress will be. The loss of even only one species often can provoke a decrease in the capacity of the system to remain preserved in case of degradation. The consequences of biodiversity loss have not been fully understood not only by a layman but by policymakers also. This chapter will help the student to understand basic concept of all aspect of biodiversity.

17.2 Concept and Status in India

Concept of biodiversity

Biodiversity is a compound word derived from ‘biological diversity’ and therefore is considered to have the same meaning. According to Convention on Biological Diversity 1992, **'Biological diversity'** means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are the part; this includes diversity within species, between species and of ecosystems.

The origin of the word **‘biodiversity’** is often attributed to W.G.Rosen in 1985. Although E. O. Wilson first used the term biodiversity in the literature in 1988 in a book entitled ‘Biodiversity’.

Biodiversityisthe variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are the part; this includes diversity within species, between species, and of ecosystems.

According to the U.S. Office of Terminology Assessment (1987), biological diversity is “the variety and variability among living organisms and the ecological complexes in which they occur”

Biodiversity Status in India

India is the seventh largest country in the world with an area of 3,287,263 square km. which is only 2.4 % of the world’s land area. India has about 45,000 plant species (including bacteria and fungi) and about 91,000 species of animals which share 8.1% of global species diversity. These numbers make India one of the twelve mega-biodiversity countries of the world, but actual number of species is yet to be discovered. As an assumtion only 22% of the total species have been recorded so far. This number may increase to 200,000 in plants and more than 360,000 in animals.

India, being a vast country, shows a great diversity in climate, topography and geology and hence the country is very rich in terms of biological diversity.

The important features that contribute to India's rich biodiversity are-

1. **Position on the Globe**: India has not a perfect tropical position on the globe, but conventionally it is considered as a tropical country, because it is separated from the north by Himalayas and its climate is very much similar to tropical climate. It is situated at the tri-junction of the Afrotropical, Indo-Malayan and Palaearctic realms, all of which support rich biodiversity.
2. **Monsoon Pattern:** The moisture **laden** winds coming from south west hit the Himalayas in the North and shed its water as copious rainfall in the south, and as snow in the upper reaches in north. The trans-Himalayan regions in Cold Desert of Ladakh, Pin Valley in Himachal Pradesh and a small segment in Uttarakhand receive precipitation in the form of snow brought by the winds transgressing over the high Himalayas. India is most diversified country as precipitation is concern. There are almost rainless areas (Hot and Cold Desert) as well as highest rainfall area (Mawsynram, Meghalaya). This diversified precipitation leads to rich biodiversity.
3. **Altitudinal Diversity:** Attitudinally the Himalaya has been classified into 1.Nival Zone–4750m, 2.Alpine Zone-4500m, 3.Sub-alpine Zone-4000m, 4.Montane Zone-300m, 5.Sub-montane Zone-2000m, 6.Tropical Zone-2000m and 7.Subtropical Zone- 1000m. These entire zones 5 are supporting a characteristic biodiversitypeculiar to the area.
4. **Variety in elevation:** The other important features that contribute to India's rich biodiversity are its variety in elevation from subtropical Zone to Naval Zone.
5. **Wetlands:**Wetlands may be man made or natural where the soil remains waterlogged or submerged for whole or part of year upon which the wetland biota depends.Wetlands, transition between terrestrial and aquatic systems, are unique habitats that sustain substantial biodiversity. According to India's fifth national report to CBD 2014; India is bestowed with a rich diversity of

wetlands, ranging from high altitude lakes of the Himalayas, floodplains and marshes of the Gangetic - Bramhaputra alluvial plains, saline flats of Green Indian Desert to extensive mangroves marshes bordering the country's East and West coastline. As per remote sensing **imagery** based assessment (at 1:50,000 scales based on data of 2006-2007), India has total of 757,060 wetlands covering a total area of ca. 15.26 million ha, roughly equal to 4.6% of its land area. Of this, inlands wetland constitute 69.22% (10.56 million ha). There are 0.556 million wetlands with area less than 2.25 ha (Figure 1.10, Figure 1.11, National Wetland Atlas 2011) India has 26 sites which have been designated as Wetlands of International importance under the Convention.

6. **Forests:** According to Global Forest Resource Assessment Report (Food and Agricultural Organization (FAO) 2005), India ranks among the top ten countries in terms of forest area. India has 1.8 % of the global forest area with per capita forests of 0.08 ha. The major forest types in India are Tropical forests, Sub-tropical forests, Temperate forests andSub-alpine & Alpine forests.
7. **Marine Environment:**India with a coastline of about 8,000 km, and an EEZ of 2.02 million sq. km, shows a very wide range of coastal ecosystems like estuaries, lagoons, mangroves, backwaters, salt marshes, rocky coasts, and stretches and coral reefs which are characterized by rich and unique biodiversity components (Venkataraman and Wafar 2005).

Bio-geographic Diversity in India:

India has ten bio-geographic regions

Table 17.1: Biogeographic Regions of India

S.N.	Biogeographic Zones	Biogeographic Provinces	% of geographical area of India
1.	Trans Himalaya	1A: Himalaya - Ladakh Mountains	3.3
		1B: Himalaya -Tibetan Plateau	2.2
		1C: Trans - Himalaya Sikkim	<0.1
2.	The Himalaya	2A: Himalaya - North West Himalaya	2.1
		2B: Himalaya - West Himalaya	1.6
		2C: Himalaya - Central Himalaya	0.2
		2D: Himalaya - East Himalaya	2.5
3.	The Indian Desert	3A: Desert – Thar	5.4
		3B: Desert – Katchchh	1.1
4.	The Semi Arid	4A: Semi - Arid - Punjab Plains	3.7
		4B: Semi - Arid - Gujarat Rajputana	12.9
5.	The Western Ghats	5A: Western Ghats - Malabar Plains	2.0
		5B: Western Ghats -Western Ghats Mountains	2.0
6.	The Deccan Peninsula	6A: Deccan Peninsular - Central Highlands	7.3
		6B: Deccan Peninsular - Chotta Nagpur	5.4
		6C: Deccan Peninsular - Eastern Highlands	6.3
		6D: Deccan Peninsular - Central Plateau	12.5
		6E: Deccan Peninsular - Deccan South	10.4
7.	The Gangetic Plains	7A: Gangetic Plain - Upper Gangetic Plains	6.3
		7B: Gangetic Plain - Lower Gangetic Plains	4.5
8.	The Coasts	8A: Coasts - West Coast	0.6
		8B: Coasts - East Coast	1.9
		8C: Coasts – Lakshdweep	<0.1
9.	Northeast India	9A: North - East - Brahamputra Valley	2.0
		9B: North - East – North East Hills	3.2
10.	Islands	10A: Islands – Andamans	0.2
		10B: Islands – Nicobars	0.1

Source: Wildlife Institute of India, 2009

1. The Trans-Himalaya

The Trans-Himalaya zone covers mainly the districts of Ladakh and Kargil in Jammu and Kashmir, and the Spiti valley, Lingti plains (Lahaul valley), and Pooh tehsil (district Kinnaur) in Himachal Pradesh. Small areas in the rain shadows of Nanda Devi range (Uttarakhand) and Kangchendzonga range (Sikkim) are also parts of this zone (Mehta and Julka 2001). The area is a distinct bio-geographic unit with harsh climatic conditions and is usually referred to as cold desert (Rodgers and Panwar 1998). The region is the most elevated zone on the earth and varies from 2800 m in the Indus to over 7000 m in the Himalayan and Karakoram ranges (Mehta and Julka 2001).

2. The Himalaya

The Himalaya zone consists of an area of 21, 0662 sq. km, approximately 6.41% of the country's total land surface. It includes northwest Himalaya (Kashmir to the Sutlej River in Himachal Pradesh), west Himalaya (Sutlej River to the Gandak River in Nepal), central Himalaya (Gandak River in Nepal through West Bengal and Sikkim to central Bhutan) and east Himalaya (central Bhutan and Arunachal Pradesh). The Himalayan flora represents 71 endemic genera and 32% endemic species. Also, five families are endemic to the region (i.e. Tetracentraceae, Hamamelidaceae, Circaeasteraceae, Butomaceae,and Stachyuraceae), while over 90% of the species inBerberidaceae and Saxifragaceae are endemicto the Himalaya. A large number of orchids, many representing neo endemic taxa, have beenreported from Sikkim and Arunachal Pradesh

3. The Desert

Thar Desert is the world's seventh largest desert and is considered the most in hospitable eco-region in Indo-Pacific region. This large eco-region lies to the west of Aravalli Range and characterized by extreme climate (annual temperature ranging from near freezing in the winters to over 50^{o}C in summers). Rainfall is scanty in the range of 100-150 mm.The Indian desert is the northwestern boundary of India and covers mainly the western and northwestern region of Rajasthan and part of Kutch region of Gujarat in the southwest. The flora of Indian desert comprises nearly 682 species (352 genera and 87 families; 86 angiosperm and a lone gymnosperm family).The degree of endemism of plant species in Thar Desert is 6.4% which is relatively higher than3% endemism the Sahara desert. Some endemic species of Thar Desert includes *Calligonum polygonoides* (Polygonaceae), *Prosopis cineraria* (Mimosaceae), *Tecomella undulata* (Bignoniaceae), *Cenchrus biflorus* (Poaceae) and *Sueda fruticosa* (Chenopodiaceae), etc.

4. The Semi-Arid

This region is a zone of transition between the true desert in the west to the extensive communities of the Deccan Peninsular India, to the south and east. This zone includes the Punjab plains, Delhi, Haryana, fringes of Jammu and Kashmir, Himachal Pradesh, and western edges of Uttar Pradesh, eastern Rajasthan, eastern Gujarat and northwest Madhya Pradesh. The Semi-arid zone represents a characteristic savannah woodland and dry deciduous and tropical thorn forest zone in Western India. The Aravalli System constitutes the heart of this zone, which primarily supports two types of vegetation: **Tropical Dry Deciduous Forest and Tropical Thorn Forest.**

5. The WesternGhats

The Western Ghats comprise the mountain range that runs along the west coast of India, from the Tapti River (Vindhya-Satpura ranges) in the north to the southern tip. The ecosystems of the Western Ghats include the tropical wet evergreen forests, the montane evergreen forests, moist deciduous forests etc. The varied topographic, climatic and geological factors of this region have made significant contribution to biodiversity. Almost one-third of all the flowering plant species in India are found in this region.

The Western Ghats zone is one of the 25 biodiversity **'hotspots'** in the world (Myers *et. al.*, 2000) and is one of the major tropical evergreen forested regions in India, exhibiting enormous plant diversity. About 4000 species of flowering plants occur in the region, which harbours nearly 27% of the total flora in India (Nayar 1996). The Western Ghats region is a major genetic estate with enrich biodiversity of ancient lineage. Fifty-six genera and 1,500 species (38%) of flowering plants and 63% of India's evergreen woody plants are endemic to the Western Ghats.Over 10% area of Western Ghats (around 13,692 km^2) is under legally designated PAs. Theconservation network in the Western Ghats includes 2 BRs; 16 NPs and 47 WLSs

6. TheDeccan Peninsula

The Deccan Peninsula biogeographic zone includes a major portion of the states of Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and Bihar. The zone is relatively homogenous and ranges from semi-arid to moist deciduous/ semi-evergreen type of climate. The central highlands comprise the Vindhya and Satpura hill ranges, Chhota Nagpur Plateau, Eastern Ghats, Tamil Nadu Plains and Karnataka Plateau (Cherian 2001). The Vindhya and Satpura hill ranges are known for a rich diversity of flora. The Deccan Peninsula is a large area of raised land covering about 43% of India's total land surface. It is bound by the Sathpura range on the north, Western Ghats on the west and Eastern Ghats on the east. The elevation of the plateau varies from 900 mts. in the west to 300 mts. in the east. There are four major rivers that support the wetlands of this region which have fertile black and red soil. Large parts are covered by tropical forests. Tropical dry deciduous forests occur in the northern, central and southern part of the plateau. The eastern part of the plateau in Andhra Pradesh, Madhya Pradesh and Orissa has moist deciduous forests.

7. The Gangetic Plains

This zone includes the Gangetic divide, the Upper Gangetic plain, the Middle Gangetic plain and the Lower Gangetic plain (Hooker 1907). This zone is very supporting for agriculture practices. Thus supports dense human population stretching from eastern Rajasthan through Uttar Pradesh to Bihar and West Bengal. The Gangetic plain is one of India's most fertile regions. The soil of this region is formed by the alluvial deposits of the Ganges and its tributaries.
The four important surface differences recognized in the geomorphology of the plains are-

Bhabar - pebble studded zone with porous beds

Terai - marshy tract

Bhangar - older alluvium of the flood plain

Terai - marshy tract

Khadar -newer alluviumThe Gangetic plains stretching from eastern Rajasthan through Uttar Pradesh to Bihar and West Bengal are mostly under agriculture. The large forest area is under tropical dry deciduous forest and the south eastern end of the Gangetic plain merges with the littoral and mangroves regions of the Sunderbans.

8. The Coasts

The coastline of India stretches from Gujarat to Cape Comorin (Kanyakumari) in the west, and onwards from Cape Comorin to the Sundarbans in the east. The coastal zone ofthe West Coast is narrow and steep in slope, due to the presence of the Western Ghats. Secondly, there are no major west-flowing rivers. As a result, mangrove ecosystems of the West Coast of India are small in size, less in diversity and less complicated in terms of tidal creek network. The presence of largerbrackish water bodies and a complex network of tidal creeks and canals characterize mangrove ecosystemsof the East Coast.The long stretch of coastline in the mainland has a very diverse set of biotic communities. The coasts of India (Total area 91319 km^2) comprise with 5 NPs and 20 WLSs (Total area 4690.63 km^2) which make 5.14 % of Biozone Area.

9. North-East Region

Some parts of the North-eastern region of India, excluding the Himalayan region, are contiguous with the Indo-Burma biodiversity hotspot, centred on the IndoChinese Peninsula, and comprising Cambodia, the Lao People's Democratic Republic, Myanmar, Thailand, Vietnam and parts of Southern China. The topography of the hotspot is complex and is characterised by a series of North-south mountain ranges that descend from the Himalayan chain and its South-eastern extensions. The plant diversity of the entire hotspot is estimated to comprise about 13,500 vascular plant species, of which about 7000 (52%) are endemic. Of the 1277 bird species found in Indo-Burma, 74 are endemic. Similarly, 71 of the 430 mammal species in the hotspot are endemic. Other vertebrate groups show much higher levels of endemism, with 189 of the 519 non-marine reptile species and 139 of the 323 amphibian species being endemic to the hotspot. Indo-Burma probably supports the highest diversity of freshwater turtle in the world. The hotspot also has a remarkable freshwater fish fauna, with 1262 documented species, accounting for about 10% of the world total, including 566 endemics (Tordoff et. al., 2012).

The north-east Indian bio-geographic zone is most significant as it represents the transition zone between the Indian, Indo-Malay and Indo-Chinese bio-geographic regions, as well as a meeting-place of Himalayan Mountains with those of Peninsular India. It comprises eight states Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region acts as a biogeographic gateway for plant migration. In India, apart from the Western Ghats, Northeast India is one of the 25 biodiversity **'hotspots'** in the world (Myers *et. al.*, 2000).

10. Islands

Islands are essentially in two major groups the Lakshadweep islands and the Andaman group of islands. The Lakshadweep Islands are an archipelago of 27 small islands stretching from 8° to 12° N latitude and 71° to 74° E longitude in the Arabian Sea. They are 320 km away from the Kerala coast. The Andaman and Nicobar Islands are an elongated north-south oriented group of 348 islandsin the Bay of Bengal stretching for 590 km from 6° to 13° N latitude and 92° to 93° E longitude.The Andaman Islands are about 190 km from Cape Negrais in Burma, the nearest point on the mainland. Five islands close together constitute the Great Andaman (300 km long), and the Little Andaman lies to the south. The Nicobar groups of Islands are separated from the Andamans as well as internally from each other by 800 m deep channels.According to National Wildlife Database, Wildlife Institute of India, 2009; Islands of India with total area of 8249 km^2 have 9 NPs and 96 WLS which contain 18.75% of total Biozone Area.

