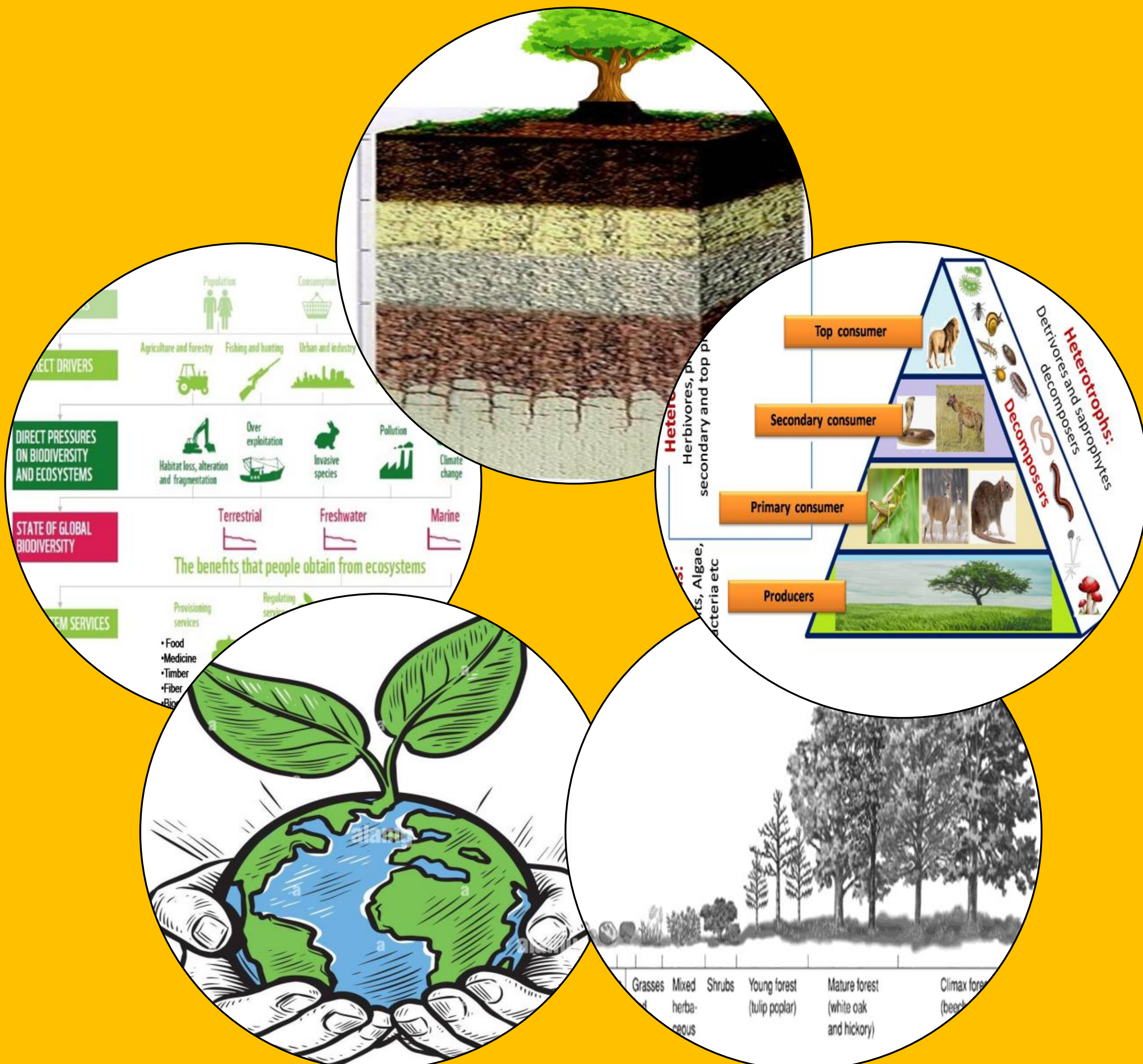
MSCBOT-602

M. Sc. III Semester

PLANT ECOLOGY



DEPARTMENT OF BOTANY

SCHOOL OF SCIENCES

UTTARAKHAND OPEN UNIVERSITY

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BLOCK-1-ECOSYSTEM ECOLOGY

UNIT-1- ECOLOGY: TYPES AND IMPORTANCE, THE EARTH ENVIRONMENT

Contents

1.1 OBJECTIVES

After reading this unit student will be able to-

- Know about ecology and its types
- Learn about the importance of ecology
- Understand the earth environment, i.e., about Biosphere, Lithosphere, Hydrosphere and Atmosphere.
- Know about the ecology of India

1.2 INTRODUCTION

Ecology is defined as the branch of science that studies the relationships between organism, their habitat and all the living and non-living factors involved in those habitats.

The scientist Reiter was the first person to use the word 'Ecology'. The term ecology was coined by combining two Greek words, oikos meaning 'house' or 'dwelling place' and logos meaning 'the study of' to denote such relationships between the organisms and with their environment. Although, there is uncertainty about the original coining of the term, however many biologists grant credit to the German zoologist Ernst Haeckel, who used the term as 'oekologie' in 1866 to refer the inter-relationships of living organisms and their environment. Many scientists defined the ecology in different ways such as:

Allee *et al.* (1949) considered ecology as "the science of interrelation between living organisms and their environment, including both the physical and biotic environments and emphasizing inter-species as well as intra-species relations".

Eugene Odum (1963) is, known as the father of modern ecology. According to him ecology is the structure and function of ecosystems.

Lewis and Taylor (1967) have defined ecology as "the study of the way in which individual organisms, populations of some species and communities of populations respond to these changes".

Smith (1977) prefers to consider ecology as "a multidisciplinary science which deals with the organisms and its place to live and which focuses on the ecosystem".

In simple terms ecology is the branch of biology that deals with scientific study of the interactions among organisms and their environment. The environment is made up of both living organisms (biotic) and physical (abiotic) components. Organisms and their environments are closely linked and dependent on one another. Any changes in the environment have an impact on living organisms, and vice versa. The main aim of ecology is to understand the distribution of biotic and abiotic factors of living thing in the environment. Ecology is a vast and encyclopedic biological subject. It is studied at various levels, such as- the main levels of study in ecology are the Biosphere, ecosystem, community, population, and organism. It refers to any form of biodiversity. The study of ecology is closely related to the fields of physiology, genetics, evolution, and behavior. An example of ecology is studying the food chain in a wetlands region.