Table 17.2 Number of Species in major groups of plants

Plant group	Number of species described in India	Number of species described World (estimated)	Percentage in India (%)
Algae	**7,244**	**40,800**	**17.75**
Bryophytes	**2,504**	**14,500**	**17.27**
Pteridophytes	**1,267**	**12,000**	**10.56**
Gymnosperms	**74**	**650**	**11.38**
Angiosperms	**17.926**	**250,00**	**7.17**
Total	**29,015**	**317,950**	**9.13**

Source: BSI (2013

17.3 Utilization and Concern of Biodiversity

There is an important question in present scenario. This is about the loss of biodiversity and its effect on mankind special reference to our country. The reasons for being concerned with the loss of biodiversity fall into its values i.e. Ethical and Aesthetic values, Economic values and its role in ecological function and stability. India should be more concerned about biodiversity loss as it can lead into climate change and change in monsoon pattern. Because of lack of modern irrigation infrastructure in India, a large population is highly dependent on the monsoon fortheir agricultural production, to the extent that any delay or shortage in the monsoon is bound to affect all aspect of their life. According to official figures from the World Bank, the Indian agricultural sector accounts for 47 percent of employment while contributing less than 20 percent of GDP. This shows that more than half a billion Indians are currently dependent on the Indian monsoon for their livelihoods.

17.4 Value of Biodiversity

Biodiversity is the most valuable gift of nature to man. Due to extreme complexity of ecosystem structure, it is very difficult to calculate the full value of all ecosystem goods and services. If we want to know how much actual value nature provides us, we have to calculate both direct and indirect value. The direct value include food resources like grains, vegetables, fruits, meat, fish, egg, milk and milk products etc. which we extract from plant and animal resources directly. These also include medicine, fiber, fuel, wool, wax, timber, resin, rubber, silk and decorative items. Environmental regulatory value, social and cultural values, ethical values, aesthetic values, and option values are considered as Indirect Value. So there are many worth of biodiversity which can be classified as-

A. **Direct Value**

   1. Consumptive Use Value
   2. Productive Use Value

B. **Indirect Value**

   3. Social and cultural value
   4. Ethical value

5. Aesthetic value
6. Option value
7. Environment service value

1. **Consumptive Use Values-** Direct Values which are consumed locally and do no figure in national and international market. Non market values of resource which are consumed directly without passing through market are considered in Consumptive Use Values.eg. Food and fuel.
2. **Productive Use Values-** Direct Values that are commercially harvested for exchange in formal markets, such as timber, meat, fish, ivory, medicinal plants
3. **Social and cultural value-** Many plants and animals are considered holy and sacred in India and are worshipped like Tulsi, peepal, cow, snake etc.Sacred plants are valuable in society, not only because of their ethnomedicinal and conservative values but cultural point of view also.
4. **Ethical value-** Lost biodiversity cannot be recreated so being the most dominant species on planet; it is our moral responsibility to save it. All species have a moral right to exist on earth, irrespective of our need for them.It is based on the principle of 'live and let others live' and 'all life forms must be preserved'. Man is only a small part of the Earth's great family of species.
5. **Aesthetic value-** What makes our planet beautiful is Biodiversity; otherwise it also looks like a barren planet like others. Biodiversityaddsquality and beauty into our life and provides some of the most beautiful aspects of our existence. Rich Biodiversity is responsible for the beauty of a landscape. These landscapes promote eco-tourism where people like to come for bird watching, photography and other activities.Wildlife films, pet-keepings and gardening are other activities based on biodiversity.
6. **Option value-** These values include the unexplored or unknown potentials of biodiversity. The economic and other values of yet-undiscovered bio-resources (new medicines, new foods) are the best reason to save biodiversity.

7. **Environment service value-**We all need a healthy environment which is a product of rich biodiversity. Every day human activities are positively supported by biodiversity. These includes:

   a. Most important product of biodiversity is oxygen, produced by photosynthetic algae and plants.

   b. pollution of water bodies is controlled by aquatic vegetation.

   c. Soil organisms have major role in breaking down pollution and maintain soil fertility. It is very important in sustainable farming.

   d. Biodiversity makes a reservoir for wild and native species and genes, used in industry research, agriculture, pharmaceutical companies, forestry etc.

   e. Insects, birds and other fauna have important role in pollination of agricultural crop and other plants.

   f. Mangrove and Coral reefs are important factor in coastal sustainability.

   g. Flood mitigation, combat desertification and pest control are the issues which can be addressed by biodiversity.

17.5 Levels of Biodiversity

Biodiversity can be subdivided at three levels as follows:

1. Genetic Diversity

This is the genetic variability of a species. Genetic diversity can be measured directly by genetic fingerprinting or indirectly by observing differences in the physical features of the organisms within the population. Lack of genetic diversity indicates that the species may not have sufficient adaptability and may not be able to survive an environmental hazard. These uniform populations are highly prone to disease harsh environment.

Greater the genetic diversity among organisms within species, indicate that the species should have sufficient adaptability and more sustenance against Environmental Perturbations.

2. Species Diversity

Species diversity refers to the number of the different species and the number of individuals of each species within community. Important parameters-

1. **Species richness:** It refers to the number of species per unit area.
2. **Species Evenness:** It refers to the relative abundance with which each species is represented in an area.

3. Ecological Diversity

This is the diversity of habitats, biological communities or ecosystems within an area. A region possessing a wide variety of habitats is preferable, and will include a much greater diversity of species, than one in which there are few different habitats. More specifically a countryside which has ponds, river, woodland, hedge rows, wet meadow land and set-aside grassland will be more species rich and more diverse. Ecological Diversity is related to species diversity.

17.6 Threats to Biodiversity

A number of species are becoming extinct due to different reasons resulting in to loss of biodiversity. The various factors which are responsible for all types of biodiversity loss including genetic diversity, species diversity and ecosystem diversity are habitat loss and fragmentation, disturbance and degradation, pollution, over-exploitation, introduction of exotic species, intensive agriculture and forestry and shifting cultivation.

1. **Habitat Loss and Fragmentation-** Over-population, Urbanization and Industriliztion require additional land every year. It can come through destruction or fragmentation of natural habitats. One primary cause of species loss is habitat destruction and fragmentation. Loss of habitat results in annihilation of species of endemic plants and microorganisms. Fragmentation of habitats results in disruption of complex interactions amongst species, destruction of species in cleared regions, annihilation of species restricted to deeper undisturbed part of the forests and decreased biodiversity in the habitat fragments. Extinction processes often occur with a time delay and populations living close to their extinction threshold might survive for long time periods before they go extinct. This time delay in extinction is called the **'relaxation time'** (Diamond 1972) and the phenomenon that declining populations will eventually go extinct in fragmented or degraded habitats has been described as an **'extinction debt'** (Tilman *et al. 1994;* Kuussaari *et al.* 2009). In present-day fragmented and perturbed landscapes, populations of many species might be on

a deterministic path to extinction even without any further habitat loss occurring.

2. **Climate Change-** A changing global climate threatens species and ecosystems. The distribution of species (bio-geography) is largely determined by climate, as is the distribution of ecosystems and plant vegetation zones (biomes). Climate change may simply shift these distributions but, for a number of reasons, plants and animals may not be able to adjust. The pace of climate change almost certainly will be more rapid than most plants are able to migrate. The presence of roads, cities, and other barriers associated with human presence may provide no opportunity for distributional shifts. Overall, climate is a major factor in the distribution of species across the globe; climate change forces them to adjust. But many are not able to cope, causing them to die out.
3. **Disturbance and Degradation**- They are of two types, **natural** and **man-made.** Natural disturbance and degradation is caused by spontaneous jungle fire, pest infestation, locust attack etc. man-made disturbance and degradation include felling of trees, use of fire for clearing vegetation etc.
4. **Pollution**- Biodiversity in India facing threat from various pollution sources especially at a time when new industrial processes are generating a variety of toxic wastes and pollutant. Generation of wastes from anthropogenic activities involving production and consumption adds to the pressures on ecosystems. Excessive use of fertilizers and pesticides has polluted our ground water and water bodies. Many species have extinct. Due to pesticides magnification in higher tropic layers, a drastic decline in fish eating birds and falcons has been seen. Eutrophication which is caused by fertilizers, sewage and organic matters, also responsible for mortality of many animals. Acid rain, which is typically caused by the burning of fossil fuels, can acidify smaller bodies of water and soil, negatively affecting the species that live there by changing breeding and feeding habits. Air pollution cause death of many sensitive plants. Radiations are harmful to both flora and fauna. Spill-over of oil in sea causes death of several marine algae, fishes and sea birds.
5. **Over-exploitation-** Excessive exploitation of a species, whether a plant or animal reduces number of individuals in a population so that it may become vulnerable to extinction, e.g., collection of medicinal plants.
6. **Intensive Agriculture-** All forms of farming have major impacts on biodiversity, especially when new land is brought into cultivation. Intensive

agriculture is based on a few high yielding varieties. This cause the reduction in genetic diversity. Modern intensive farming produces plentiful, cheap food but is dependent on heavy use of agrochemicals and is a major driver of the ongoing collapse of wildlife populations.

7. **Introduction of Exotic Species-** According to India's forth report to CBD; *173 alien plant species recorded in India.* Non-native or alien species are often introduced for their economic and other use. Native species are subjected to competition for food and space due to the introduction of such species. This can cause dramatic change to native species and natural communities. It is more concerned about the effect of exotic species wherever the affected community contains endemic species.

   Different parts of the earth with similar habitats are occupied by different groups of species. If every species would have access to each habitat, a very few number of dominant species could present across the globe. This type of homogenization is restricted by the limited power of species dispersal and physical barriers. These barriers have been breached by transport opportunities provided by humans, which cause large number of exotic species introduction.

8. **Shifting or Jhum Cultivation-**Some rural or tribal people tend to destroy biodiversity for their land requirements. This is known as **Jhum cultivation** which is practiced in North-Eastern India.

17.7 Biodiversity Hotspots

The idea of hotspots was first mooted in 1988 by ecologist Norman Myers, who identified ten tropical forest **"hotspots"**defined as an area of exceptional levels of plant endemism and by serious levels of habitat loss (threat). In 1990 Myers added a further eight hotspots, including four Mediterranean-type ecosystems. Myers et al. (2000) identified 25 biodiversity hotspots all over the world.

Conservation International adopted Myers hotspots as its institutional blueprint in 1989, and in 1996, the organization made the decision to undertake a reassessment of the hotspots concept, including an examination of whether key areas had been overlooked. The key criteria for determining a hotspot are endemism (the presence of species found nowhere else on earth) and degree of threat. To qualify as a biodiversity hotspot, a region must meet two strict criteria: (1) It must have at least 1,500 vascular plants as endemics which is to say, it must have a high percentage of plant life found nowhere else on the planet. A hotspot, in other words, is irreplaceable. (2) It must have 30% or less of its original natural vegetation. In other words, it must be threatened.

Around the world, 35 areas qualify as hotspots. They represent just 2.3% of Earth's land surface, but they support more than half of the world's plant species as endemics i.e., species found no place else and nearly 43% of bird, mammal, reptile and amphibian species as endemics.Out of the 34 global biodiversity hotspots, four are present in India (Conservation International 2013).

1. **Eastern Himalayas -** Eastern Himalaya form part of Himalayan global biodiversity hotspot.
   Of the estimated 10,000 species of plants in the Himalaya hotspot, 71 genera and approximately 3160species are endemic. The Eastern Himalayan region is exceptionally rich in diversity and endemism and hence is of great significance. The Eastern Himalaya, on the whole has an estimated 9000 plant species, out of which 3500 (39%) are endemic. In the Indian portion of the Eastern Himalaya there occur 5800 plant species, approximately 2000 (36%) of which are endemic. The area is also rich in wild relatives of plants of economic significance, for example, rice, banana, citrus, ginger, chilli, jute and sugarcane.
2. **Western Ghats -**The Western Ghats are part of the Western Ghats-Sri Lanka global hotspot, running roughly in a North-south direction for about 1500 kilometres parallel to the coast bordering the Arabian Sea. The importance of the Western Ghats in terms of their biodiversity can be seen from the known inventory of their plant and animal groups and the levels of endemism in these taxa. Western Ghats harbour 7388 species of flowering plants. Of these, 5584 species are indigenous, 377 are exotic naturalised and 1427 are cultivated or planted. Of the indigenous 5584 species, 2242 species are Indian endemics (found only in India) and 1261 are the Western Ghats endemics. Apart from the above, there are 586 taxa with subspecies and variety status, bringing total taxa in the Western Ghats to 7974 (Nayar, et. al., 2014).
3. **North-East** - Part of Indo-Burma global biodiversity hotspot.Some parts of the North-eastern region of India, excluding the Himalayan region, are contiguous with the Indo-Burma biodiversity hotspot, centred on the Indo-Chinese Peninsula, and comprising Cambodia, the Lao People's Democratic Republic,

Myanmar, Thailand, Vietnam and parts of Southern China. The plant diversity of the entire hotspot is estimated to comprise about 13,500 vascular plant species, of which about 7000 (52%) are endemic.

4. **Andaman and Nicobar Islands -**The Nicobar Islands are part of the Sundaland hotspot, which includes a small portion of Southern Thailand; nearly all of Malaysia; Singapore, at the tip of the Malay Peninsula; all of Brunei Darussalam; and the entire western half of the megadiverse country of Indonesia, including Kalimantan. They belong to the Andaman and Nicobar group of islands.Of the 3500 plant species that have been reported from the Andaman and Nicobar group of islands, 422 floral genera and 648 species (13.11% endemic) have been reported from Great Nicobar Island. These belong to 142 families, of which 14% are endemic. Out of the 120 pteridophyte species of the Andaman and Nicobar Islands, 50% are from Great Nicobar Island alone. A total of 110 wild orchids are reported from these islands, of which 19 genera, with 25 species, are endemic.

Himalaya and Western Ghats are the two Indian mountain biodiversity global hotspots.

17.8 Role of Biodiversity in Ecosystem Function and Stability

Biodiversity underpins the function and stability of ecosystems, which are of high value due to the life-supporting services they provide that meet human needs, both material and spiritual. Biodiversity supports ecosystem services that have economic value for humans in terms of direct or indirect use. They are providing services, such as supplying of fuel and fodder, and regulating services, such as carbon sequestration and prevention of soil erosion. Moreover, biodiversity has non-use or existence value. For millions of Indians, biodiversity supports theirlivelihoods and ways of life. In the Indian context especially, a range of socio-cultural values are derived from biodiversity that are philosophical, cultural and religious. Ecosystem diversity is reflected in the cultural and religious diversity of India through the varied values attached to biodiversity components and landscapes. The socio-cultural as well as aesthetic values attached to species and landscapes are reflected not only in the age-old tradition of sacred groves but also through formal designation of natural heritage sites which are most often also sites of significant local, regional or national cultural heritage.

Biodiversity has major role in ecosystem function and stability by generating and maintaining soils (pedogenesis), converting solar energy into chemical energy (photosynthesis), sustaining biogeochemical cycles, cycling important nutrients like nitrogen through nitrogen fixation, detoxifying pollutants and decomposing wastes.

Ecosystem stability is considered to be associated with proper functions cited above. The rich biodiversity thus may be instrumental in ecosystem stability and functions as cycling and recycling of nutrients can be better maintained in an ecosystem with high species and genetic diversity.

17.9 Summary

Biodiversity can be defined as the totality of genes, species and ecosystems of a given region. Biodiversity can be studied at Genetic diversity, Species diversity, Ecological/Ecosystem diversity. India has about 45,000 plant species (including bacteria and fungi) and about 91,000 species of animals which share 8.1% of global species diversity. India has 12 bio-geographical areas which make it one of the twelve mega-biodiversity countries of the world. The varied edaphic, climatic and topographic conditions have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, coastal and marine ecosystems, and deserts. The mountainous region covers an area close to 100 mha, arid and semi-arid zones are spread over 30 mha and the coastline is about 8000 km long.Biodiversity is the most valuable gift of nature to man.The direct value include food resources like grains, vegetables, fruits, meat, fish, egg, milk and milk products etc. which we extract from plant and animal resources directly. These also include medicine, fiber, fuel, wool, wax, timber, resin, rubber, silk and decorative items. Environmental regulatory value, social and cultural values, ethical values, aesthetic values, and option values are considered as Indirect Value. There are many threats which cause biodiversity loss.The various factors which are responsible for all types of biodiversity loss including genetic diversity, species diversity and ecosystem diversity are habitat loss and fragmentation, disturbance and degradation, pollution, over-exploitation, introduction of exotic species, intensive agriculture and forestry and shifting cultivation.The key criteria for determining a hotspot are endemism (the presence of species found nowhere else on earth) and degree of threat.Out of the 34 global biodiversity hotspots, four are present in India. Biodiversity has major role in ecosystem function and stability.

17.10 Glossary

- **Adaptation :** Process of adjustment of an organism in particular habitat
- **Afforestation :** Planting of large areas with trees
- **Alien species :** A species that does not normally occur in an area but which has been introduced by human activity
- **Altitude :** heights above sea level
- **Biodegradation :** Oxidative breakdown of organic matters by microbial activity
- **Biodiversity :** Variety and variation among living organism
- **Biome :** A major ecological community of organisms maintained under a particular climatic zone with a specific vegetation type
- **Biota :** The flora and fauna of an area
- **Biotic community :** plants and animals naturally occurring in the same environment and are mutually sustaining and interdependent
- **Biozone-**The temporal and stratigraphic range of a kind of organism (as of a species) as reflected by its occurrence in fossiliferous rocks
- **Cities :** Convention on the International Trade in Endangered species
- **Climate :** Long-term weather conditions and factors of an environmental area due to its geographical conditions
- **Coral reefs:** Diverse underwater ecosystems held together by calcium carbonate structures secreted by corals. Coral reefs are built by colonies of tiny animals found in marine waters that contain few nutrients
- **Cultivation :** Preparation of land to grow crops
- **Ecology :** The study of living organism in relation to their environment
- **Ecosystem :** A unit consisting of biotic and abiotic components interacting to produce a stable system
- **Endangered :** Organism/species danger of extinction

- **Endemic :** Only occurring in a particular area
- **Environment :** Physical, chemical, biotic and cultural factor that affect organism
- **Eutrophication :** The process in which an ecosystem becomes nutrient enriched
- **Fauna :** All the animal species that occur in a particular region
- **Fertilizers :** Animal manure or synthesized chemical that is added to soil to increase its productivity for crops
- **Focal species :** A species that is the focus of conservation efforts
- **Globally threatened :** A category of threat that indicates that a taxon is threatened on a world scale
- **Habitat :** The place where a species lives in nature
- **Hot spot :** A rich biodiversity area with high degree of endemism (the presence of species found nowhere else on earth) threat
- **Hybrid :** An organism that is produced from a cross between parents from two distinct species
- **Invasive :** Colonising an area from outside
- **Latitude :** Distance from the equator
- **Native species :** Species that occur naturally in an area
- **Natural resources :** A component of the environment that is of value in serving human needs
- **Pedogenesis :** Process of soil development
- **Pollutant :** Any substance that pollutes the environment
- **Population :** A group of organisms of the same species live in same area
- **Ramsar site :** Wetland of international importance designated under the Ramsar convention 1971
- **Rare :** Taxa with small populations that are not at present Endangered or Vulnerable but are at risk
- **Red data book :** A book listing threatened and endangered species published by IUCN

- **Sacred grooves :** Relic forest patches, traditionally protected by communities in reverence of a deity
- **Seed bank :** An artificial store in which seeds are kept usually as a means to ensure that the particular species may be conserved
- **Species :** Closely related, physically similar being that can interbred to produce fertile offspring
- **Sustainability :** Meet the needs of the present without compromising the ability of future generation to meet their own needs
- **Topography :** The surface feature of the earth
- **Vulnerable :** Taxa believed likely to move into endangered category in the near future if the causal factors continue operating
- **Wetland :** An area that is saturated by surface water having life adapted under those conditions

17.11 Self -Learning Exercises

Section-A (Very Short Answer Type Questions)

Fill in the blanks-

1. The word 'biodiversity' was given by ……………
2. India has ……… biogeographic regions.
3. The word 'hotspots' was given by ………………..
4. ……….. and ………. are the two Indian mountain biodiversity global hotspots.

Section-B (Short Answer Type Questions)

1. Define 'biodiversity'.
2. What is species diversity?
3. What is biodiversity hotspot?
4. Write a short note on 'hot spots in India'.

Section-C (Long Answer Type Questions)

1. Describe values and threats of biodiversity.
2. India has a rich biodiversity status. Explain?

Answer of section A

1. W.G. Rosen
2. 10
3. Norman Myers
4. Eastern Himalayas, Western Ghats

17.12 References

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Unit - 18

Conservation Biology

Structure of the Unit:

18.0 Objectives

The main objective of this unit is to explain following issues

- present scenario of environmental basis of plant species based on IUCN.
- principles of conservation
- General Account of Activities of major institutes like BSI, NBPGR, ICAR, CSIR and DBT.

18.1 Introduction

India is one of the twelve mega-biodiversity countries of the world. A large numbers of species are native to India. In recent years Indian biodiversity is facing serious threat as tropical forests are disappearing at an alarming rate of 0.6 % per year. It is very important to understand the basic principles which help in conservation of biodiversity. Biodiversity management is very complex subject which contain multiple stockholders so every aspect should be handle accordingly.

18.2 Principles of Biodiversity Conservation

These principles were adopted in CBD (convention on biological diversity).

The following 12 principles are complementary and interlinked.

Principle 1: The objectives of management of land, water and living resources are a matter of societal choices.

Different sectors of society view ecosystems in terms of their own economic, cultural and society needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2: Management should be decentralized to the lowest appropriate level.

Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

1. Reduce those market distortions that adversely affect biological diversity;
2. Align incentives to promote biodiversity conservation and sustainable use;

3. Internalize costs and benefits in the given ecosystem to the extent feasible.

The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems.

Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: Ecosystem must be managed within the limits of their functioning.

In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable of artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.

Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9: Management must recognize the change is inevitable.

Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential "surprises" in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change.

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Biological diversity is critical both for its intrinsic value and because of the key role, it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use are desirable. All relevant information from any concerned area should be shared with all stakeholders and actors. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

18.4 Extinction

Extinction of species is one of the most serious problems we are facing today. It is the worst aspect of biodiversity loss. The nature of this problem is quite different from other global issue as it is completely irreversible. Recent years, we have witnessed marked decline among each group of flora and fauna population which also include some species extinction. A species or taxon is considered to be extinct when there is no reasonable doubt that the last individual has died.We have already discussed about the value of biodiversity. It is ethically, aesthetically and economically important to minimize the rate of loss of species extinction.

18.5 Environmental Status of Plants based on International Union for Conservation of Nature (IUCN)

The IUCN Red List is the world's most comprehensive information source on the global conservation status of animal and plant species and their links to livelihoods. 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.

For each assessed species, The IUCN Red List provides information on population size and trends; geographic range and habitat needs. To date more than 76,000 species have been assessed with more than 22,000 at risk of extinction. Comprehensive assessments have been completed for many species groups including mammals, amphibians, birds, reef-building corals and conifers.

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), and throughout its historic range have failed to record an individual. Surveys time frame depends on taxon’s life cycles 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), and 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.

The following three categories, Critically Endangered, Endangered and Vulnerable, are assigned to taxa on the basis of quantitative criteria that are designed to reflect varying degrees of threat of extinction; taxa in any of these three categories are collectively referred to as ‘threatened’.There are five quantitative criteria which are used to determine whether a taxon is threatened or not, and if threatened, which category of threat it belongs in (Critically Endangered, Endangered or Vulnerable). The five criteria are as following:

A. Declining population (past, present and/or projected)

B. Geographic range size, and fragmentation, decline or fluctuations

C. Small population size and fragmentation, decline, or fluctuations

D. Very small population or very restricted distribution

E. Quantitative analysis of extinction risk (e.g., Population Viability Analysis)

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, 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, 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, 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 if ongoing conservation actions abate or cease.

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.It is important to emphasize that "least concern" simply means that, in terms of extinction risk, these species are of lesser concern than species in other threat categories. It does not imply that these species are of no conservation concern.

The remaining two categories do not reflect the threat status of taxa.

Data Deficient (DD)

A taxon is Data Deficient when there is in-adequate 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 are 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, if a considerable period of time 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 is has not yet been evaluated against the criteria.

18.6 General Account of Activities of BSI, NBPGR, ICAR, CSIR, DBT

Botanical Survey of India (BSI)

Botanical Survey of India (BSI) is the apex research organization under the Ministry of Environment, Forests & Climate Change, Govt. of India for carrying out taxonomic and floristic studies on wild plant resources of the country through Survey, Documentation and Conservation.

The Botanical Survey of India (BSI) was established in 1890 with the objectives of exploring the plant resources of the country and identifying plant species with economic virtue.

InBritish India, objectives behind establishment of BSI were exploring diverse geographical conditions, vegetable resources, forest wealth and medicinal plants. Botanical collections were also done and send to Linnaeus, Sir Joseph Banks, Hooker and other scientists of that era.

In 1954, the Government reorganized the BSI with the objectives of-

(1) Undertaking intensive floristic surveys and collecting accurate and detailed information on the occurrence, distribution, ecology and economic utility of plants in the country

(2) Collecting, identifying and distributing materials that may be of use to educational and research institutions

(3) Acting as the custodian of authentic collections in well planned herbaria and documenting plant resources in the form of local, district, state and national flora

During the successive plan periods, the functional base of Botanical Survey of India was further expanded to include various new areas such as inventorisation of endemic, rare and threatened plant species; evolving conservation strategies; studies on fragile ecosystems and protected areas, like sanctuaries, national parks and biosphere reserves; multiplication and maintenance of endemic and threatened plant species, wild ornamentals etc., in Botanic Gardens and Orchidaria; documentation of traditional knowledge of plants and development of National Database on Herbarium (including type specimens) and live collections, plant distribution and nomenclature, botanical paintings/ illustrations, plant uses, etc.

Over the years, the functional role of the Survey was further expanded. After the ratification of the Convention on Biological Diversity (CBD: 1994), Enactment of Biological Diversity Act (2002) and Biological Diversity Rules (2004), BSI has become an important institution as its mandate has direct relevance to Articles 6 (Conservation), 7 (Identification & Monitoring), 9 (Ex situ conservation), 12 (Research & Training), 13 (Public education & Awareness), 17 (Exchange of Information) and 18 (Technical & Scientific Cooperation) of CBD.

Functions of BSI

1. ***ex-situ* Conservation**

   Botanical Survey of India is actively engaged in the *ex-situ* conservation through its chain of Botanical gardens established in different regional circles. They are actively engaged in collection, introduction, multiplication and maintenance of germplasm of orchids, bamboos, palms, medicinal plants, legumes, ferns, wild edible plants, insectivorous plants, gymnosperms and other economically important plant species. Mass multiplication of some of the rare and highly valued ornamental orchids through tissue culture has also been taken up successfully by Botanical Survey of India.

2. **Floristic and Taxonomic studies**

   The taxonomic studies so far conducted by the Survey for the preparation of National/State/District Floras, fragile ecosystems and revisionary studies on families/genera/tribes have resulted in the discovery of about 1500 taxa new to India and about 700 taxa new to science. While the taxonomic account of more than 100 families (out of about 300 currently known to occur in India) for the flora of India has been completed, the account of over 86 families have been published in Flora of India Vols. 1 – 5, 12 & 13, whereas about 3 families constituting Flora of India vols. 6 – 7 and are under process of publication. The Survey has also published a large number of state and District Floras. As regards the non-flowering plants particularly the Cryptogams, Botanical Survey has made significant contributions towards the study of Bryophytes, Pteridophytes, fungi, Red Algae and Lichen Flora of Eastern Himalayas.

3. **Exploration of Plant Resources**

   BSI is exploring country's plant resources as a result of intensive and extensive surveys conducted by its units. In addition to routine surveys Botanical Survey of India has also participated in more than 20 multidepartmental/ multi disciplinary expeditions

4. **Inventorisation (Listing) of Endangered Plant Species**

   Based on the survey and exploration as well as herbarium and literature studies, about 1500 species of flowering plants and few hundreds of Pteridophytes, Bryophytes, Lichens and Fungi have been identified as threatened. After careful and critical evaluation of their status and threat perceptions, the Survey has compiled Data Sheets on 1182 species, 708 of which have already been published as Red Data Book of Indian Plants: volume 1 – 3 (vol. 4 & 5 are in press). Recently, under a Ministry of Environment & Forests sponsored research project, revalidation of rare taxa listed in Red Data Book (1 – 5) has been taken up by Botanical Survey of India in order to revise their status as per the latest IUCN - 2001 categories.

5. **Floristic studies of Fragile Ecosystems**

   Floristic studies of more than 25 fragile ecosystems, like Cold Deserts of Trans-Himalayas, Mothronwala freshwater swamps, Rann of Kutch, Agumbe, Nallamalais, Chilika Lake, Mahanadi delta, Mangrove ecosystems, Coastal ecosystems, etc. have also been completed and many others are under investigation.

6. **Floristic studies of protected areas**

   The Survey has completed floristic studies on five Biosphere Reserves namely – Great Nicobar, Nilgiri, Gulf of Mannar, Manas and Nanda Devi and 31 National Parks. Out of this taxonomic accounts of 4 Biosphere Reserves and five National Parks have been published. Whereas, studies on remaining Biosphere Reserves is in progress. Besides, accounts of the floristic diversity in 23 Tiger Reserves and some selected Wildlife Sanctuaries have also been brought out by the Survey. Botanical Survey has taken up the detailed study of the various aspects of the floristic diversity in the remaining Biosphere Reserves and National Parks of the country by the help of MoEF.

7. Ethnobotanical Studies

India has about 563 tribal communities having age-old traditional knowledge through their long association with the forests. They have accumulated valuable knowledge on the use of wild plants in their daily life for food, fuel, fodder, clothing, health-care and other purposes. Botanical Survey of India initiated recording and documenting this ethnobotanical data of all tribes belonging to the states of Bihar, Goa, Karnataka, Orissa, Rajasthan, Himachal Pradesh, Chattisgarh, Uttaranchal, Andaman & Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Jammu & Kashmir, Madhya Pradesh, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal for critical studies leading to sustainable utilisation of bio-resources, documentations of traditional knowledge system.

8. **Environmental Impact Assessment**

Ever since the Environmental Impact assessment in relation to major developmental projects was made mandatory by the Govt. of India; Botanical Survey of India has carried out such studies on the flora of more than 100 such major project sites.

9. **Geo-botanical Studies**

The Survey has also successfully carried out and completed the Geobotanical and Bio-geochemical studies in Singhbhum Copper belt, Bihar and Khetri Copper belt in Rajasthan in collaboration with Geological Survey of India.

10. National Database

Database on Indian flora, herbarium holdings and taxonomic bibliography is being done at the Computer Units of Northern Circle, Dehra Dun and Southern Circle, Coimbatore.

- Computerisation of Type specimens deposited in BSI herbaria is in progress
- Computerisation of data on live plant collections in the gardens of various regional circles of BSI is in progress.
- Computerisation of a National Database on Rare, Threatened and Endangered plants of Indian flora, ENVIS centre, Kolkata.

11. Services

1-Library

2-Identificaton and fieldwork

3- E.I.A. studies

4- Training- (1) Herbarium methodology

(2)Advance training in gardening and plant cultivation

National Bureau of Plant Genetic Resources (NBPGR)

The National Bureau of Plant Genetic Resources (NBPGR) has its headquarter at New Delhi. The Bureau draws guidelines from the Crop Science Division of ICAR, Institute Management Committee, Research Advisory Committee, Institute Research Council and Germplasm Advisory Committees.

Establishment of NBPGR

The establishment of NBPGR is consider to be held in August 1976 as the 'Division of Plant Introduction' was upgraded to an independent institute 'National Bureau of Plant Introduction' which was renamed as 'National Bureau of Plant Genetic Resources' (NBPGR) in January 1977.

Mandate

To act as nodal institute at national level for acquisition and management of indigenous and exotic plant genetic resources for food and agriculture, and to carry out related research and human resource development, for sustainable growth of agriculture.

Objectives of NBPGR

- To plan, organize, conduct and coordinate exploration and collection of indigenous and exotic plant genetic resources.
- To undertake introduction, exchange and quarantine of plant genetic resources.
- To characterize, evaluate, document and conserve crop genetic resources and promote their use, in collaboration with other national organizations.
- To develop information network on plant genetic resources.
- To conduct research, undertake teaching and training, develop guidelines and create public awareness on plant genetic resources.

Divisions, Units and Cells of NBPGR

1. **Division of Plant Exploration and Germplasm Collection**

Mandate-

- To plan, co-ordinate and conduct explorations in collaborative mode for the collection of germplasm in different agri-horticultural crops, their wild relatives and other economic plants from different phyto-geographical/ agro-ecological regions of diversity within and outside the country.

2. **Division of Germplasm Evaluation**

Mandate

- Characterization and evaluation of germplasm of agri-horticultural crops.
- Identification of trait specific germplasm for utilization in crop improvement.
- Regeneration, multiplication and maintenance of germplasm of various crops.
- Promoting enhanced use of genetic resources through organization of germplasm field days and supply.