The interaction of organisms with their environment leads to the formation of group of organisms called **ecological hierarchy** or ecological levels of organization. It means the ranking of the ecological members. Every species existing in the universe makes the ecology. The basic unit of an ecological system is an individual organism. The different hierarchies of ecological systems are presented below:

Hierarchy of Ecology

Biosphere
⇧
Biome
⇧
Ecosystem
⇧
Community
⇧
Population
⇧
Species
⇧
Individual

The levels of ecological study offer different insights into how organisms interact with each other and the environment. The study of ecology is divided into two major subdivisions: (i) Autecology, (ii) Synecology

1. **Autecology**: It deals with the ecology of individual species and its population including the effect of other organisms and environmental conditions on every stage of life cycle. In other words, it is a study of inter-relationship between individual species or its population and its environment.

2. **Synecology:** The branch of ecology that studies about the relationship of various groups of organisms to their common environment. It deals with the plant communities their composition, behavior and relation to the environment.

Autecology helps to understand the relationships between a particular organisms and environment and synecology helps to understand the relationships between communities and environment. For example, if the study is to be carried out about the study of any tree with the environment than it is known to be autecology. If we study effect of forest on environment then it is said to be synecology.

In the words of Herreid II (1977) "the two types of study, autecology and synecology, inter-relate, the synecologist painting with a broad brush the outline of the picture and autecologist stroking in the finer details".

1.3 TYPES OF ECOLOGY

Ecological studies are either organism-based or habitat-based and are conducted at different levels. Autecology and synecology are two main branches of ecology. Besides these major ecological subdivisions, different branches were created to explain different specific and detailed aspects of ecology. There are specialized branches of ecology as follows:

1. **Organism level:** Organism-level ecology is concerned with the adaptations that allow individuals to live in particular habitats. These adaptations can be morphological, physiological, and behavioural.
   - **(i). Autecology:** Autecology, also called species ecology, the study of the interactions of an individual organism or a single species with the living and non living factors of its environment.
   - **(ii). Population Ecology:** It is the study of the processes that affect the distribution and abundance of animal and plant population.
   - **(iii). Community Ecology:** Community ecology, study of the organization and functioning of communities, which are assemblages of interacting populations of the species living within a particular area or habitat.

2. **Based on Habitat or Ecosm or Ecosystem level:**

(A) Terrestrial Ecosystems

- **(i). Forest ecology:** Forest ecology is the scientific study of the interrelated patterns, processes, flora, fauna and ecosystems in forests.
- **(ii). Grassland ecology:** Grassland ecology is the study of all aspects of the ecology of grasslands, which are regions dominated by grass species but containing other non-woody plants and, in the case of Savannahs, some trees as well.
- **(iii). Desert ecology:** Desert ecology is the study of interactions between both biotic and abiotic components of desert environment.
- **(iv). Wetland or marsh ecology:** A wetland is a low-lying land area that is saturated with water, either permanently or seasonally, and contains hydric soils and aquatic vegetation. Marshes, swamps and bogs are typical wetlands.

(B) Aquatic Ecosystems

- **(i). Marine ecology:** It is the scientific study of living things in the ocean and how they interact with their environment.
- **(ii). Lagoon ecology:** Lagoon is defined as a shallow body of water separated from the ocean or from larger bodies of water by a reef or other barrier. An inlet off of the Pacific Ocean that is separated from the ocean by a coral reef is an example of a lagoon.
- **(iii). Estuarine ecology:** is a semi-enclosed coastal body of water which has a free connection with the open sea, thus strongly affected by tidal action, and within which sea water is mixed with fresh water from land drainage. Coastal bays, tidal marshes, river mouths, water bodies behind barrier beaches etc ate the examples of estuaries.

(iv). **Fresh water ecology or Limnology:** Limnology is the study of inland waters, both lotic waters (running water bodies), such as rivers, streams and lentic waters (standing water bodies), like lake, ponds etc.

3. **Applied Ecology:** Applied ecology is an integrated treatment of the ecological, social, and biotechnological aspects of natural resource conservation and management. It includes the following:

(i). **Agricultural ecology:** Agricultural ecology is the study of agricultural ecosystems and their components as they function within themselves and in the context of the landscapes that contain them.

(ii). **Phytosociology:** The branch of plant ecology concerned with the composition, distribution, characteristics, and interrelationships of plant species in plant communities.

(iii). **Paleoecology:** The study of the relationships between organism and their environment, and the way organisms functioned in physical and biological interaction, within the geologic past.

(iv). **Conservation ecology**: It deals with the application of ecological principles for proper management of resources leading to high and sustained yield of useful biological material for human welfares.

(v). **Cytoecology:** It deals with the cytological details in a species in relation to population in different environmental conditions.

(vi). **Ecological energetic and production ecology:** These deal with the mechanisms and quantities of energy conversion and flow through organisms, production processes, the rate of increase of organic weight over space and time through both green plants and animals.

(vii). **System ecology:** It deals within the structure and function of ecosystem by means of applied mathematics, mathematical models, and computer programs. It concentrates on input and output analysis and has stimulated the development of applied ecology-the application of ecological principles to the management of natural resources, agricultural production, and problems of environmental pollution.

(viii). **Landscape ecology:** It is the science that studies and improves the relationship between ecological processes in the environment and specific ecosystems. This occurs at various landscape scales, spatial development patterns, and within organizational update and policy levels.

(ix). **Radiation ecology:** It is concerned with the effects of radioactive materials on living systems. There are two important facets of radiation ecology: (i) effects of radiation on individual, populations, communities and ecosystems, and (ii) the fate of radioactive substances released into the environment.

(x). **Ecophysiology:** It is the study of how the environment, both physical and biological, interacts with the physiology of an organism. It includes the effects of climate and nutrients on physiological processes in both plants and animals, and has a particular focus on how physiological processes scale with organism size.

(xi). Gene ecology: Genetic ecology is the study of the stability and expression of varying genetic material within abiotic mediums. This field of study focuses on interaction, exchange, and expression of genetic material that may not be shared by species had they not been in the same environment.

1.4 IMPORTANCE OF ECOLOGY

The study of ecological principles provides a background for understanding the fundamental relationships of the natural community and also the sciences dealing with particular environment such as soil, ocean, forest and inland waters. Many practical applications of this subject are found in forestry, agriculture, horticulture, fisheries, biology etc. The science of plant ecology deals with the scientific study of relationships of plants and their environment and describes the home life plants. It brings out the physiological relationships between plant and their environmental conditions. Science ecological principles are the basis of practice in agriculture and forestry. Ecological is crucial for human well being and prosperity. It provides new knowledge of the interdependence between organisms with their natural environment that is essential for food production, ensuring resources like land and water, and sustaining biodiversity in a changing climate. Ecology is the basis of nature conservation. The following reasons explain the importance of ecology.

1. **Helps in conservation of environment:** The study of ecology allows us to understand the negative impact of human behaviour on the environment. By first identifying the primary means by which the problems we experience in our environment begin, we can help guide conservation efforts. By following this identification process, we show where our efforts will have the greatest impact. Environmental conservation means protecting the planet, conserving its natural resources and improving the quality of life for all living things.
2. **Proper Resource allocation:** Resource allocation is the process of planning, managing, and allocating resources within ecological knowledge. We can know the resources necessary for the survival of various organisms. Ecology provides the basis for developing good conservation policies. Especially when those to whom natural resources are entrusted possess ecological knowledge in areas such as forestry, wildlife, agriculture, land management and fisheries.
3. **Enhances energy conservation:** Conserving energy means reducing energy use by adapting human behavior and habits. All living things require energy for growth and development. Lack of ecological understanding leads to overexploitation of energy resources such as food, light and radiation, resulting in their depletion. Proper knowledge of ecological requirements prevents unnecessary waste of energy resources and saves energy for future purposes.
4. **Eco-Friendliness:** The term most commonly refers to products that contribute to green living, or practices that help conserve resources such as energy and prevent air, water, and noise pollution. Ecology promotes harmonious life within the species and the adoption of a lifestyle that protects the ecology of life.
5. **Aids in disease and pest:** Pests and diseases are a natural part of ecosystems. Many diseases are spread by vectors. Ecological research provides the world with new ways

to understand how vectors and pests behave, and provides people with the knowledge and techniques to deal with pests and diseases.

1.5 THE EARTH ENVIRONMENT

The word ‘environment’ is derived from an old French word “Environ” means ‘encircle’. The environment is the physical, chemical and biological component that affects the life of an organism. The environment is the sum of all biotic (living) and abiotic (non-living) factors that surround and affect an organism. Biotic factors include the availability of food organisms and the presence of biological specificity, predators, parasites and competitors. Abiotic factors include amount of sunlight, ambient temperature, pH of the water soil in which an organism lives. Any external force, substance, or condition that surrounds and affects in any way the life of an organism becomes a factor of its environment. These factors are called environmental factors.

An environmental factor that, by its decrease, increase, presence or absence, limits the growth, metabolic processes, or dispersal of organisms. The environmental requirements of different organisms are individual and vary according to needs and age. Life activities of organisms are affected by the maximum or minimum amount of environmental components such as water, light, nutrients, space, temperature, and humidity.

German Scientist Justus Von Leibig formulated ‘the law of the minimum’, which states that if any plant is deficient in any of its essential nutrients, the plant will grow poorly, even if all other essential nutrients are abundant. However, not only too little of something is a limiting factor, but also too much may limit the growth and distribution of an organism. The concept of the effect of maximum as well as minimum has been incorporated into the law of tolerance by American Zoologist victor Ernest Shelford (1931). According to the Law of Tolerance states that the success of an organism is based on a complex set of conditions, and that each organism has certain minimum, maximum, optimal factors or combinations of factors that determine its success.

The life containing and life supporting environment of the world is restricted to a very irregular layer (5 to 20 km thick) around the globe. This thin veil of life on Earth is called the biosphere. The Earth is made up of four spheres: the biosphere, atmosphere, hydrosphere, and lithosphere.

1.5.1 Biosphere

The global life-containing and life-sustaining environment is limited to a very thin and irregular veil or film around the world. This thin veil of living material of earth is called the ecosphere and biosphere. The word biosphere came from Greek “bios” that refers to “life” and “sphaira” that refers to “sphere”. The biosphere is defined as a region on, above, and below the earth’s surface where life exist. The Austrian Geologist Eduard Suess (1831-1914) first used the term biosphere in 1875 to describe the space on earth that contains life. According to Hutchinson (1970), the biosphere is that part of earth in which life exist. Biosphere is the entire inhabited part of the earth and its atmosphere including the living components. It extends from a few kilometers into the atmosphere to the deep-sea vents of the Ocean.

Biosphere provides the necessary environmental conditions for survival. It is the zone of the earth where land, water, air and other biotic and abiotic elements interact with each other to support life. The entire global environment is basically made of abiotic (non-living) and biotic (living) components. These components together constitute the biosphere. The abiotic global environment is composed of the atmosphere (air), the lithosphere (earth) and the hydrosphere (water), and the biotic component is made of various forms of life inhabiting in the abiotic environment.

The biosphere is one of the four layers that surround the earth along with the lithosphere (rocks), is the outer surface of earth composed of solid and rock, the atmosphere is the surrounding gaseous envelope, and the hydrosphere refers to earth’s liquid water including oceans, lake and rivers.

Biosphere can be divided into many major categories of land called Biomes. A biome is a large region of earth that has a certain climate and certain types of living things. There are five major types of biomes: grassland forest, deserts, forests, and tundra, through some of these biomes can be further divided into more specific categories, such as Savanna, freshwater, marine, taiga, tropical rainforest and temperate.

Biomes are subdivided into small units which are called as zones. For example a forest biome can be divided into canopy zone and ground zone. The animals and plants of each biome have traits that help them to survive in their particular biome. Land-based biomes are called terrestrial biomes. Water-based biomes are called aquatic biomes. Temperatures, precipitation amounts and prevalent organisms characterize the biomes of the World.

Biosphere is made of different types of ecosystem. Living organism requires inorganic metabolites like water, minerals, and oxygen, nitrogen and carbon dioxide etc, for building and maintenance of lives. Living organisms obtain all such inorganic substances from the abiotic counter-parts of the biosphere. The biosphere acts as a life support system for the planet, helping to regulate the composition of the atmosphere, maintaining soil health and regulating the hydrological (water) cycle. Besides the biosphere, the three other main components of the earth are described below.

1.5.2 Atmosphere

The earth is enveloped by a gaseous layer called atmosphere. The atmosphere is the layer of gases which surrounds the earth from all sides and is attached to the earth’s surface by the gravitational force of the earth. Gravity prevents gases that make up the atmosphere from escaping to space. Atmosphere is composed of 78% gas, 21% oxygen gas, 0.9% argon, and trace amounts of water vapour, carbondioxide, methane, ozone, and sulfur dioxide. Atmosphere has four main layers. We start measuring these from sea level and move towards space. The first layer is the troposphere, then the stratosphere, and mesosphere and thermosphere. Above the thermosphere the atmosphere merges with outer space in the layer known as the exosphere. Each of these layers holds different properties. e.g., differences in temperature density, composition of gases etc. The composition of the atmosphere is almost uniform up to about 80 km altitude. The higher the level, the lighter the gas. The atmosphere is denser closer to the Earth and thinner further away. Atmospheric pressure is closer to the Earth than farther from it. The atmosphere has an ozone layer at an altitude of about 32 to 48 km. This layer acts as a barrier that prevents the sun's ultraviolet rays from reaching the earth, which are deadly to living organisms. Among the various components of atmospheric gases, oxygen, nitrogen, and carbon dioxide are essential for the normal functioning of living organisms, as they act as metabolites of living organisms.