3. **Division of Germplasm Conservation**

Mandate

- The Division of Germplasm Conservation is entrusted with the responsibility of conservation of Plant Genetic Resources for the posterity and sustainable use

4. **Division of Genomic Resources**

Mandate

- To develop genomic and bioinformatics tools, technologies and approaches for enhanced utilization of genomic resources and to discover and validate the function of important genes from the genetic resources of agri-horticultural crop.

5. **Division of Plant Quarantine**

Mandate

- Quarantine Processing of Plants/ Planting Material under Trans-boundary Exchange
- Pest-free Conservation of indigenously collected Germplasm
- Supportive Research to Develop Techniques for Detection and Salvaging of Germplasm
- Policy Issues on Related Bio-security Issues
- Human Resource Development

6. Germplasm Exchange Unit

Mandate

- To undertake introduction and exchange of Plant Genetic Resources for research purposes

7. Tissue Culture and Cryopreservation Unit

Mandate

- Conservation of economically important plants and their wild relatives using **in vitro** conservation and cryo-preservation techniques

8. Agriculture Knowledge Management Unit(AKMU)

Mandate

- The use of information and communication technology for plant genetic resources information management including software, methodologies and standards related to the management, analysis, and exchange of plant genetic resources data.

The objectives are to

- Develop and manage PGR databases and PGR web portal
- Develop and administer NBPGR website and NBPGR e-mail
- Develop and implement software solutions and standards necessary for PGR informatics and analytics

9. Institute Technology Management Unit (ITMU)

ITMU is short form of **Intellectual Property Management and Technology Transfer Unit,** i.e. IPM&TTU. ITMU is responsible for IP protection/ management and technology transfer/commercialization with internal capabilities as well as external legal and business experts wherever required. ITMU acts as the Secretariat for the Institute Technology Management

Committee (ITMC). This committee is designated at the institute level for IP management, technology transfer, and technology commercialization. ITMC is the final decision making body for IP related matters/progress/concerns.

10. All India Co-ordinated Research Network on Underutilized Crops-

Mandate

- To find out new plant resources for food, fodder, fuel, energy and industrial uses.
- To identify/develop superior genotypes for different agro-climatic regions.
- To standardize the package of practices for cultivation of these crops

Regional Stations

1. **Shimla**(Himachal Pradesh): Established in 1960 at Phagli, Shimla.

   The mandate of the station is the collection, evaluation, characterization and maintenance of temperate crops

2. **Jodhpur** (Rajasthan): Established in 1965, in the CAZRI Campus.

   Undertakes exploration, evaluation and seed increase for agri-horticultural crops of arid, semi-arid zones

3. **Thrissur** (Kerala): Established in 1977.

   Responsible for collection and evaluation of germplasm of southern peninsular region with particular emphasis on spices and plantation crops

4. **Akola** (Maharashtra): Established in 1977.

   Responsible for exploring Maharashtra, Karnataka, Goa, Daman and Diu for germplasm collections. It also undertakes evaluation and maintenance of crops suited to Central India and Deccan Plateau

5. **Shillong** (Meghalaya): Established in 1978.

   Involved in collection and evaluation of agri-horticultural germplasm of north-eastern region including Sikkim and parts of northern Bengal

6. **Bhowali** (Uttarakhand): Established in 1985.

   Responsible for exploration, characterization, evaluation and multiplication of agri-horticultural crops, of sub-tropical and sub-temperate regions

7. **Cuttack** (Orissa): Established in 1985 in CRRI Campus.

The mandate is exploration of agri-horticultural crops of eastern peninsular region with main emphasis on rice germplasm

8. **Hyderabad** (Andhra Pradesh): Established in 1985.

   Engaged in speedy repatriation of pest and pathogen-free material as well as quarantine clearance of germplasm. Undertakes exploration, evaluation and seed increase for agri-horticultural crops of Andhra Pradesh and adjoining areas

9. **Ranchi** (Jharkhand): Established in 1988.

   A centre for evaluation and maintenance of germplasm of tropical fruits and other field crops of Bihar, eastern Uttar Pradesh and West Bengal

10. **Srinagar** (Jammu & Kashmir): Established in 1988.

    Responsible for exploration, collection and maintenance of agri-horticultural germplasm of temperate crops of Jammu and Kashmir region

Indian Council of Agricultural Research (ICAR)

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India. Formerly known as Imperial Council of Agricultural Research, it was established on 16 July 1929 as a registered society under the Societies Registration Act, 1860 in pursuance of the report of the Royal Commission on Agriculture. The ICAR has its headquarter at new Delhi.

The Council is the apex body for co-ordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. With 100 ICAR institutes and 70 agricultural universities spread across the country, this is one of the largest national agricultural systems in the world.

The ICAR has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development that has enabled the country to increase the production of foodgrains by 5 times, horticultural crops by 9.5 times, fish by 12.5 times, milk 7.8 times and eggs 39 times since 1951 to 2014, thus making a visible impact on the national food and nutritional security. It has played a major role in promoting excellence in higher education in agriculture. It is engaged in cutting edge areas of science and technology development and its scientists are internationally acknowledged in their fields.

Milestones

- Initiation of the first All-India Co-ordinated Research Project on Maize in 1957
- Status of Deemed University accorded to IARI in 1958
- Establishment of the first State Agricultural University on land grant pattern at Pantnagar in 1960
- Placement of different agricultural research institutes under the purview of ICAR in 1966
- Creation of Department of Agricultural Research and Education (DARE) in the Ministry of Agriculture in 1973
- Opening of first Krishi Vigyan Kendra (KVK) at Puducherry (Pondicherry) in 1974
- Establishment of Agricultural Research Service and Agricultural Scientists' Recruitment Board in 1975
- Launching of Lab-to-Land Programme and the National Agricultural Research Project (NARP) in 1979
- Initiation of Institution-Village Linkage Programme (IVLP) in 1995
- Establishment of National Gene Bank at New Delhi in 1996
- The ICAR was bestowed with the King Baudouin Award in 1989 for its valuable contribution in ushering in the Green Revolution. Again awarded King Baudouin Award in 2004 for research and development efforts made under partnership in Rice Wheat Consortium.
- Launching of National Agricultural Technology Project (NATP) in 1998 and National Agricultural Innovation Project (NAIP) in 2005

Mandate

- To plan, undertake, aid, promote and co-ordinate education, research and its application in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences

- To act as a clearing house of research and general information relating to agriculture, animal husbandry, home science and allied sciences, and fisheries through its publications and information system; and instituting and promoting transfer of technology programmes
- To provide, undertake and promote consultancy services in the fields of education, research, training and dissemination of information in agriculture, agroforestry, animal husbandry, fisheries, home science and allied sciences
- To look into the problems relating to broader areas of rural development concerning agriculture, including postharvest technology by developing co-operative programmes with other organizations such as the Indian Council of Social Science Research, Council of Scientific and Industrial Research, Bhabha Atomic Research Centre and the universities
- To do other things considered necessary to attain the objectives of the Society

Council of Scientific and Industrial Research (CSIR)

The Council of Scientific & Industrial Research (CSIR) is the premier industrial research and development (R&D) organization in India. It was founded on 26 September 1942, by a resolution of the then Central Legislative Assembly. It is funded mainly by the India Ministry of Science and Technology and it is one of the world's largest publicly funded (R&D) organisations, having linkages to academia, other R&D organisations and industry.

The Council of Scientific & Industrial Research (CSIR), known for its cutting edge R&D knowledgebase in diverse S&T areas, is a contemporary R&D organization. Having pan-India presence, CSIR has a dynamic network of national laboratories, Innovation Complexes and units. CSIR's R&D expertise and experience is embodied in about 4600 active scientists supported by about 8000 scientific and technical personnel.

Although CSIR is mainly funded by Science and Technology Ministry, it operates as an autonomous body registered under the Registration of Societies Act of 1860.

CSIR covers a wide spectrum of science and technology – from radio and space physics, oceanography, geophysics, chemicals, drugs, genomics, biotechnology and nanotechnology to mining, aeronautics, instrumentation, environmental engineering and information technology. It provides significant technological intervention in many areas with regard to societal efforts which include environment, health, drinking water, food, housing, energy, farm and non-farm sectors. Further, CSIR's role in S&T human resource development is noteworthy

CSIR Achievements

- Achieved the first breakthrough of flowering of Bamboo within weeks as against twenty years in nature.
- First to analyze genetic diversity of the indigenous tribes of Andaman and to establish their origin out of Africa 60,000 years ago.
- Developed the first transgenic Drosophila model for drug screening for Human Cancer.
- First to introduce DNA fingerprinting in India.
- Helped India to be the first Pioneer Investor under the UN law of Sea Treaty.
- Invented the first ever only once a week non-steroidal family planning pill in the world by the name of *Saheli*.
- Designed India's first ever parallel processing computer Flosolver.
- Partnered more than 50,000 companies with turnover ranging from Rs 5 lakhs to Rs 500,000 crores.
- Rejuvenated India's one hundred year old refinery at Digboi using the most modern molecular distillation technology.
- Provided the critical technology for the NMP Lube Extraction Plant of capacity of 2,50,000 tonnes per year.
- Development of a versatile portable PC-based software 'Bio-Suite' for bioinformatics.
- Design of 14 seater plane 'SARAS'.
- Established first ever in the world 'Traditional Knowledge Digital Library' accessible in 8 international languages.
- Remained in Top 3 in the list of PCT patent applications amongst all developing countries.
- Topped list of USA patents holders.

- Successfully challenged the grant of patent in the USA for use of haldi (turmeric) for wound healing and neem as insecticide.

Research Laboratories under CSIR

1. C-MMACS - CSIR Centre for Mathematical Modelling and Computer Simulation, Bangalore
2. CBRI - Central Building Research Institute, Roorkee
3. CCMB- Centre for Cellular and Molecular Biology, Hyderabad
4. CDRI - Central Drug Research Institute, Lucknow
5. CECRI- Central Electro Chemical Research Institute, Karaikudi
6. CEERI - Central Electronics Engineering Research Institute, Pilani
7. CFRI - Central Fuel Research Institute, Dhanbad
8. CFTRI - Central Food Technological Research Institute, Mysore
9. CGCRI - Central Glass and Ceramic research Institute, Calcutta
10. CIMAP - Central Institute of Medicinal and Aromatic Plants, Lucknow
11. CLRI - Central Leather Research Institute, Chennai
12. CMERI - Central Mechanical Engineering Research Institute, Durgapur
13. CMRI - Central Mining Research Institute, Dhanbad
14. CRRI - Central Road Research Institute, New Delhi
15. CSIO - Central Scientific Instruments Organisation, Chandigarh
16. CSMCRI - Central Salt and Marine Chemicals Research Institute, Bhavnagar
17. IGIB - Institute of Genomics and Integrative Biology, Delhi
18. IHBT - Institute of Himalayan Bioresource Technology, Palampur
19. IICB - Indian Institute of Chemical Biology, Calcutta
20. IICT - Indian Institute of Chemical Technology, Hyderabad
21. IIP - Indian Institute of Petroleum, Dehradun
22. IMT - Institute of Microbial Technology, Chandigarh
23. IITR - Indian Institute of Toxicology Research, Lucknow (Formerly known as Industrial Toxicology Research Centre)

24. NAL - National Aerospace Laboratories, Bangalore
25. NBRI - National Botanical Research Institute, Lucknow
26. NCL - National Chemical Laboratory, Pune
27. NEERI - National Environmental Engineering Research Institute, Nagpur
28. NGRI - National Geophysical Research Institute, Hyderabad
29. NIO - National Institute of Oceanography, Goa
30. NISCAIR - National Institute of Science Communication and Information Resources, New Delhi
31. NISTADS - National Institute of Science, Technology and Development Studies, New Delhi
32. NML - National Mettalurgical Laboratory, Jamshedpur
33. NPL - National Physical Laboratory, New Delhi
34. RRL, Bhopal - Regional Research Laboratory, Bhopal
35. RRL, Bhubaneshwar - Regional Research Laboratory, Bhubaneshwar
36. RRL, Jammu - Regional Research Laboratory, Jammu
37. NEIST (RRL), Jorhat - North East Institute of Science and Technology, Jorhat , Jorhat
38. National Institute for Interdisciplinary Science and Technology - Thiruvananthapuram
39. SERC, Structural Engineering Research Centre, Chennai

CSIR Units

1. CSIR-UNIT : Open Source Drug Discovery (OSDD), New Delhi
2. CSIR-UNIT : Traditional Knowledge Digital Library (TKDL), New Delhi
3. CSIR-UNIT : Translational Research and Innovative Science Through Ayurveda (TRISUTRA), New Delhi
4. CSIR-UNIT : Human Resource Development Centre (HRDC), Ghaziabad
5. CSIR-UNIT : Unit for Research and Development of Information Products (URDIP), Pune

Department of Biotechnology (DBT)

The setting up of a separate Department of Biotechnology (DBT), under the Ministry of Science and Technology in 1986 gave a new impetus to the development of the field of modern biology and biotechnology in India. In more than a decade of its existence, the department has promoted and accelerated the pace of development of biotechnology in the country.

Mandate

- Promote large scale use of Biotechnology
- Support R&D and manufacturing in Biology
- Responsibility for Autonomous Institutions
- Promote University and Industry Interaction
- Identify and Set up Centres of Excellence for R&D
- Integrated Programme for Human Resource Development
- Serve as Nodal Point for specific International Collaborations
- Establishment of Infrastructure Facilities to support R&D and production
- Evolve Bio Safety Guidelines, manufacture and application of cell based vaccines
- Serve as nodal point for the collection and dissemination of information relating to biotechnology.

Programme of DBT

1. **Basic Research:** Basic Research in Modern Biology-Recent times have seen a surge in research related to innovation, invention and product orientation. In fact, top experts have made it clear that innovation in biosciences can make it a bigger industry than information technology. But basic research must remain the cornerstone of the biotech edifice, for without basic research the country will always remain knowledge deficient. Hence, the Department of Biotechnology has developed a very strong bench for basic research in modern biology.
2. **Medical Biotechnology:** DBT's Medical Biotechnology is an umbrella programme which encompasses a whole range of areas targeted towards bringing about solutions to various medical problems that increase human

morbidity and mortality. The programmes aim to prevent human diseases, diagnose them early and also find solutions (therapeutic) that can manage the medical problem.

3. **Agriculture Biotechnology:** Along with pursuing basic research, genome sequencing and genomic studies for identification of useful genes, QTLs & validation of their function; developing transgenic crops and crop improvement through marker aided selection for tackling various abiotic & biotic stresses and quality traits are high priority in the agriculture biotechnology programme of the department.
4. **Food and Nutrition:** The major areas covered under this programme are
    - Food Processing using biotech interventions
    - Nutrition Biology
    - Addressal of micro and macro nutrient deficiencies through development of fortified foods with generation of clinical evidence
    - Health care products/ Nutraceuticals/ Dietary food supplements
    - Probiotics for holistic health
    - Addressal of Celiac diseases
    - Addressal of Vitamin B12 deficiency
    - Nutriepigenomics
    - Postharvest processing and value addition
    - Food safety and allerginicity
    - Shelf life extension of perishable foods etc.

5. Bioresources, Environment and Bioenergy

- Silk and medicinal plants- DBT is involved in administering a plethora of scientific research to utilize bioresources. Some of the biological resources that DBT focuses on are medicinal and aromatic plants and silkworms.
- Bioenergy- DBT is focussed on second generation biofuels.

- Environment- DBT has been attending to environmental challenges with the main focus on, development of mitigation technologies for climate change, development of microbial technologies for environmental improvement, development of treatment process of industrial effluent, bioremediation of xenobiotic compounds, biodiversity conservation, and characterisation of biodiversity.
- Bio-systems and Bioprocess Engineering - Department of Biotechnology has constituted a new Task Force on Biosystems and Bioprocess Engineering with an aim to find innovative and efficient solutions for the development and improvement of sustainable bioprocesses of commercial interest, taking into account the environmental requirements and constraints involved in large scale production processes.
- The National Bioresource Development Board (NBDB)-The National Bioresource Development Board (NBDB) was set up under the aegis of DBT in 1999 with a mission to evolve a broad policy framework for research and development for sustainable utilization of bioresources and an effective plan of action for economic prosperity of the nation through accelerated R&D using modern tools of bio-sciences.