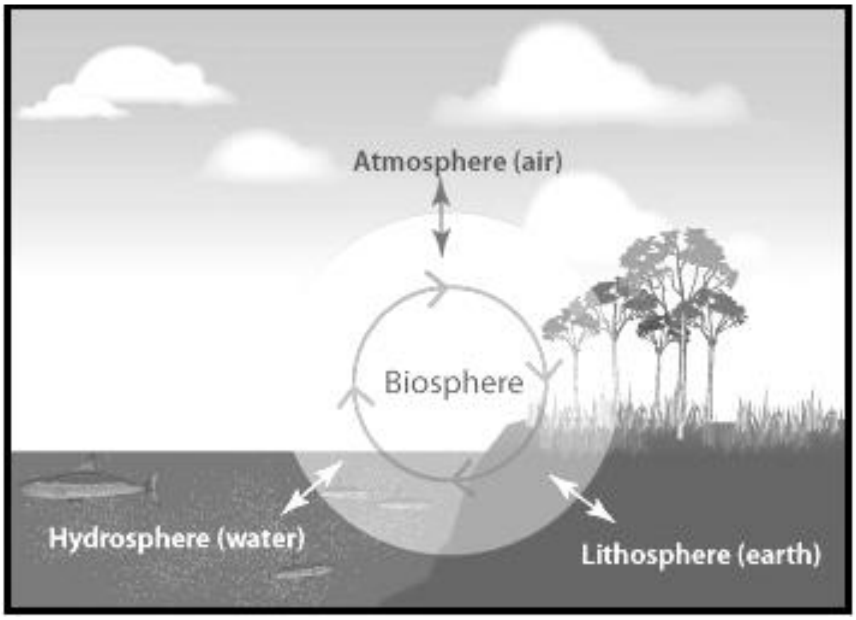

Fig.1.1: Biosphere and its components

Structure of Atmosphere: The atmosphere is divided into five concentric layers which can be distinguished on the basis of temperature. These layers are as follows:

(i). Troposphere: The lowest layer of atmosphere in which man and other living organisms live is called troposphere, ("Tropos" means change) This represents the linear portion of the atmosphere that extends upto 20 km above the earth's surface. It is thin in the polar regions i.e. about 10 km from earth surface. It contains more than 90 percent of gases in the atmosphere. The important events, such as cloud formation, lightning, thundering, thunder storm formation etc, all take place in troposphere. Troposphere is characterized by weather change and steady decrease in temperature with increasing amplitude and it may decrease upto-60^{o}c in the upper layers. The average temperature near the soil surface is about 15^{0}c. The upper layers of troposphere which gradually merges with the next zone or stratosphere is called tropopause. The troposphere provides oxygen that humans can breathe, keeps earth at a livable temperature, and allows for weather to occur, making it a very important part of the atmosphere.

(ii). Stratosphere: The second layer of air mass extending about 30 km above tropopause is called Stratosphere (it is also called ozonosphere).The uppermost layer of stratosphere is called stratopause. In this zone the temperature shows an increase in temperature from a minimum of about -60°C to maximum of 5°C. The increase in temperature is due to ozone formation under the influence of UV (ultraviolet) rays of solar radiation. Ozone is formed from oxygen by a photochemical reaction in which solar energy (symbolized as hv) splits the oxygen molecule to form atomic oxygen which then combines with oxygen molecule to form ozone.

O_2 _______________ 2O (atomic oxygen)

O_2 + O ______O_3 (Ozone)

The above reactions are reversible. Ozone content of stratosphere is constant which means that ozone is being produced from oxygen as fast as it is broken down to molecular oxygen. The highest concentration of ozone (90%) in stratosphere approximately 20-25 km above, around the earth surface is known as ozonosphere. It is important because it absorbs ultraviolet radiation of the Sun and prevents from reaching the earth surface where it would be dangerous to living organism.

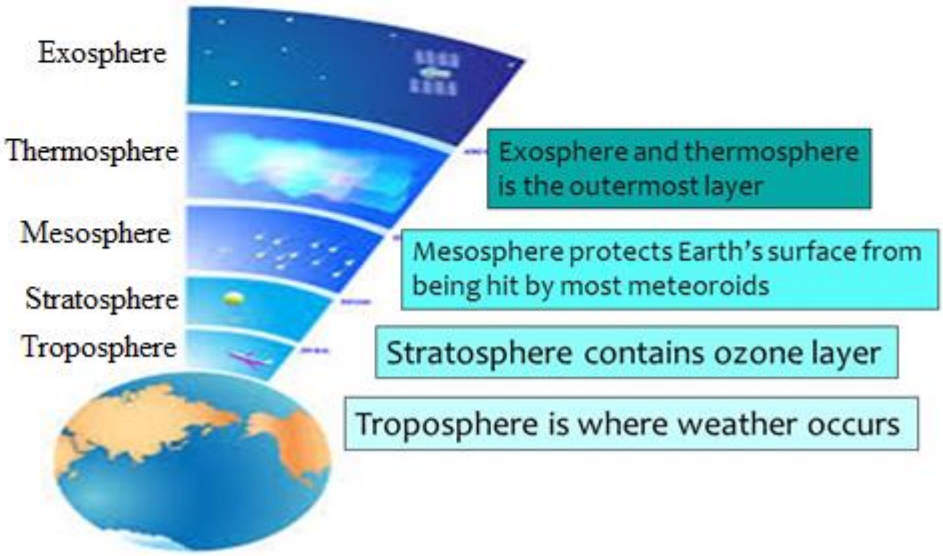

Fig. 1.2: Layers of atmosphere
(Source: http://www.indiagk.net/2016/07/earths-atmosphere-layers.html)

(iii). Mesosphere: The third layer of atmosphere next to stratopause is called mesosphere. It is about 40 km in height. The mesosphere is characterized by low atmospheric pressure and low temperature. The temperature begins to drop from stratopause, goes a decreasing with the increase in the height and reaches a minimum of about -95°C at a level same 80 to 90 km above the earth surface. The upper limit of the mesosphere is called mesopause.

(iv). Thermosphere: Next to mesosphere is thermosphere, which extends upto 500 km above the earth surface is completely cloudless and free of water vapor. Thermosphere is characterized by steady temperature increase with the height from mesopause. The thermosphere includes the regions in which ultraviolet radiations and cosmic rays cause ionization of molecules like oxygen and nitric oxide. This region is called ionosphere. In ionosphere, molecules of gases are so widely spaced that high frequency audible sound is not carried by the atmosphere.

(v). Exosphere: The region of atmosphere above the thermosphere is called exosphere or outer space which lacks except those of hydrogen and helium. This extends upto 32190 km from the earth. Exosphere has a very high temperature due to solar radiation. The earth is magnetic, field become more important than gravity in distribution of atomic particles in the exosphere.

Importance of Atmosphere

1. **The atmosphere and Sound**: Sound is a form of energy that travels in waves. Sound waves cannot travel through empty space, but they can travel through gases. Gases in the atmosphere provide a source for sound to travel through, and it also allows birds, insects, and airplanes to fly through.
2. **The atmosphere and living things:** The gases in the atmosphere, namely oxygen and carbondioxide, allow organisms on earth to live. Plants need carbondioxide for photosynthesis. Through photosynthesis plants are able to use carbondioxide to create sugar for food. The reaction for photosynthesis is:

   $$6CO_2 + 6H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 \text{ (sugar)} + 6O_2$$

   Animlas undergo a process that allows them to use oxygen in order to convert sugar into usable energy. Plants also undergo this process in order to consume some sugars they produce. The reaction for respiration is:

   $$C_6H_{12}O_6 \text{ (sugar)} + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{usable energy}$$

3. **The atmosphere and Earth's temperature:** The atmosphere keeps the temperature of the earth constant so that it is suitable to support life. The water vapour and carbondioxide present in the lower layers of the atmosphere absorb the heat radiated by the earth's surface, and as such they keep the atmosphere warm even during night. Gases in the atmosphere keep out some of the Sun's scorching heat during the day.
4. **The atmosphere and earth's water:** The atmosphere serves an important purpose as a medium for the movement of water. The atmosphere contains a lot of water vapour and acts as an important reservoir for water. It plays significant role in the water cycle. It facilitates the formation of clouds which remains suspended until they are heavy enough to pour down on the earth as rain or snow.
5. **The atmosphere and the Sun's rays:** The atmosphere acts like a blanket or a glasshouse for the earth. The earth's atmosphere acts as an insulating layer that protects the earth's surface from the intense light and heat of the sun. It protects us from UV and other short wavelength light that would otherwise do a lot of damage to the DNA of living organisms. The presence of ozone layer does this by reflecting the UV rays of the Sun. Gases reflect or absorb the strongest rays of sunlight and receives

the radiation of the Sun but does not allow the insolation to escape into space. As such it keeps the earth warm.

1.5.3 Hydrosphere

All the water bodies on the earth' surface namely lakes, rivers, ponds, ocean, sea together with ice and snow; are collectively called the hydrosphere. The word hydrosphere comes from the Greek word hydro which means 'water' and 'sphere' stands for a 'round', ball-like, spherical shape. The hydrosphere is the biosphere's aquatic component and it covers about 73% area of the earth's surface. About 97 percent of the total water of the globe is found in the ocean and the rest 3 percent consists of the water of the ponds, lakes, rivers and the water obtained from snow and ice. Water is the major inorganic nutrient needed by all living organisms; hence, water is essential to all life. First life originated in water. Water is one of the main agents in pedogenesis and is also the medium for several different ecosystems. The chemical formula for water is H_2O which indicates that a single molecule of water is made up of two hydrogen atoms and one oxygen atom. Water moves through the hydrosphere in a cycle, known as hydrological cycle. It is critical to the existence of the hydrosphere. It consists of different stages described below.

Hydrological Cycle

Water as an important ecological factor determines the structure and function of the ecosystem. Water is constantly being cycled between the atmosphere, the ocean and the land. This process occurs in the cycle continuously so it is called the water cycle or hydrological cycle. This cycling is a very important process that helps sustain life on earth. Cycling of all other nutrients is also dependent upon water as it provides there transportation during the various steps. It acts as a solvent medium for their uptake of nutrients by organism. The continuous circulation of water in earth atmosphere system is composed of the following components: Evaporation, transpiration, sublimation, condensation, precipitation, runoff, infiltration and percolation, groundwater flow. The energy for driving the water cycle comes from the sun. Solar heat evaporated water from the ocean which is the great reservoir of water and other bodies of water (such as river, ponds, lakes etc) through the process of evaporation. A lesser amount of water is also evaporated from the surface of land and from plants, a process called as evapotranspiration. The direct conversion from soild (ice and snow) to vapour, is known as sublimation. All this vaporized water forms clouds which moved by winds, may pass over land where they are cooled enough to precipitate the water as rain or snow. Some of the precipitated water soaks into ground, some runs off the surface into stream and goes directly back to the Seas. Then it evaporates into the atmosphere to start cycle all over again. During the process of water cycle, water changes into three states of matter- Solid, liquid and gas. The frozen part of the hydrosphere for e.g., glaciers, icecaps, iceberg etc. has its own name, the Cryosphere. Earth's climate and climate variability are largely driven by the cycling of water and energy exchanged among the ocean, atmosphere, and land.

Components of Hydrosphere

- **Glaciers:** Water that melts off of glaciers.

- **Oceans:** 97 % of the earth's water is salt water located mainly in the sea.
- **Ground water**: Rainwater that infiltrates rocks and soil into the earth's surface make up a small portion of the fresh water on earth.
- **Fresh water:** Only a small portion of the earth's water is freshwater (only about 3%), which is found in a variety different places such as rivers, lakes, underground etc.
- **Surface Water:** Surface sources of freshwater consist of lakes, rivers, and streams.

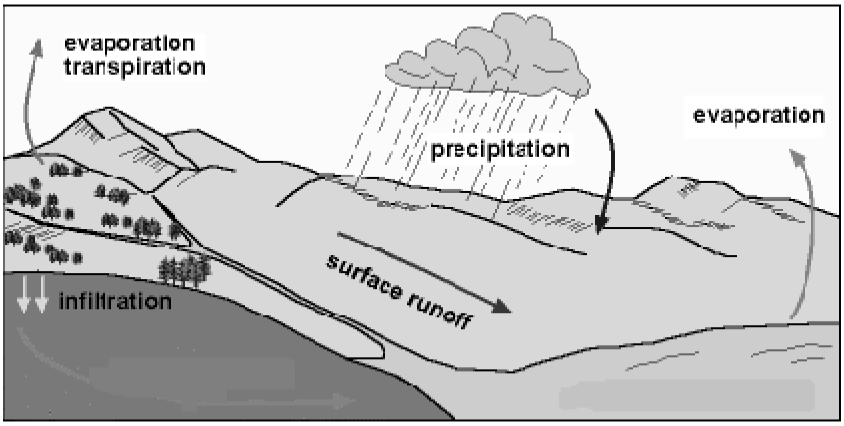

Fig. 1.3: Hydrological Cycle

Importance of hydrosphere: Hydrosphere plays an integral role in the survival of all life forms.