6. **Animal Biotechnology**
7. **Aqua-culture and Marine Biotechnology**
8. **Bioinformatics**
9. **International Collaborations**

   There is an increasing need for scientific capacity building to match the increasing global challenges. International collaborations are an important vehicle for accelerating the pace of growth in research and development. DBT over the decade has strategically developed strong international collaboration with numerous countries and non-governmental organisations.

10. **Human Resource Development**

    The DBT has helped nourishing many talents who have been appreciated globally as some of the most brilliant minds. DBT is implementing an

Integrated Human Resource Development Programme in multidisciplinary areas of biotechnology, comprising-

- Post graduate teaching programme
- Star college Scheme for strengthening of UG science
- Fellowships for Doctoral & Post-Doctoral research science and Biotech
- Short-term training courses for upgrading the skills of mid-career scientists and UG and PG Teachers
- Short Term Training Programme for mid-career scientists and UG & PG teachers

18.3 Summary

We are living in an era of unprecedented mass extinction of biological diversity. If we want to cease this extinction rate we must focus on biodiversity management. CBD has given some biodiversity conservation principles which should be followed for proper management. India is one of the mega-bio-diversity centres. It is our moral duty to keep this away from threats. Numbers of government organizations are working on different aspects of bio-diversity conservation.

18.4 Glossary

- **Adaptation :** Process of adjustment of an organism in particular habitat
- **Afforestation :** Planting of large areas with trees
- **Alien species :** A species that does not normally occur in an area but which has been introduced by human activity
- **Biodegradation :** Oxidative breakdown of organic matters by microbial activity
- **Biodiversity :** Variety and variation among living organism
- **Biome :** A major ecological community of organisms maintained under a particular climatic zone with a specific vegetation type
- **Biota :** The flora and fauna of an area
- **Biotic community :** plants and animals naturally occurring in the same environment and are mutually sustaining and interdependent

- **BSI :** Botanical survey of India
- **CBD :** Convention on biological diversity
- **Cities :** Convention on the International Trade in Endangered species
- **Climate :** Long-term weather conditions and factors of an environmental area due to its geographical conditions
- **CSIR :** Council of Scientific and Industrial Research
- Cultivation **:** Preparation of land to grow crops
- **DBT :** Department of biotechnology
- **Ecology :** The study of living organism in relation to their environment
- **Ecosystem- :** A unit consisting of biotic and abiotic components interacting to produce a stable system
- **Endangered :** Organism/species danger of extinction
- **Endemic :** Only occurring in a particular area
- **Environment :** Physical, chemical, biotic and cultural factor that affect organism
- **Fauna :** All the animal species that occur in a particular region
- **Focal species :** A species that is the focus of conservation efforts
- **Globally threatened :** A category of threat that indicates that a taxon is threatened on a world scale
- **Habitat :** The place where a species lives in nature
- **Hot spot :** A rich biodiversity area with high degree of endemism (the presence of species found nowhere else on earth) threat
- **Hybrid :** An organism that is produced from a cross between parents from two distinct species
- **ICAR :** Indian council of agricultural research
- **Invasive :** Colonising an area from outside
- **IUCN :** International Union for Conservation of Nature
- **Natural resources :** A component of the environment that is of value in serving human need

- **NBPGR :** National Bureau of Plant Genetic Resources
- **Population :** A group of organisms of the same species live in same area
- **Ramsar site :** Wetland of international importance designated under the Ramsar convention 1971
- **Rare :** Taxa with small populations that are not at present Endangered or Vulnerable but are at risk
- **Red data book :** A book listing threatened and endangered species published by IUCN
- **Sacred grooves :** Relic forest patches, traditionally protected by communities in reverence of a deity
- **Seed bank :** An artificial store in which seeds are kept usually as a means to ensure that the particular species may be conserved
- **Species :** Closely related, physically similar being that can interbred to produce fertile offspring
- **Sustainability :** Meet the needs of the present without compromising the ability of future generation to meet their own needs
- **Vulnerable :** Taxa believed likely to move into endangered category in the near future if the causal factors continue operating

18.5 Self-Learning Exercises

Section-A: (Very Short Answer Type Questions)

Fill in the blanks-

1. IUCN stands for……..
2. CEERI - Central Electronics Engineering Research Institute is situated in………

Section-B : (Short Answer Type Questions)

1. Describe role of NBPGR briefly.
2. Write a short note on Principles of biodiversity conservation.

Section-C : (Long Answer Type Questions)

1. Write a note on Environmental status of plants based on International Union for Conservation of Nature (IUCN).

2. Describe role and functions of BSI.

Answer of section A

1. International Union for Conservation of Nature
2. Pilani, Rajasthan

18.6 References

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Unit–19

Strategies for Conservation-I: *in-situ* Conservation

Structure of the Unit

19.0 Objectives

The main objective of this unit is to give you a brief account of present scenario of *in-situ* conservation of biological diversity. The major objectives of present study are:

- To understand the various components of *in-situ* conservation of biological diversity;
- To study the mechanism of *in-situ* conservation and different Protected Area Network (PA) in India;
- To understand the significance of *in-situ* conservation.

19.1 Introduction

There is a general perception and recommendation that biodiversity should be conserved inside their natural habitat. Species are conserved and maintained in their natural state in stable environment. e*x-situ* collections may be ineffective at preserving genetic diversity and the evolutionary potential of populations for adaptive or neutral evolution. ex-situ conservation generally lead to develop some variety of non adaptive genotypes that will depress population fitness. *In-situ* conservation can be done by develop protected areas such as national park, Wildlife Sanctuaries, Conservation Reserves and Community Reserves are backbone of biodiversity conservation, while also contributing to people's livelihoods, particularly at the local level.

19.2 Concept of *in-situ* Conservation

According to the Convention on Biological Diversity (CBD) in-situ conservation is defined as "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties".

in-situ conservation aims to enable biodiversity to maintain itself within the context of the ecosystem in which it is found.

in-situ management approaches can either be species-centred (targeted at populations of selected species) or ecosystem-based (whole ecosystems).

Advantages of *in-situ* conservation

1. It helps in protecting the biological diversity of the area. In order to ensure the survival of the species we protect the entire natural habitat or the ecosystem.
2. Endangered species are protected against extinction.
3. It helps in restoring degraded areas by supply biotic and abiotic component. In fact, the method involves promotion of natural system to take care of its own self - we simply provide conditions to let flourish themselves.
4. It maintains the quality of life of forest dwellers and tribals.
5. It maintains genetic diversity and provides material for genetic improvement of crops. In a natural system organisms not only live and multiply but evolve as well. A natural ecosystem allows free play of natural agencies - like drought, storms, snow, fluctuation in temperatures, excessive rains, fires, pathogens etc.

- which provide an opportunity to the organisms to adjust to the prevailing conditions of the environment and evolve into a better adopted life form. In **ex situ** conservation we isolate species which cause evolution process frozen.

6. It also helps in pollution control.
7. ***in-situ*** conservation is a cheap and convenient way of conserving biological diversity as we play a supportive role only. This reduces the cost of conservation efforts enormously.
8. A large number of organisms are protected and maintained in the process. The biological wealth of our planet is very imperfectly known to us. By sorting out and protecting a few species in artificial habitats, we shall almost certainly leave a large number of life forms which are also as important to us as are those organisms which we are currently trying to preserve and protect. Thus, in-situ conservation offers way to protect to a large number of organisms simultaneously known or unknown to science, Bigger breeding populations can be kept ***in -situ.***

Disadvantages

1. ***in-situ*** it is difficult to control illegal exploitation (e.g. poaching)
2. ***in-situ*** the environment may need restoring and alien species are difficult to control.
3. An important disadvantage of in-situ conservation is that it requires large areas of earth's surface if we have to preserve the full complement of biotic diversity of a region. This involves minimizing or excluding human activity and interference from that locality which is often difficult in the face of growing demand for space.

19.3 Protected Area

A protected area is a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values**.** (IUCN Definition 2008)

19.3.1 IUCN Protected Areas Categories System

IUCN protected area management categories classify protected areas according to their management objectives. The categories are recognised by international bodies such as the United Nations and by many national governments as the global standard for defining and recording protected areas and as such are increasingly being incorporated into government legislation.

(I- a) Strict Nature Reserve

This category strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphic features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring

(I- b) Wilderness Area

Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

(II) National Park

Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.

(III) Natural Monument or Feature

Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

(IV) Habitat/Species Management Area

Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.

(V) Protected Landscape/ Seascape

A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

(VI) Protected area with sustainable use of natural resources

Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

19.3.2 Protected Area Network (PA network) in India

India has a very long tradition of setting aside areas for conservation of wild flora and fauna. After independence, several Protected Areas (PAs) were designated in the form of National Parks and Wildlife Sanctuaries, but the approach was largely ad hoc. In 1983, the Government of India (GOI) decided that rational planning and implementation of a comprehensive network of PAs would be the keystone of the National Wildlife Action Plan and entrusted the Wildlife Institute of India (WII) to formulate plans for such a network (Rodgers et. al., 2002). The WII prepared a biogeographic classification of India designed to facilitate conservation planning with a review of existing protected areas and recommendation of new PAs to ensure an adequate network covering the range of biological diversity in the country. There are 4 categories of the Protected Areas as, National Parks, Sanctuaries, Conservation Reserves and Community Reserves. This network has grown steadily, and as of 2014 there are 690 PAs (102 National Parks, 527 Wildlife Sanctuaries, 57 Conservation Reserves and 4 Community Reserves) covering 166,851 km^2 or 5.07% of the country's geographical area (Source: WII, 2014).

National Park

National Park is an area having adequate ecological, faunal, floral, geomorphological, natural or zoological significance. TheNational Park is declared for the purpose of protecting, propagating or developing wildlife or its environment, like that of a Sanctuary. The difference between a Sanctuary and a National Park mainly lies in the vesting of rights of people living inside. Unlike a Sanctuary, where certain rights can be allowed, in a National Park, no rights are allowed. No grazing of any livestock shall also be permitted inside a National Park while in a Sanctuary; the Chief Wildlife Warden may regulate, control or prohibit it. In addition, while any removal or exploitation of wildlife or forest produce from a Sanctuary requires the recommendation of the State Board for Wildlife, removal etc., from a National Park requires recommendation of the National Board for Wildlife.India's first national park was established in 1936 as Hailey National Park, now known as Jim Corbett National Park, Uttarakhand.

Sanctuary

Sanctuary is an area has adequate ecological, faunal, floral, geomorphological, natural or zoological significance. The Sanctuary is declared for thepurpose of protecting, propagating or developing wildlife or its environment. Certain rights of people living inside the Sanctuary could be permitted. Further, during the settlement of claims, before finally notifying the Sanctuary, the Collector may, inconsultation with the Chief Wildlife Warden, allow the continuation of any right of any person in or over any land within the limits of the Sanctuary.

Conservation Reserves

Conservation Reservescan be declared by the State Governments in any area owned by the Government, particularly the areas adjacent to National Parks and Sanctuaries and those areas which link one Protected Area with another. Such declaration should be made after having consultations with the local communities. Conservation Reserves are declared for the purpose of protecting landscapes, seascapes, flora and fauna and their habitat. The rights of people living inside a Conservation Reserve are notaffected.

Community Reserves

Community Reservescan be declared by the State Government in any private or community land, not comprised within a National Park, Sanctuary or a Conservation Reserve, where an individual or a community has volunteered to conserve wildlife and its habitat. Community Reserves are declared for the purpose of protecting fauna, flora and traditional or cultural conservation values and practices. As in the case of a Conservation Reserve, the rights of people living inside a Community Reserve are not affected.

19.3.3 Marine Protected Area network in India

India has a vast coastline of 7517 km, of which 5423 km is in peninsular India and 2094 km in the Andaman, Nicobar and Lakshadweep Islands, with an exclusive economic zone of 2.02 million km^2. This coastline also supports a huge human population, which is dependent on the rich coastal and marine resources. It is estimated that nearly 250 million people live within a swath 50 km wide along the coastline of India. Therefore, the ecological services of the marine and coastal ecosystems of India play a vital role in India's economic growth and in ensuring human well-being. The MPA network in India has been used as a tool to manage natural marine resources for biodiversity conservation and for the well-being of people dependent on these resources. India has designated four legal categories of PAs, National Parks, Wildlife Sanctuaries, Conservation Reserves and Community Reserves. Scientific monitoring and traditional observations confirm that depleted natural marine resources are getting restored and/or pristine ecological conditions have been sustained in well managed MPAs. There are 23 MPAs present in peninsular India and more than 100 MPAs in the country's islands. Of the 23 MPAs in the peninsula, Gulf of Mannar Marine National Park, Sundarbans National Park, Gulf of **Kachchh** National Park, Gahirmatha Marine Sanctuary, Coringa Wildlife Sanctuary, Chilika Wildlife Sanctuary have unique marine biodiversity and provide a range of ecological services to the local communities. These 23 MPAs cover an area of about 6158 km^2, which is 3.85% of the total area covered under the entire PA network of India or less than 0.2% of the total land area of India. The total area of the Andaman and Nicobar Islands is 4947 km^2, of which 1510 km^2 is protected under the provisions of India's Wildlife (Protection) Act, 1972. There are 105 PAs in the Andaman and Nicobar Islands, of which about 100 include marine areas. These MPAs cover more than 30% of the terrestrial area of the islands and protect more than 40% of the coastal habitat. Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park are important MPAs here. In the Lakshadweep group of islands, Pitti Island (0.01 km^2) is the only island having the status of an MPA.

19.4 Biosphere Reserve

According to Man and the Biosphere (MAB) Programme of the United Nations Educational, Scientific and Cultural Organization (UNESCO); Biosphere reserves are areas of terrestrial, marine and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. They are internationally recognized, nominated by national governments and remain under sovereign jurisdiction of the states where they are located. Biosphere reserves serve in some ways as 'living laboratories' for testing out and demonstrating integrated management of land, water and biodiversity as well as 'Science for Sustainability support sites' – special places for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including conflict prevention and management of biodiversity.

Structure of Biosphere Reserve

Biosphere reserves have three inter-related zones that aim to fulfil three complementary and mutually reinforcing functions:

1. **Core area-**The core area(s) comprise a strictly protected ecosystem that contributes to the conservation of landscapes, ecosystems, species and genetic variation.
2. **Buffer area-**The buffer zone surrounds or adjoins the core areas, and is used for activities compatible with sound ecological practices that can reinforce scientific research, monitoring, training and education.
3. **Transition area-** The transition area is the part of the reserve where the greatest activity is allowed, fostering economic and human development that is socio-culturally and ecologically sustainable.

Functions of Biosphere Reserve

Conservation function- to contribute to the conservation of landscapes, ecosystems, species and genetic variation; species and genetic variation;

Development function– to foster economic and human developmentwhich is socio-culturally and ecologically sustainable;

Logistic function–to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

Biosphere Reserve in India

The MoEF, initiated the National Biosphere Reserve Programme in 1986 with the primary aim of conservation of an entire range of living resources and their ecological foundations, along with sustainable use of natural resources and improvement of the livelihoods of local inhabitants. This programme also had the objective of ensuring community participation for effective management of biodiversity resources and integration of traditional knowledge and scientific research for conservation, education and training as a part of the overall management of BRs. Considering the diversity of ecosystems and recognising the importance of BRs in ensuring long-term conservation and sustainable use of India's representative and diverse biological diversity, so far 18 BRs have been notified by the GoI.

Globally, There are 651 biosphere reserves in 120 countries, including 15 transboundary sites (Source-http://www.unesco.org/ new/ en/ natural-sciences/environment/ ecological sciences/biosphere-reserves/). These Reserves are required to meet a minimal set of criteria and adhere to a minimal set of conditions before being admitted to the World Network of Biosphere Reserves designated by the UNESCO. The world's major ecosystem types and landscapes are represented in this network, which is devoted to conserving biological diversity, promoting research and monitoring as well as seeking to provide models of sustainable development in the service of human kind with special reference to the local communities which mostly consist of traditional societies.

These Reserves are rich in biological and cultural diversity and encompass unique features of exceptionally pristine nature. The goal is to facilitate conservation of these representative landscapes and their immense biological diversity and cultural heritage, foster economic and human development which is culturally and ecologically sustainable and to provide support for research, monitoring, education and information exchange. The scheme is a pioneering effort at pursuing the increasingly difficult yet urgent task of conserving ecological diversity under mounting pressures. The programme was initiated in 1986 and till date, 18 sites have been designated as Biosphere Reserves (BRs) in different parts of the country (Table-19.1). The Ministry through the Centrally Sponsored Scheme of 'Biosphere Reserve' provides 100% financial assistance to the concerned State/UT Governments for conservation and management of the designated Biosphere Reserves. The Indian National Man and Biosphere (MAB) Committee constituted by the MoEFCC is the apex body to oversee the programme, provide policy guidelines and review the programme. Out of the 18 Biosphere Reserves designated nationally, so far nine Biosphere Reserves, viz., Nilgiri (Tamil Nadu, Kerala and Karnataka), Gulf of Mannar (Tamil Nadu), Sunderban (West Bengal), Nanda Devi, (Uttarakhand), Pachmarhi (Madhya Pradesh), Similipal (Orissa), Nokrek (Meghalaya), Achanakmar-Amarkantak (Chhattisgarh & Madhya Pradesh) and Great Nicobar have been included in the World Network of Biosphere Reserves of UNESCO.