1. **A substance found in living cells:** The hydrosphere is the source of water is a substance found in living cells. In each living cell, there is at least 75% water that promotes the cells normal functioning. The majority of chemical reactions in living organisms involve materials that are dissolved in water. Without water, no cell would survive or be able to carry out its normal functions. The hydrosphere houses the water and serves as a source and reservoir of water to living organisms.

2. **Habitat for many Life forms:** The hydrosphere is home to a wide variety of plants and animals, for instance, water dissolves many nutrients such as nitrite, nitrate, and ammonium ions, as well as gases such as oxygen and carbondioxide. These compounds play an integral role in the existence of life in water.

3. **Atmospheric existence:** The hydrosphere contributes significantly to the current state of atmosphere. When the earth was formed, it had only a thin atmosphere. This atmosphere was comparable to mercury's current atmosphere as it was densely packed with helium and hydrogen. Helium and hydrogen were later evacuated from the atmosphere. As the earth cooled the gases and water vapour were produced, forming the present atmosphere.

4. **Control the weather:** Water has a high specific heat, which means it absorbs or loses a lot of heat with small temperature changes, as well as a high latent heat, which means it absorbs or releases a lot of heat with evaporation or freezing. These

properties aid in the stabilisation of plant temperatures and the surrounding environment. It plays an important role in regulating temperatures on Earth, ensuring that temperatures remain within a range suitable for life. The properties of latent heat of water are important not only because they moderate the temperature of the biosphere, but also because they play an important role in the hydrological (water) cycle by evaporating water and causing it to precipitate (condensate) as rain and dew.

5. **Human requirements:** Human benefit from hydrosphere in numerous ways. Besides drinking, water is used for both home and industrial purposes. It can also be used for agriculture, transportation and hydropower to generate electricity.

1.5.4-Lithosphere

The solid component of earth is called lithosphere. The term lithosphere is derived from the Greek words ‘lithos’, meaning stone, and ‘sphaira’, meaning ball or globe. It is the terrestrial component of the biosphere. The uppermost part of the lithosphere that chemically reacts to the biosphere, atmosphere and hydrosphere through the soil forming process is called the pedosphere. The soil provides food, shelter, anchorage and concealment from predators to living organisms. Under the lithosphere is the asthenosphere, the weaker, deeper and hotter part of the mantle. It is a solid rock layer where extreme pressure and heat cause the rocks to flow like a liquid. The asthenosphere's rocks are not as dense as those in the lithosphere.
Tectonic activity is the most well-known feature associated with the earth's lithosphere. A lithospheric plate, also known as a tectonic plate, is a massive and irregular slab or solid rock that usually includes both the oceanic and continental lithospheres. These tectonic plates vary in size. The majority of tectonic activity occurs at the plates' boundaries, where they may collide, tear apart, or slide against each other. Thermal energy (heat) from the lithosphere's mantle allows for the movement of tectonic plates. Thermal energy makes the lithosphere's rocks more elastic. Tectonic activity in the lithosphere is responsible for some of Earth's most dramatic geologic events, including earthquakes, volcanoes, and deep ocean trenches. The lithosphere can be shaped by tectonic activity: At rift valleys and ocean ridges, where tectonic plates are shifting apart from one another, both oceanic and continental lithospheres are the thinnest. Lithosphere is multilayered and includes following three main layers:

1. **Crust:** Crust is the outermost layer of the earth about 8 to 40 km above mantle. Its surface is covered with soil supporting rich and varied biotic communities on which humans and animals live and plants grow. Silica (Si) and aluminium (Al) are major constituent minerals. Hence it is often termed as SIAL.
2. **Mantle:** Mantle lies between the core and crust. It is the second layer of the earth. It extends about 2900 km above the core. This is in a molten state. It is made up of magnesium and silicate rich iron. It is the chief source of magma that finds its way to the surface during volcanic eruptions.
3. **Core:** Core lies beneath the mantle. The core is the central fluid or vaporized sphere having diameter of about 2500 km from the centre and is possibly composed of nickel-iron. Core is divide into two sub-zones:

(a). Solid inner core: It is the centre and the hottest layer of the earth. Thickness of solid inner core is 1,250 km and its temperature is about 5500-7000 degree C. It is composed of nickel and iron, solid due to extreme pressure.

(b). Liquid outer core: Its temperature is about 6100 to 4400 degree C and composed of iron and molten nickel. Outer core spins, creating the earth's magnetic field that protects from solar wind.

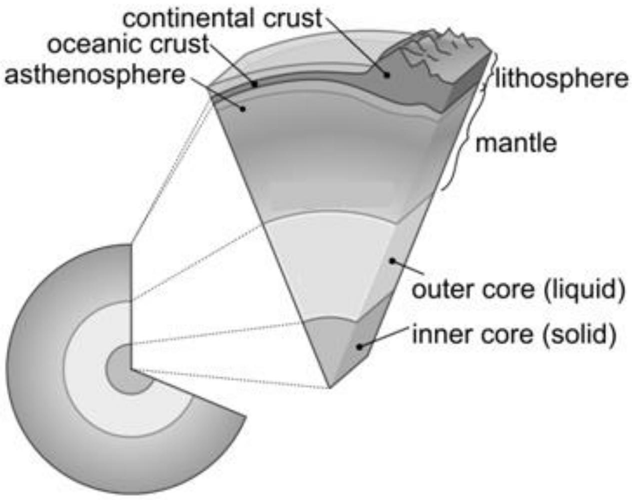

Fig.1.4: Lithosphere comprising the crust and lithospheric mantle
(Source: https://en.wikipedia.org/wiki/Lithosphere#/media/File:Earth_cutaway_schematic-en.svg)

Table 1: Major Elements in the Earth's crust

S.No.	Element	Percent by Volume
1.	Oxygen	46.60%
2.	Silicon	27.72%
3.	Aluminum	8.13%
4.	Iron	5.00%
5.	Calcium	3.63%
6.	Sodium	2.83%
7.	Potassium	2.59%
8.	Magnesium	2.09%

Types of lithosphere: Lithosphere can be mainly divided into oceanic and continental lithosphere.

1. **Oceanic lithosphere:** The oceanic lithosphere is found in ocean basins and is associated with the oceanic crust. It is denser than the continental lithosphere and is composed primarily of ultramafic mantle and mafic crust (oceanic crust). As a result, the oceanic lithosphere is much younger than the continental lithosphere because new oceanic lithosphere is constantly being produced at mid-ocean ridges and recycled back to the mantle at subduction zones. The oceanic lithosphere thickens and moves away from the mid-ocean ridge as it ages. This thickening is caused by conductive cooling, which converts hot asthenosphere into the Lithospheric mantle and causes the oceanic lithosphere to become increasingly dense with age.
2. **Continental lithosphere:** The continental lithosphere is connected to the continental crust and has direct contact with the atmosphere. The continents and continental

shelves are formed by layers of sedimentary and igneous rock. This layer is mostly made up of granite rock.

Importance of Lithosphere

1. Different types of rocks such as sedimentary, igneous and metamorphic rocks are found in the lithosphere.
2. Lithosphere helps to provide the necessary nutrients required to the plants. It provides grasslands, forests and is a rich source of minerals. The Lithosphere is largely important because it is the area that the biosphere (the living things on earth) inhabits.
3. Lithosphere is the major source of fuels such as petroleum, coal and natural gas. When the biosphere interacts with the lithosphere, organic compounds can become buried in the crust, and dug up as coal, oil and natural gas that we can use for fuels.
4. Tectonic plates shift due to convection currents lower down in the mantle, and this can cause the formation of mountains, earthquakes and volcanoes. Earthquakes and volcanoes help in the growth of new vegetation and life as they give rise to fertile soil and lands.
5. The lithosphere serves as a source of minerals and elements, such as copper, magnesium, iron, aluminum.

1.6 ECOLOGY IN INDIA

In India there occur so much variation in ecological conditions from one place to another due to wide climatic and seasonal fluctuations, the ecological conditions of a given area donot remain static for a long time and the flora and fauna of the Indian sub continent have evolved wide range of adaptations to cope with them.

The ancient Sanskrit literature is full of description of plants, vegetation and fauna as related to the environment. References to ecological thoughts, and Charak described the importance of jala means water, vayu means air and gases, Desha means topograpgy and time in regulation of plants life.

Theophrastus (300 B.C.) and other Greek philosophers and scientists like Aristotle, Hippocrates (father of medicine), Reaumur gave ecologically oriented descriptions of organisms. Linnaeus (1970) recognized the influence of environmental factors on the distribution of plants. The first comprehensive ecological contribution was made by Winfield Dudgeon (1921) who published an ecological account of the Upper Gangetic Plains employing the concept of seasonal succession therein. He discussed the role of environment in succession of communities. This was, however, elaborated later by Saxton (1922), Misra (1946, 1958, 1959), however, contradicted this view of succession, and concluded that the processes mentioned therein might be better referred to as seasonality of communities rather than true ecological succession. The Indian ecological society was established in 1974 with eminent ecologist, educationist and administrator, Prof. A.S. Atwal as the founder president. It is one of the pioneering organizations of India engaged in advances in ecological sciences and environmental protection.

Ramdeo Mishra (1908-1998) is known as the father of ecology in India. He laid the strong foundation of ecology in India. He helped in shaping ecology as a major discipline for teaching as well as for research in traditional departments in India in many ways. His research laid the foundations for understanding of tropical communities and their succession, environmental responses of plant populations and productivity and nutrient cycling in tropical forest and grassland ecosystems. He formulated the first post graduate course in ecology in India. Due to his efforts government of India established the National committee for environmental planning and coordination (1972).

The second school of ecology developed with Prof. R. Misra at Banaras Hindu University, Varanasi and Sagar since 1942. Earlier workers (1942-48) examined the effect of soil factors on the plant distribution, the nature of seasonal changes and succession in the plant communities. From 1948-1955 they revealed the dynamics of vegetation and environmental factors in grassland and forests. From 1966 to 1967 emphasis was given on autoecology and production ecology. Since 1967 onwards much emphasis, is on energy flow and productivity of various ecosystem. Champion and Pant (1931), Phadnis (1925), Jagat Singh (1925), and Griffith and Champion (1947) were made autecological studies on forest trees.

In India Prof. F.R. Bharucha student of Braun Blanquet established the first school of ecology at Bombay. He was the director of the Institute of Science from 1954-1959. He was made substantial contribution to grassland and desert ecology. He was the president of Indian Ecological society, vice president of International Botanical Congress and was commissioned by UNESCO to write the report on ecological research. The extensive investigations into the phytosociology of grasslands and mangroves by Bharucha (1941), deserts by Sarup and co-workers and forests by G.S Puri, (1950, 1951, 1960) made turning point in the history of development of ecology in India. Prof. G.S.Puri (1950, 51) made extensive forest ecological investigation and published them in two volumes of the "Indian Forest Ecology" (1950).

Troup (1925), Champion (1929, 1935, 1937), Bor (1947, 1948) etc engaged themselves in the study of ecology of forest vegetation.

In the next phase (1963-1971) the Banaras Centre concentrated on autecology of medicinal plants and weeds (R.S. Tripathi), grassland productivity (J.S. Singh) and forest litter decomposition and productivity (K.P.Singh).

Keeping in view the role of biological productivity in human welfare, launching of IBP (International Council of Scientific Unions) made an important landmark in the development of ecology in India.

S.C. Pandeya developed active centre at Rajkot on Systems analysis, production ecology, desert ecology, grazing lands and other areas. At Shillong, P.S. Ramakrishnan started work in 1974 on ecology of shifting cultivation, weed ecology etc.

At Nainital, (Kumaun University), J.S. Singh started work in 1976 on Himalayan ecology, particularly on forest degradation, regeneration, biomass pattern, productivity, nutrient cycling etc. From a small beginning, ecology has emerged into a frontline science by the turn of the 20th century.

1.7 SUMMARY

Ecology is the branch of science that studies the relationship of human beings to their geographical and social environment. The study of ecology is divided into two subdivisions: (i) Autecology, is the study of inter-relationship between individual species and its environment. (ii) Synecology, is the study of plant communities and its environment. Ecology can be classified into different types as landscape ecology, population ecology, community ecology, freshwater ecology, grassland ecology, ecological energetic and production ecology etc. Ecology seeks to understand life process, adaptation and biodiversity. Environment, on the other hand, aims to identify the internal and external factors that affect population. The biosphere, atmosphere, hydrosphere, and lithosphere are the four spheres that make up the earth environment.