Table. 19.1 List of Designated Biosphere Reserves (BRs)

S. No	Name of the BR & total geographical area (Km2)	Date of Designation	Location in the State (s)/Union Territory
1	**Nilgiri** (5520)	1.8.1986	Wynad, Nagarhole, Bandipur, Madumalai, Nilambur, Silent Valley and Siruvani hills in Tamil Nadu, Kerala and Karnataka.
2	**Nanda Devi** (5860.69)	18.1.1988	Part of Chamoli, Pithoragarh and Almora districts in Uttarakhand.
3	**Nokrek** (820)	1. 9.1988	Part of East, West and South Garo Hill districts in Meghalaya.
4	**Manas** (2837)	14.3.1989	Part of Kokrajhar, Bongaigaon, Barpeta, Nalbari, Kamprup and Darang districts in Assam.
5	**Sunderban** (9630)	29.3.1989	Part of delta of Ganges & Brahamaputra river system in West Bengal.
6	**Gulf of Mannar** (10500)	18.2.1989	India part of Gulf of Mannar extending from Rameswaram island in the North to Kanyakumari in the South of Tamil Nadu.
7	**Great Nicobar** (885)	6.1.1989	Southernmost island of Andaman and Nicobar Islands.
8	**Similipal** (4374)	21.6.1994	Part of Mayurbhanj district in Orissa.
9	Dibru-Saikhova (765)	28.7.1997	Part of Dibrugarh and Tinsukia districts in Assam.
10	Dehang-Dibang (5111.5)	2.9.1998	Part of Upper Siang, West Siang and Dibang Valley districts in Arunachal Pradesh.

11	**Pachmarhi** (4981.72)	3.3.1999	Part of Betul, Hoshangabad and Chhindwara districts in Madhya Pradesh.
12	Khangchendzonga (2931.12)	7.2.2000	Part of North and West districts in Sikkim.
13	Agasthyamalai (3500.36)	12.11.2001	Part of Thirunelveli and Kanyakumari districts in Tamil Nadu and Thiruvanthapuram, Kollam and Pathanmthitta districts in Kerala.
14	**Achanakmar-Amarkantak** (3,835. 51)	30.3.2005	Part of Anuppur and Dindori districts of Madhya Pradesh and Bilaspur district of Chattisgarh.
15	Kachchh (12,454)	29.1.2008	Part of Kachchh, Rajkot, Surendranagar and Patan districts in Gujarat.
16	Cold Desert (7,770)	28.8.2009	Pin Valley National Park and surroundings; Chandratal & Sarchu; and Kibber Wildlife sanctuary in Himachal Pradesh.
17	Seshachalam (4755.997)	20.9.2010	Seshachalam hill ranges in Eastern Ghats encompassing part of Chittoor and Kadapa districts in Andhra Pradesh.
18	Panna (2998.98)	25.8.2011	Part of Panna and Chhattarpur districts in Madhya Pradesh

Ministry of Environment, Forests and Climate Change

* Sites with bold letters have been included in the World Network of BRs of UNESCO.

19.5 Wetland

Under the text of the Ramsar convention (Article 1.1) wetlands are defined as:

"Areas of marsh, fen, peat-land or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m".

Wetlands are one of the most important resources throughout life history of human being. Wetlands have played a major role in development of human civilization as these are the source of water. These are transitional areas between aquatic and terrestrial ecosystems where the water table is at or near the surface, or the land is covered by shallow water. They are amongthe most productive ecosystems of the world, although they account only about 4 per cent of the earth's ice-free land surface (Prigent, 2001). But unfortunately, preservation of wetland ecosystem has received very little attention till recently. The ever increasing demand for economic growth during the last half century with utter disregard for the long term ecological consequences has led to over exploitation of wetlands.

Wetland status in India

India has rich diversity of wetlands, ranging from high altitude lakes of the Himalayas, floodplains and marshes of the Gangetic - Bramhaputra alluvial plains, saline flats of Green Indian Desert to extensive mangroves marshes bordering the country's East and West coastline. As per remote sensing imagery based assessment, India has total of 757,060 wetlands covering a total area of 15.26 million ha, roughly equal to 4.6% of its land area. Of this, inlands wetland constitute 69.22% (10.56 million ha). There are 0.556 million wetlands with area less than 2.25 ha. India is a signatory to Ramsar Convention and is committed to 'wise use' of all wetlands in her territory. As on date, 26 sites have been designated as Wetlands of International importance under the Convention (listed below). Conservation of wetlands is one of the high priority areas of MoEF.

Conservation and management of wetland is monitored by following two plans-

1. NWCP- The Ministry has been providing financial support to State Governments for implementing action plan for conserving wetlands under the National Wetland Conservation Programme (NWCP) since 1986.
2. NLCP- In 2001, National Lake Conservation Plan (NLCP) was introduced to address pollution issues in urban and semi-urban environment through interception, diversion and/or treatment of pollution load entering the lake.

As on December 2012, nearly 150 priority sites have been prioritized for conservation and management under these schemes. In February 2013, the

Ministry has since launched the National Programme on Conservation of Aquatic Ecosystem (NPCAE) for conservation of both lakes and wetlands with a significant increase in allocation of resources.

Importance of Wetlands

Wetlands provide many valuable services at population, ecosystem and global levels. These signify the importance of wetlands and the need fortheir conservation. The value of the wetlands in terms of theeconomic systems perceived by the human being and the need to consider the value of a wetland as a part of an integrated landscape differ with each other and most of the times conflicting. It is needless to mention that wetlands are highly productive ecosystems and are essential for preserving the biodiversity and ecological security. The interactions of physical, chemical and biological components of wetlands enable it toperform thevital functions. A detailed account of this is presented by Mitsch and Gosselink (2000). Significant functions, values and attributes of wetlands which owe their importance to wetlands as follows-.

(a) Functions

- Water storage
- Storm protection and flood mitigation
- Shoreline stabilisation
- Ground water recharge and discharge
- Water purification
- Retention of sediments, nutrients and pollutants
- Stabilisation of local climate particularly temperature and rainfall.

(b) Values

- Water supply – maintenance of quantity and quality
- Fisheries
- Agriculture – through maintenanceof water table
- Grazing
- Timber production
- Energy sources such as peat and plant matter
- Wildlife resources

- Recreation and tourism opportunities

(c) **Attributes**

- Biological diversity:wetlands supportavifauna, especially waterfowl; fish, reptiles, mammals, and invertebrate species as well as several plant species, besides a variety of microorganisms like plankton of both phyto and zoo origin.
- Cultural heritage: open landscapes, wildlife and local traditions.

Environmental Threats to Wetlands

Wetlands have been under constant threat of environmental degradation due to natural as well as anthropogenic activities. Some of the major environmental threats to the wetlands and their biodiversity are

1. **Encroachment:** People consider wetlands as low value lands or wastelands and in order to 'develop' such lands they have been encroached for agriculture, urban expansion and other such purposes.
2. **Pollution:** A large number of wetlands are subjected to inflows of domestic sewage, solid waste and industrial effluents. Fertiliser and pesticide run-off from agricultural lands aggravate the pollution load. Pollution results in eutrophication, reduces dissolved oxygen, increases the biological oxygen demand etc.which, many a times causes large-scale mortality of fish and other aquatic life. Eutrophication creates ecological conditions that are deleterious to most aquatic life forms.
3. **Aquaculture development:** Indiscriminate use of wetlands for aquaculture is a major threat to the ecological character of wetlands. Intensive input of feed for the fish and prawn culture, subsequent draining of the nutrient rich water into adjacent sea/river system results in eutrophication and degradation of wetlands.
4. **Siltation:** Siltation is a natural ecological process in filling up of the wetlands. However, the anthropogenic activities in the catchment of a wetland would accelerate the process. This natural process coupled with anthropogenic activities would lead to shrinkage and loss of many wetland habitats as well as alteration inbiological composition.
5. **Weed infestation:** The eutrophication process creates conducive conditions for the weeds to proliferate the wetlands and poses a threat. Aquatic species like *Eichornia crassipes* and*Ipomea aquatic*infestation is a common problem in

India. Italtersand impairsthe ecological functions of wetlands. In addition to the above, natural succession, changes in hydrological cycle and sea level etc. are some of the other factors responsible for changing the character and quality of wetlands.

Effect of Wetlant degradation

Decrease in biological diversity, deterioration of water quality, sedimentation and shrinkage in areas under wetlands, decrease in migratory bird population, decrease in fish productivity and prolific growth of unwanted aquatic biota are major effect of wetland degradation.

Ramsar Convention

The Convention on Wetlands of International Importance especially as Waterfowl Habitat is generally known asthe **Ramsar Convention**. It owes its name after the town in Iran where it was adopted in 1971. It is the oldest and first inter-governmental conservation convention. It came into being due to serious decline in population of waterfowl and need for conservation of habitats of migratory waterfowl. The convention provides the framework for national action and international cooperation for the conservation and wiseuse of wetlands and itsresources including biodiversity.

Account of Ramsar sites in India

There are 26 sites which are designated as Ramsar Sites. (Table 19.2)

Table 19.2 Ramsar sites in India

S.N.	Ramsar site	State	Wetland type
1	Ashtamudi Wetland	Kerala	Coastal-Natural-Lagoon
2	Bhitarkanika Mangroves	Orissa	Coastal-Natural-Mangrove
3	Bhoj Wetland	Madhya Pradesh	Inland –Manmade- Reservoir/Barrage
4	Chandertal Wetland	Himachal Pradesh	Inland-Natural-High Altitude Wetland
5	Chilika Lake	Orissa	Coastal-Natural-Lagoon
6	Deepor Beel	Assam	Inland-Natural-Lake
7	East Calcutta Wetlands	West Bengal	Inland Manmade-Water logged
8	Harike Lake	Punjab	Inland Manmade Reservoir/Barrage
9	Hokera Wetland	Jammu & Kashmir	Inland-Natural-Lake/pond
10	Kanjli	Punjab	Inland-Manmade-Reservoir/Barrage
11	Keoladeo National Park	Rajasthan	Inland-Manmade-Water logged
12	Kolleru Lake	Andhra Pradesh	Coastal-Natural-Lake/pond
13	Loktak Lake	Manipur	Inland-Natural-Lake/pond
14	Nalsarovar Bird Sanctuary	Gujarat	Inland-Natural-Lake/pond
15	Point Calimere Wildlife and Bird Sanctuary	Tamil Nadu	Coastal wetland complex
16	Pong Dam Lake	Himachal Pradesh	Inland Manmade Reservoir/Barrage
17	Renuka Wetland	Himachal Pradesh	Inland-Natural-Lake/pond
18	Ropar	Punjab	Inland Manmade Reservoir/Barrage
19	Rudrasagar Lake	Tripura	Inland-Natural-Water logged
20	Sambhar Lake	Rajasthan	Inland-Natural-Lake/pond
21	Sasthamkotta Lake	Kerala	Inland-Natural-Lake/pond
22	Surinsar-Mansar Lakes	Jammu &Kashmir	Inland-Natural-Lake/pond
23	Tsomoriri	Jammu &Kashmir	Inland-Natural-High Altitude Wetland
24	Upper Ganga River (Brijghat to Narora Stretch)	Uttar Pradesh	Inland-Natural-River Stream
25	Vembanad-Kol Wetland	Kerala	Coastal-natural-Lagoon
26	Wular Lake	Jammu &Kashmir	Inland-Natural-Lake/pond

Source: NWIA GIS database

19.6 Mangroves and Corals Reefs

India has a long coastline of about 7,517 km in length consisting of 2,383 km^2 of extensive coral reef beds and 4,667 km^2 (which is 0.14% of the Country's total geographical area.) of mangrove habitats that are home to more than 12,000 species of flora and fauna.

Mangroves

Mangroves are plants that survive high salinity, tidal regimes, strong wind velocity, high temperature and muddy anaerobic soil – a combination of conditions hostile for other plants. The mangrove ecosystems constitute a symbiotic link or bridge between terrestrial and marine ecosystems. They are found in the inter-tidal zones of sheltered shores, estuaries, creeks, backwaters, lagoons, marshes and mud-flats.

Mangrove vegetation has been reported in all the coastal States/UTs. India is home to some of the best mangroves in the world. West Bengal has the maximummangrove cover in the country, followed by Gujarat and Andaman & Nicobar Islands. However, not all coastal areas are suitable for mangrove plantation as mangroves require an appropriate mix of saline and freshwater, and soft substrate like mud flats to enable it to grow and perpetuate. The mangrove cover in the Country is 4628 km^2. The Ministry provides financial assistance to the State Forest Departments for all identified mangrove areas for conservation and management. Besides, the Ministry also supports R&D activities with emphasis on targeted research on mangrove biodiversity, its management and various aspects of pollution in the identified areas.

The mangrove cover of India (2.69% of the global mangrove area and 8% of Asia's mangroves) is home to umbrella species such as the tiger as well as many threatened species such as the River terrapin, Gangetic river dolphin, Estuarine crocodile and Fishing cat. About 59% of this cover is on the East coast, along the Bay of Bengal, 28% on the West coast, bordering the Arabian Sea, and 13% on the Andaman and Nicobar Islands. These mangroves are also inhabited by 12 species of salt marsh vegetation and 11 species of seagrass (Kathiresan 2004). Two globally threatened mangrove species are also found in India: **Sonneratia griffithii** and **Heritiera fomes** (Kathiresan 2010). The largest mangrove habitat is found in the **Sundarbans,** West Bengal. It is the single largest block (>10,000 km^2) of tidal halophytic mangroves in the world. Seagrasses are submerged aquatic vegetation specialised to live in marine environments though they constitute less than 0.02% of angiosperms representing 72 species and 14 genera. They have leaves, roots, conducting tissues, flowers and seed and prepare their own food through photosynthesis and represent one of the most productive ecosystems in the marine environment, with an average net production of about 1012 g/m^2 /yr. They are acting as the carbon sink in the coastal environment by sequestering 12% of the carbon fixed in the global oceans. This ecosystem provides food, habitat and nursery areas for a myriad of vertebrates (such as Dugong and Green turtle) and invertebrate organisms. Seagrass ecosystems support rich biodiversity, are sensitive to changes in water quality and being the sedentary primary producer, they have been recognized as important indicator species reflecting the health of the coastal environment. Besides mangroves and coral reefs, this ecosystem is also being subjected to a lot of stress mainly from point and nonpoint sources of pollution, sedimentation and turbidity. In India, extensive seagrass meadows are reported from Gulf of Mannar, Palk Bay, Gulf of Kachchh, Lakshadweep and Andaman and Nicobar group of islands. India is bestowed with 15 species of seagrasses belonging to six genera. Remote sensing measurements indicate that about 14000 ha of seagrasses are found distributed within 5 m depth contours and the seagrasses beyond 5 m depth are not yet quantified in the aforesaid seagrass sites. *Cymodocea rotundata, Cymodocea serrulata, Thalassia hemprichii, Halodule uninervis* and *Halophila ovalis* are the major contributors to the biomass in these regions.

Mangroves for the Future - India Mangroves for the Future (MFF), is a partnership-based initiative promoting investment in coastal ecosystems conservation through sustainable development. MFF provides a collaborative platform to help countries, sectors and agencies in the MFF region to tackle the growing challenges to coastal sustainability.

MFF in India primarily focuses on improving the scientific knowledge base for enhanced management of coastal and marine ecosystems, and in working with coastal communities to increase resilience through livelihood interventions and ecosystem restoration. National and regional symposia supported by MFF have greatly contributed by establishing baseline database for coastal and marine ecosystems (specifically mangroves, coral reefs and fisheries). Knowledge and educational products and initiatives are also helping to raise awareness about

India's valuable coastal resources. MFF (India) works through its small grant, medium grant and large grant and projects and regional initiatives, to bridge knowledge gaps on vulnerable coastal and marine ecosystems and threatened species for better-informed conservation actions and policy interventions. The MFF (India) programme is implemented by IUCN India Country Office.

Coral Reefs

Coral reefs are the skeletons of stony coral polyps cemented together. Coral reefs form the most dynamic ecosystem, providing shelter and nourishment to marine flora and fauna. They are the protectors of the coastlines and the coastal populations mostly depend on the coral reef ecosystems wherever they are present. The term **'coral'** has been used to describe a variety of invertebrate animals of the Phylum Cnidaria including hard and soft corals. The Indian reef area is estimated to be 2383.87 km2. However, 'coral' is most often used as the common name for hard corals of the Order Scleractinia. The four major coral reefs areas identified for intensive conservation & management in India are:

i) Gulf of Mannar;

ii) Gulf of Kachchh;

iii) Lakshadweep; and

iv) Andaman and Nicobar Islands.

The coral reef beds in the Gulf of Kachchh, Gulf of Mannar, Lakshadweep Islands and Andaman and Nicobar Islands are inhabited by several rare and threatened species such as the dugong, the Hawksbill turtle and Giant clams, which indicate the health of these ecosystems. A total of 478 species of corals belonging to 89 genera have so far been recorded from India, forming 60% of the known hermatypic genera of the world (ICMAM-PD 2001, SAC 2010).

The emphasis is more on preventive aspects through monitoring and surveillance as the restoration work is both costly and time consuming. The Ministry provides financial assistance to the State Forest Departments for all the four identified coral reef areas for conservation and management of coral and associates. Besides, the Ministry also supports R&D activities with emphasis on targeted research on coral biodiversity, its management and various aspects of pollution in these areas. Objectives – Conservation and management of mangroves and coral reefs; – Eco-restoration and afforestoration in potential and also in degraded coastal areas; – Maintenance of genetic diversity especially of threatened and endemic species; and

– Creation of awareness on importance of these ecosystems leading to their conservation; andSanctioning of approved annual MAPs of identified Mangrove and Coral Reef sites.

19.7 Summary

In-situ conservation is prime method of biodiversity conservation in which plants and animals are kept in their natural habitat. It is considered better conservation method than 'Off site' conservation. It is cheaper, more convenient, ecologically and evolutionary friendly method; as it not only conserve species but conserve entire ecosystem. It also maintains genetic diversity and provides material for genetic improvement of crops. In a natural system organisms not only live and multiply but evolve as well. Protected areas are designed to achieve the long term conservation of nature with associated ecosystem services and cultural values**.** There are 4 categories of the Protected Areas as, National Parks, Sanctuaries, Conservation Reserves and Community Reserves.

19.8 Glossary

- **Adaptation :** Process of adjustment of an organism in particular habitat
- **Afforestation :** Planting of large areas with trees
- **Alien species :** A species that does not normally occur in an area but which has been introduced by human activity
- **Bio-degradation :** Oxidative breakdown of organic matters by microbial activity
- **Bio-diversity :** Variety and variation among living organism
- **Biome :** A major ecological community of organisms maintained under a particular climatic zone with a specific vegetation type
- **Bio-sphere reserve:** Biosphere reserves are areas of terrestrial and coastal ecosystems promoting solutions to reconcile the conservation of biodiversity with its sustainable use. They are internationally recognized, nominated by national governments and remain under sovereign jurisdiction of the states where they are located.
- **Biota :** The flora and fauna of an area

- **Biotic community :** plants and animals naturally occurring in the same environment and are mutually sustaining and interdependent
- **Biozone :** The temporal and stratigraphic range of a kind of organism (as of a species) as reflected by its occurrence in fossiliferous rocks
- **Cities :** Convention on the International Trade in Endangered species
- **Climate :** Long-term weather conditions and factors of an environmental area due to its geographical conditions
- **Coral reefs:** Diverse underwater ecosystems held together by calcium carbonate structures secreted by *corals*. *Coral reefs* are built by colonies of tiny animals found in marine waters that contain few nutrients
- **Cultivation :** Preparation of land to grow crops
- **Ecology :** The study of living organism in relation to their environment
- **Ecosystem :** A unit consisting of biotic and abiotic components interacting to produce a stable system
- **Endangered :** Organism/species danger of extinction
- **Endemic :** Only occurring in a particular area
- **Environment :** Physical, chemical, biotic and cultural factor that affect organism
- **Eutrophication :** The process in which an ecosystem becomes nutrient enriched
- **Fauna :** All the animal species that occur in a particular region
- **Fertilizers :** Animal manure or synthesized chemical that is added to soil to increase its productivity for crops
- **Focal species :** A species that is the focus of conservation efforts
- **Globally threatened :** A category of threat that indicates that a taxon is threatened on a world scale
- **Habitat :** The place where a species lives in nature
- **Hermatypic :** reef-building corals
- **Hot spot :** A rich biodiversity area with high degree of endemism (the presence of species found nowhere else on earth) threat

- **Hybrid :** An organism that is produced from a cross between parents from two distinct species
- **Invasive :** Colonising an area from outside
- **Native species :** Species that occur naturally in an area
- **Natural resources :** A component of the environment that is of value in serving human needs
- **Pollutant :** Any substance that pollutes the environment
- **Population :** A group of organisms of the same species live in same area
- **Protected areas :** National parks, wilderness areas, community conserved areas, nature reserves and so on – are a mainstay of biodiversity conservation, while also contributing to people's livelihoods, particularly at the local level
- **Ramsar site :** Wetland of international importance designated under the Ramsar convention 1971
- **Rare :** Taxa with small populations that are not at present Endangered or Vulnerable but are at risk
- **Red data book : A** book listing threatened and endangered species published by IUCN
- **Sacred grooves :** Relic forest patches, traditionally protected by communities in reverence of a deity
- **Species :** Closely related, physically similar being that can interbred to produce fertile offspring
- **Sustainability :** Meet the needs of the present without compromising the ability of future generation to meet their own needs
- **Topography :** The surface feature of the earth
- **Vulnerable :** Taxa believed likely to move into endangered category in the near future if the causal factors continue operating
- **Wetland :** An area that is saturated by surface water having life adapted under those conditions

19.9 Self-Learning Exercises

Section-A (Very Short Answer Type Questions)

Fill in the blanks-

1. First national Park in India is…….
2. First Biosphere Reserve designated in India is…….
3. Nokrek biosphere reserve is situated in ……… state.

Section-B (Short Answer Type Questions)

1. Define Biosphere Reserve.
2. Name four Coral Reef areas in India.

Section-C (Long Answer Type Questions)

1. Describe Protected Area network in India.
2. Describe role of Wetland in biodiversity conservation.
3. Give an account on Biosphere Reserve.

Answers Section-A

1. Jim Corbett National Park, Uttarakhand
2. Nilgiri (01-08-1986)
3. Meghalaya

19.10 References

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Unit-20

Strategies for Conservation-II: *ex-situ* Conservation

Structure of the Unit:

20.0 Objectives

The aim of this unit is to give you a brief account of present scenario of ex-situ conservation of biological diversity. The major objectives of present study are:

- To understand the various components of *ex-situ* conservation of biological diversity;
- To study the mechanism of *ex-situ* conservation and strategies for conservation of plants, animals and micro-organisms;
- To understand the significance of *ex situ* conservation.

20.1 Introduction

There is a general perception that biodiversity should be conserved inside their natural habitat. But due to some unavoidable reasons it is always not possible to conserve or protect biodiversity ***in-situ***. This can lead to develop some new strategy where gene pool is conserved 'off side'. Gene pool can be restored ***ex-situ*** by conserving whole plant (botanical garden and arboreta) or plant parts (gene bank). Botanical gardens are oldest form of conservation. This type of conservation method can be proved beneficial where stress factors are working on an endangered flora or fauna.

20.2 Concept of *ex-situ* Conservation

ex-situ conservation is the technique of conservation of all levels of biological diversity outside their natural habitats through different techniques like zoo, captive breeding, aquarium, botanical garden, and gene bank. It is conservation of selected rare flora / fauna in place outside their natural habitat.

Significance of *ex situ* conservation-

Plants cannot be conserved always inside their natural habitat as there is an ever increasing demand for cropland to feed the raising population. Forests and other natural habitats are required for extending urbanization and industrialization. Natural areas are submerged at large scale as dams are built for prevent flood, supply water for irrigation and generate electricity. This loss of habitat makes ***ex situ*** conservation very important method of conservation.

ex-situ conservation is very important for those plants and animals which cannot be conserved ***in-situ*** due to different reasons.

There are different methods for conserving biodiversity ***ex-situ***.

20.3 Botanical Gardens

Botanical gardens are the institutions or establishments where plants are cultivated and maintain for scientific, educational, and ornamental purposes. Plants from different varieties including ornamental, wild and medicinal from different geographical regions are maintained in botanical gardens. An ideal botanical garden must include green houses, a library, a herbarium, research laboratories, and several miscellaneous resources including photographs, paintings, illustrations, reprints, note-books and specimens of several types.

Botanical gardens are the most conventional methods of ex-situ conservation, in which specimens are protected for breeding and reintroduction into the wild when necessary and possible. Botanic gardens have had a changing role throughout history, beginning often as medicinal gardens for the study and cultivation of plants with healing properties and going through many phases including of course as pleasure gardens and currently as a site of conservation of plants and in the education of the people. Botanical gardens are important places of systematic study and research on flora of the region. These are the places of great academic and economic importance. They are of value not only to the botanists, horticulturists and foresters but also to the students, tourists and laymen.

They have also a key role in the mitigation of the effects of climate change, and could be absolutely vital to the survival of the planet as they are perfectly placed to help move species around and help ecosystems to adapt to new climates in different regions.

Role of Botanical Gardens

1. **Taxonomic Studies:** Botanical gardens provide valuable information on various plants Local flora, bonsai, rare plants etc. They act as “outdoor laboratories” for students and researchers.
2. **Botanical Research:** Botanical gardens supply wide range of plant species, seeds, flowers, fruits for botanical research.
3. **Conservation:** Botanical gardens conserve and propagate rare species and genetic diversity.
4. **Education:** They supply facilities for courses in local flora, horticulture, hybridization, plant propagation, etc. There educational programmes include workshops, training sessions for teachers, students, naturalists etc.
5. **Public Services. :** They help the public in identifying the local and exotic plant species; provide instructions for home gardening’s, propagation of plants; supply plant resource;, through sale or exchange.
6. **Aesthetics and Recreation:** They attract people who have made gardening as their hobby.
7. **Urban greening:** Urban greening is the improvement of through planting and green landscaping. The benefits of such projects are far more than aesthetic as they can reduce pollution in local area; improve social networks, and improve individual feelings towards nature.

8. **Cultural centres and places of spirituality:** Botanic gardens sometimes contain important spiritual places, and are often important community spaces, especially in urban areas which otherwise have little access to greenery.
9. **Employment:** They create job opportunities for a large number of young botanists.
10. **Skill development:** Horticulture and cultivation skills can be developed in botanical garden.

Some important botanical garden

1. **Royal Botanical Garden, Kew, England –** Largest botanical garden in world and its herbarium is also largest in world, having 6 million specimens.
2. **Acharya Jagadish Chandra Bose/Indian botanical garden, Kolkata-** Largest Botanical Garden in India and its herbarium is largest in India, having 1 million specimens. Indian botanical garden is located in Shivpur, Howrah in West Bengal. This botanical garden is famous for wide variety of species of plants. The great banyan tree is the landmark of this garden which is considered as the largest in the world. This garden was earlier termed as company Bagan or Calcutta Bagan.There are wide variety of species of plants grown in this garden brought from other countries. All types of Orchids, palm trees- 109 selections of palm trees, Coconut, water lilies, Shivalinga tree, Bread fruit tree is found here.
3. **NBRI / National Botanic Garden-** National Botanical Research Institute located at Lucknow (UP) formally known as National Botanical Garden. The present garden and its laboratories are spread over 27 acres of land on the bank of river Gomti. Popular attractions of this garden are its Rosarium, Palm house, Cactus house, Fern house, Orchid house, and orchards of mango, Citrus and guava. It has well-equipped laboratories of Plant Morphology, Aromatics, Cytogenetics, Plant breeding, Tissue culture, Virology, Palynology, Plant Physiology, Entomology, etc.
4. **Botanical Garden of Forest Research Institute, Dehradun-**It is perhaps the youngest member of the family of botanic gardens in India, yet it has attained the status of one of the 500 principal botanic gardens of the world.

It covers an area of about 20 acres in New Forest Estate, Dehradun, and is the main Indian centre of research in problems related with plant introduction. There are about 700 species of plants belonging to about 400 genera and about 100 families in this garden. Over half of these 700 species have been introduced from different parts of the world. The garden has a greenhouse, a cactus house and a Plant Introductory Nursery. Its biggest attraction is a big herbarium holding over 30, 00, 00 plant specimens from all over the world.

5. **Garden of Agri horticultural society of India, Kolkata-**Agri horticultural society is located in Alipore, Kolkata and is famous for growing huge collections of rare medicinal plants.
6. **Lal Bagh, Bangalore-** Lal bagh is termed as Red garden situated in Bangalore. Lal Bagh was started by Sultan Hyder Ali and his son Tipu Sultan. Tipu Sultan completed the work of this garden and brought some of the rare & exotic plants to this garden. It is a genetic center for maintaining plants. Various scientific, technical researches are organized here.
7. **Governmentbotanical garden, Ooty-** Government botanical garden located in Udamangalam in Tamil Nadu which is famous for huge collection of roses. This garden is considered as the largest garden for roses in India. There are many lawns consisting thousands of species of exotic plants, shrubs, trees and bonsai plants.
8. **Brindavan garden, Karnataka-**IFGTB Botanical Garden - The Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, Tamil Nadu

20.4 Gene Bank

Biological diversity occurs at three different levels, Ecosystem diversity, Species diversity, Genetic diversity.

Genetic diversity gives species the ability to adapt to changing environments, including pests, diseases, and climate change. It is very important to conserve these valuable genetic resources so that these can available for use and study in the future. There are two main approaches to maintaining genetic diversity: ***in-situ*** conservation and ***ex-situ*** conservation. ***in-situ*** conservation is concerned with maintaining species within their natural environments. Ex situ conservation comprises of methods that maintain the genetic integrity of collected germplasm samples outside their natural habitats. Genetic resources that are maintained outside of their natural habitats and managed under artificial conditions in facilities are known as **gene banks.**

Gene bank is a type of biorepository where genetic material is collected, stored, catalogued and made available for redistribution. Local crop varieties, known as **'landraces',** are the result of generations of careful farmer selection. Due to a combination of environmental and social changes in farming communities, intensification of cultivation of a particular high yielding crop globally and inbreeding in small populations, large numbers of local crop varieties are disappearing at an alarming rate, which cause rapid decline in genetic diversity.

Conserving the genetic diversity of our crops, landraces and related wild species is essential to ensure future plant breeders can access this variation, especially in view of increased food demand by a growing world population and climate change. Genebank play an important role in the conservation, availability and use of a wide range of plant genetic diversity for crop improvement for food and nutrition security.They help bridge the past and the future by ensuring the continued availability of genetic resources for research, breeding and improved seed delivery for a sustainable and resilient agricultural system.

Gene banks also preserve cells or organisms that host unusual gene variants- genes with special traits. Those genes might later prove useful when some disease epidemic strikes, when the climate changes or when other factors threaten the survival of plants or animals. Farmers could use the banked deposits stored cells or tissues to restore genetic diversity or to introduce traits from other breeds or varieties.

For plants, this could be achieved by freezing cuttings from the plant, or stocking the seeds (e.g. in seedbanks). For animals, this could be done by freezing of sperm and eggs until further need. With corals, fragments are taken which are stored in water tanks under controlled condition.

Plant genetic material in a 'gene bank' is preserved at -196°C in Liquid Nitrogen as mature seed (dry).

In plants, it is possible to unfreeze the material and propagate it, however, in animals; a living female is required for artificial insemination.

A gene bank can hold many different types of materials. There may be seeds that will grow into whole plants or eggs and sperm that can be united to create an animal. There may be animal embryos, which can be implanted into surrogate mothers. Some gene banks store stem cells, which scientists may one day use to produce eggs and sperm. Banks can even store reproductive organs, such as ovaries and testes. After thawing, these organs can grow into animals of other breeds or even other species. Later, when mature, these organs will produce sperm or eggs with the genes of the animal from which they had been harvested. In animals, it is not possible to create a whole organism through stored genetic material directly but it can be created by artificial insemination after **In Vitro** Fertilization of stored eggs and sperms.

In an effort to conserve agricultural biodiversity, gene banks are used to store and conserve the plant genetic resources of major crop plants and their crop wildrelatives.

Difficulties

Gene banks use low temperatures to stop chemical and biological activity that might break down cells. Freezing and thawing cells has to be done quickly and carefully so that the material will still be viable after it has warmed back up. But some plant and animal materials which are not resilient require extra special care.

20.5 Seed Bank

A seed is an embryonic plant enclosed in a protective outer covering called the **seed coat,** usually with some stored food. It is a characteristic of flowering plants.

Seeds of many plant species remain viable for a long time when they are kept in reduced moisture and at low temperature. Cryogenic preservation is suspended liveliness at sub-freezing temperature and low moisture content.

A seed bank stores seeds as a source for planting in case seed reserves elsewhere are destroyed. It is a type of gene bank. The seeds stored may be food crops, or those of rare species to protect biodiversity. The reasons for storing seeds may be varied. In the case of food crops, many useful plants that were developed over centuries are now no longer used for commercial agricultural production and are becoming rare. Storing seeds also guards against catastrophic events like natural disasters, outbreaks of disease, or war. Seed banks can be set up at the community, national and international level.Because the crops we rely for food are grown in parts of the world distant to the centres of their domestication, the sharing of genetic material across national borders for research and plant breeding is essential.

Establishment of Seed bank accomplished in the following three steps:

1. **Collection and Drying of seed sample-** Collection of seeds are done after testing their viability. The simplest method of viability test is to determine the percentage of seed germination. Different types of stains and tests can be used e.g. 2, 3, 5-triphenyltetrazolium chloride. Size of seed sample depends on requirement of seed sample.

   Seeds are dried in a conditioning room with a temperature of 16°C and a relative humidity of 14%. It can also be done by a drying agent like Silica gel or Drierite.
2. **Storing-** seeds are stored in a container made up of metal, glass, and plastic. Seeds are first dried (to prevent germination during storage) and stored at low temperatures to increase longevity.
3. **Labeling-** labeling of sample is done for identification.

   An important part of the work at seed banks is to ensure the seed collection remains alive: seeds need to be periodically checked for viability and the material regenerated to replenish the collection with fresh seed and planting materials

20.6 Pollen Bank

This is a method in which pollen grains are stored. We can make plants which are facing extinction in the present world. Using this technique, we can make plants with one set chromosome. Pollen can be preserved for conservation of biodiversity of important and endangered flowering plants. Pollen from flowering plants can be preserved by Cryogenic technique. These are so tiny that millions of pollens can be stored in a very small vial (a small container), thus gives an opportunity to preserve the full range of variations within the desired population. These stored pollens can be used in hybridization programme directly whenever needed, which is not possible in the case of seeds. When seeds are subject to develop hybrids, they must be retrieved from the seed bank and then planted in the field. This process consume more time. Pollen bank can be used to describe a pollen reference collection which serves as a tool to study the records of **fossilized** pollen collected from sediments to reconstruct the historic vegetation of the site where the material was collected.

The process of storing pollen is quite simple. The pollen containing stamen of desired plant species is removed, inserted into the gelatin capsule and shaken to deposit the pollen on the capsule wall. The stamen is then withdrawn. Labeling and storing is done for further use.

20.7 DNA Bank

DNA banking is the secure, long term storage of an individual’s genetic material. DNA is most commonly extracted from blood, but can also be obtained from cheek cells, saliva, or other tissues in animals. In plants, DNA can be extracted from any part. Plant material is dried using silica gel and stored at -80^0 C to extract DNA from it. When fresh supplies not available, DNA can be obtained from dried plant material stored in botanical research institutions that house pressed and dried plant specimens called ‘herbarium’. DNA banks can serve many purposes in today's society. DNA banks allow for conservation of genetic material and comparative analysis of an individual's genetic information.

DNA banking is more economical than other forms of germplasm banking, as it occupies far lesser space, almost indefinitely viable and a small sample can be shared by many researchers through PCR amplification, without the need for repetitive extractions.

Uses

1. **Conservation-** DNA banking is used to conserve genetic material, especially that of organisms that face extinction. This is a more prominent issue today due to deforestation and climate change, which serve as a threat to biodiversity. The genetic information can be stored within lambda phage and plasma vectors. Most DNA provided by DNA banks is used for studies to attempt to develop more productive or more environmentally friendly agricultural species. Some DNA banks also store the DNA of rare or endangered species to ensure their survival.
2. **Gene mapping-** The DNA bank can be used to compare and analyze DNA samples. Comparing the samples allowed scientists to work on the **‘Human Genome Project’**, which maps out many of the genes on human DNA.
3. **Preventative genetics-** It has also led to the development of preventative genetics. Samples from the DNA bank have been used to identify patterns and determine which genes lead to specific disorders. Once people know which genes lead to disorders, people can take steps to lessen the effects of that disorder. This can occur through adjustments in lifestyle, as demonstrated in

Preventive healthcare, or even through gene therapy. We can also know about the disease which can be developed in near future. By doing this we can take preventative measures to minimize these risks. Current technology is already capable of using DNA to predict certain health predispositions in the family, and advances are being made to identify many more. Knowing a family's genetic history assists in early detection, making it possible to take measures to prevent or mitigate the devastating effects of the disease.

4. **Forensic investigation-** This system makes it possible to rule out or confirm the verdict of a suspect based on their personal genetic information. Once an individual's DNA is stored, it remains in the system. Evidently law enforcement can identify and track criminals more easily.

20.8 *in-vitro* Repositories

ex-situ in vitro repositories conservation refers to of living animal or plant in artificial environment, under cryogenic conditions. In animals this is achieved by cryopreservation of embryos, semen, oocytes or tissue having the potential to reconstitute live animal in future.

This is necessary when there is a critically threat of a breed or species becoming extinct. ***In-vitro*** repositories ensure availability of adequate gene pool sustained for future improvement programme.

20.9 Cryo Bank

The conventional methods of storage fail to prevent from losses caused byattack of pathogens and pests, climatic disorders and natural disorders. However, the conventional methods could not save the viability of short lived seeds of economic plants, these materials can be successfully stored by cryogenic techniques, due to which growth-rate of cells retards; consequently biological activities are conserved for long time. In this technique, a seed or embryo is preserved at very low temperatures. It is usually preserved in liquid nitrogen at -196°C. This is helpful for the conservation of species facing extinction.

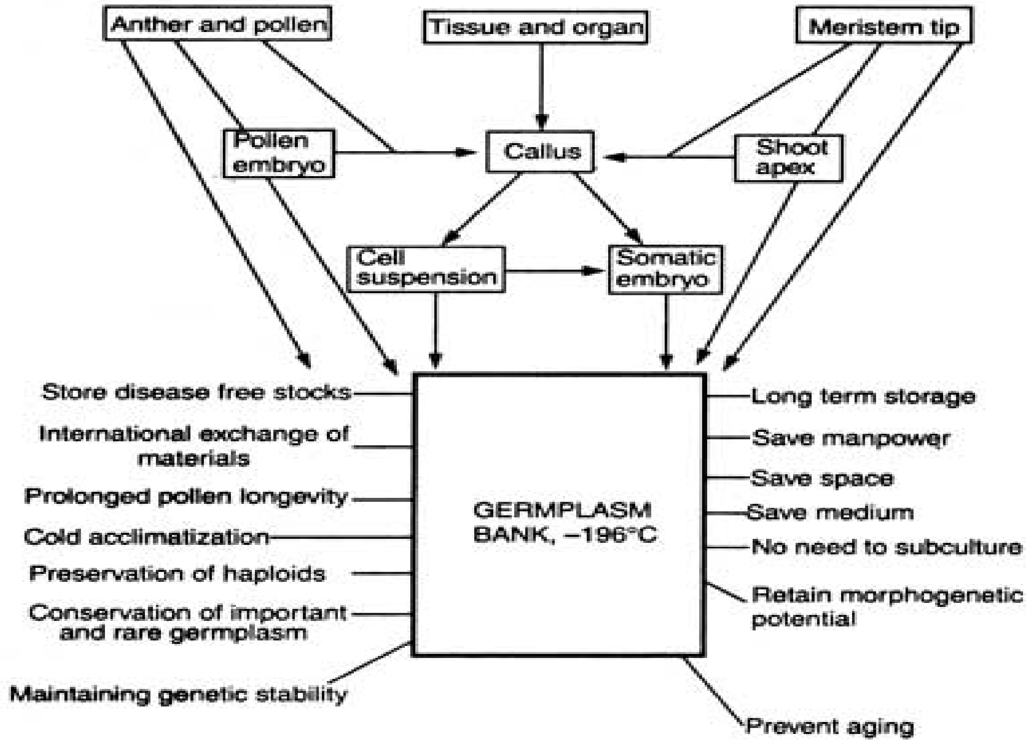

Fig. 20.1 : Potentials and Prospects of Cryopreservation of Plant cell, tissue and organ culture and establishment of 'Germplasm Bank' (after Bajaj, 1977a).

Difficulties in Cryopreservation

The difficulties are-

1. high specific feature of plant cells, such as their large size, strong vacuolization and abundance of water
2. cell damage during freezing and subsequent thawing caused by ice crystals formed inside the cells and by cell dehydration
3. gradual formation of large crystals of more than 0.1mm whose facets rupture many cell membranes (Shimada and Ashahina, 1975)

However, in the presence of cryoprotectants (the chemicals decreasing cryodestruction) and reduced temperature, free water has enough time to leave the cells. Therefore, it can freeze on the crystal surface in the solution (Samygin, 1974). This results in marked dehydration and protoplast shrinkage (Muzur, 1977). Excessive time and degree of plasmolysis are the reasons of cell destruction during slow freezing, since they cause irreversible contractionofthe plasmalemma (Wiest and Steponkus, 1978).

Methods of Cryopreservation

The freezing-storage-thawing cycle is an external procedure consisting of the following basic stages-

(i) **Selection of Materials-** Young meristematicsmall cells which are highly cytoplasmic, non-vacuolated and thin walled are good materials to be selected for this purpose.

(ii) **Addition of Cryoprotectors / Cryopreservatives-** Chemicals which decrease cryodestruction like sugars, glycols, sugar alcohols, alcohols, polyvinylpyrrollidone, polyethylene glycol (PEG), polyethylene oxide (PEO), dextrans, hydroxystarch, glycerine, sucrose, and some amino acids (e.g. proline) are used as Cryopreservatives. Bajaj (1987) has advised to use a mixture of two or three cryoprotectants at low concentrations rather than a single cryoprotectant at a high concentration as it could be toxic. During treatment, the cultures should be maintained in ice to avoid deleterious effects.

(iii) **Freezing-** Freezing should be done in such a way that it does not cause intracellular freezing and crystal formation, as it is possible in sudden freezing. To avoid this problem, regulated rate of cooling or pre-freezing is done.

(iv) **Storage in Liquid Nitrogen-** If the cells are not stored at sufficiently low temperature, an additional injury to the cultures may be caused. The storage temperature should be such that it stops all metabolic activity and prevents biochemical injury (Bajaj 1987). Prolonged storage of frozen materials is possible only when the temperature is lower than -130°C. This can be simply achieved with the help of liquid nitrogen, which keeps the temperature -196°C.

(v) **Thawing-** Thawing is the process of releasing the vials containing cultures from the frozen state to elevate the temperature between 35 and 40°C. It should be done quickly but without over heating. As soon as the last ice crystals disappear, the vials are transferred into a water bath at 0°C (Popov, 1985).

(vi) **Washing and Reculturing-** Washing of plant materials is done to remove the toxic cryoprotectants. When low toxic or non-toxic cryoprotectants are used, the cultures should not be washed, but simply recultured. Washing follows the following procedure: dilution, resuspension, centrifugation and removal of cells.

(vii) **Regeneration of Plantlets-** The viable cells are cultured on growth media to regenerate into plantlets.

20.10 Summary

Natural ecosystem and biodiversity have been placed at an alarm and threat by the unethical human influences. ***ex-situ*** conservation is the process of protecting an endangered flora or fauna outside its natural habitat. A small part of population is removed from its degrading or threating habitat and placed it in new 'off side' habitat which may be wild or artificial. ***ex-situ*** conservation of wild endangered plant species through seed banking is currently being recommended by botanical garden, arboreta or gene bank. Botanical gardens are the institutions or establishments where plants are cultivated and maintain for scientific, educational, and ornamental purposes.Gene banks maintain genetic resources outside of their natural habitats under artificial conditions. Seed banks, Tissue bank, Pollen Bank, Field gene bank, DNA bank are types of gene bank.

20.11 Glossary

- **Adaptation :** Process of adjustment of an organism in particular habitat
- **Afforestation :** Planting of largqe areas with trees
- **Alien species :** A species that does not normally occur in an area but which has been introduced by human activity
- **Altitude-**heights above sea level
- **Biodegradation :** Oxidative breakdown of organic matters by microbial activity
- **Biodiversity :** Variety and variation among living organism
- **Biome :** A major ecological community of organisms maintained under a particular climatic zone with a specific vegetation type
- **Biota :** The flora and fauna of an area
- **Biotic community :** plants and animals naturally occurring in the same environment and are mutually sustaining and interdependent

- **Biozone :** The temporal and stratigraphic range of a kind of organism (as of a species) as reflected by its occurrence in fossiliferous rocks
- **Cities :** Convention on the International Trade in Endangered species
- **Climate :** Long-term weather conditions and factors of an environmental area due to its geographical conditions
- **Coral reefs:** Diverse underwater ecosystems held together by calcium carbonate structures secreted by *corals*. *Coral reefs* are built by colonies of tiny animals found in marine waters that contain few nutrients
- **Cultivation :** Preparation of land to grow crops
- **Ecology :** The study of living organism in relation to their environment
- **Ecosystem :** A unit consisting of biotic and abiotic components interacting to produce a stable system
- **Endangered :** Organism/species danger of extinction
- **Endemic :** Only occurring in a particular area
- **Environment :** Physical, chemical, biotic and cultural factor that affect organism
- **Eutrophication :** The process in which an ecosystem becomes nutrient enriched
- **Fauna :** All the animal species that occur in a particular region
- **Fertilizers :** Animal manure or synthesized chemical that is added to soil to increase its productivity for crops
- **Focal species :** A species that is the focus of conservation efforts
- **Gene Bank :** Gene bank is a type of biorepository where genetic material is collected, stored, catalogued and made available for redistribution
- **Globally threatened :** A category of threat that indicates that a taxon is threatened on a world scale
- **Habitat :** The place where a species lives in nature
- **Hot spot :** A rich biodiversity area with high degree of endemism (the presence of species found nowhere else on earth) threat

- **Hybrid :** An organism that is produced from a cross between parents from two distinct species
- **Invasive :** Colonising an area from outside
- **Latitude :** Distance from the equator
- **Native species :** Species that occur naturally in an area
- **Natural resources :** A component of the environment that is of value in serving human needs
- **Pedogenesis :** Process of soil development
- **Pollutant :** Any substance that pollutes the environment
- **Population-** A group of organisms of the same species live in same area
- **Ramsar site :** Wetland of international importance designated under the Ramsar convention 1971
- **Rare :** Taxa with small populations that are not at present Endangered or Vulnerable but are at risk
- **Red data book :** A book listing threatened and endangered species published by IUCN
- **Sacred grooves :** Relic forest patches, traditionally protected by communities in reverence of a deity
- **Seed bank :** An artificial store in which seeds are kept usually as a means to ensure that the particular species may be conserved
- **Species :** Closely related, physically similar being that can interbred to produce fertile offspring
- **Sustainability :** Meet the needs of the present without compromising the ability of future generation to meet their own needs
- **Topography :** The surface feature of the earth
- **Vulnerable :** Taxa believed likely to move into endangered category in the near future if the causal factors continue operating
- **Wetland :** An area that is saturated by surface water having life adapted under those conditions

20.12 Self-Learning Exercises

Section-A (Very Short Answer Type Questions)

1. Largest botanical garden in the world is …….
2. Indian Botanical Garden' is situated in……..
3. Svalbard Global Seed Vault is situated in…………..

Section-B (Short Answer Type Questions)

1. Define Seed Bank.
2. Define Gene Bank.
3. Write a note on cryo bank.
4. What do you understand by Pollen bank?

Section-C (Long Answer Type Questions)

1. Describe role of Botanical Garden in biodiversity conservation.
2. What is Cryopreservation? Describe in detail.

Answer of Section- A

1. Royal Botanical Garden, Kew, England
2. Shivpur, Kolkata, West Bengal
3. Norway

20.13 References

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