The history of ecology in India began with the descriptive accounts of forests by the officers engaged in forests services in first two decades of the century. Prof. Bharucha established the first school of ecology at Bombay. S.C. Pandey, J.S. Singh, G.S. Puri, K.P. Singh, R. Mishra etc are some notable ecologist.

1.8 GLOSSARY

Ecology: The science of relationship between living organism and their environment.
Environment: The sum total of all biotic and abiotic factors that surround and influence organisms.
Atmosphere: The gaseous envelope surrounding a planet.
Biosphere: The planet earth along with its living organisms and atmosphere which sustain life, i.e. the earth and atmosphere in which organism live.
Hydrosphere: The part of the earth composed of water (ocean, sea, ice cap, lake, river etc.)
Lithosphere: It is the outer solid shell of the earth.
Troposphere: The lowest region of the atmosphere, extending from the earth’s surface to a height of about 6-10 km.
Stratosphere: It is the second major layer of earth’s atmosphere, just above the troposphere, and below the mesosphere.
Mesosphere: It is the third layer of the atmosphere, directly above the stratosphere and directly below the thermosphere.
Asthenosphere: A layer in the mantle that is relatively weak and viscous; lies below the solid lithosphere.
Crust: Outer envelope of the earth surface.
Exosphere: Outermost layer of atmosphere lying beyond the ionosphere.
Ozone layer: A layer of atmosphere (above 30-50 km from earth surface) which contains ozone produced by UV radiation.
Latent heat- Water possesses the highest heat of fusion and heat of evaporation, collectively called latent heat.
Specific heat: Specific heat is a measure of heat capacity, or how much heat a material can store when changing temperature.

Transpiration- The process by which the plant body releases water in the form of vapours through its aerial parts is known as transpiration.
Evaporation: It occurs when surface water is energized by solar radiation.
Sublimation: The movement of water from a solid to a gaseous state without ever entering the liquid state. This allows water from snow or glaciers to enter the atmosphere directly.
Condensation: Condensation is the conversion of water vapour in the air to liquid water.
Precipitation: Precipitation is the falling of water from the sky in various forms (rain, snow, etc.).
Infiltration: The process by which water on the ground surface enters the soil is known as infiltration.
Runoff: When there is more water than land can absorb, runoff occurs. The extra liquid runs off the land and into nearby creeks, streams, or ponds.
Sedimentary rock: Sedimentary rocks form from previously existing rocks or fragments of once-living organisms. They form as a result of deposits accumulating on the Earth's surface.
Metamorphic rock: Metamorphic rocks are rocks that have been altered by intense heat or pressure during their formation.
Igneous rock: Igneous rocks form when molten material from deep within the earth, known as magma, cools and solidifies, forming crystals.

1.9 SELF-ASSESSMENT QUESTION

1.9.1 Multiple Choice Questions:

1. Who coined the word 'ecology'?
   (a) Strasburger (b) P. Odum
   (c) Ernst Haeckel (d) Roxburgh
2. Organisms interact with physical environment that comprises of
   (a) Atmosphere (b) Hydrosphere
   (c) Lithosphere (d) All of these
3. The crust of the Earth along with the cooler, upper part of a mantle is called the-
   (a) Mesophere (b) Stratosphere
   (c) Troposphere (d) Lithosphere
4. Who is considered as the "father of ecology in India"?
   (a) M.S. Swaminathan (b) S.L. Mehta
   (c) Ramdev Mishra (d) Agharkar
5. Name the atmospheric layer that is completely cloudless and free of water vapour.
   (a) Stratosphere (b) Exosphere
   (c) Troposphere (d) Thermosphere
6. The region of air close to the earth and extending up to 10 km high is called:
   (a) Atmosphere (b) Exosphere
   (c) Troposphere (d) Thermosphere
7. Which layer of the atmosphere is also called ozonosphere?
   (a) Exosphere (b) Troposphere
   (c) Mesosphere (d) Stratosphere
8. Who published two volumes of the "Indian Forest Ecology" (1950)?
   (a) F.R. Bharucha (b) Ramdev Mishra

(c) G.S. Puri (d) J.S. Singh

9. Wide variety of living organisms is called:
(a) Population (b) Biodiversity
(c) Habitat (d) Diversity

10. Shelford's law of tolerance is named after:
(a) Jacob Shelford (b) James Shelford
(c) Ernest Shelford (d) None of the above

1.9.1-Answer Key: 1-(c), 2-(d), 3-(d), 4-(c), 5-(d), 6-(c), 7-(d), 8-(c), 9-(b), 10-(c)

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1.12 TERMINAL QUESTIONS

1.12.1 Short answer type Questions:

1. Why is the lithosphere important?
2. Why do we need atmosphere?
3. What is a tectonic plate?
4. What do you understand by the term hydrosphere?
5. Write a short note on Oceanic lithosphere?

1.12.2 Long answer type Questions:

1. Define ecology. Discuss about the types of ecology.
2. Describe in detail about the importance of ecology.
3. Define atmosphere and discuss about its structure.
4. Write a short note on:
   (a) Hydrosphere
   (b) Lithosphere
   (c) Biosphere
5. Give a detailed account about Ecology in India.
6. Discuss about the layers of the atmosphere.

UNIT-2- ECOLOGICAL FACTORS

Contents

2.1 OBJECTIVES

After reading this unit students will be able:

- To understand about the ecological factors
- To discuss about abiotic factors- climatic edaphic and physiographic factors
- To know about biotic factors
- To discuss about anthropogenic factors

2.2 INTRODUCTION

An ecosystem is a community of living organisms interacting with each other and their non-living environment. Modern ecology focuses on the basic functional ecological unit, the ecosystem. Ecosystems are composed of organisms interacting with each other and with their environment such that energy is exchanged and system level processes, such as the cycling of elements, emerge. A.G. Tansley (1935) coined the term "ecosystem" as a biological assemblage interacting with its associated physical environment and located in a specific area. The environment includes chemical, physical and biological components. When a component surrounding an organism affects the life of an organism, it becomes a factor.

In any ecosystem, a living organism is influenced by a number of factors and forces which are known as eco-factors or ecological factors. These environmental factors which influence the behavior, growth, distribution, abundance, and ultimate survival of organisms are of two basic types: abiotic (non-living) environment which determine the interactions between the population and the biotic (living) environmental factors which include interactions between different populations and instinctive control mechanism that are internal to the population itself. (Clapham, Jr., 1973)

All these ecological factors can be divided into the following three groups:

1. Abiotic factors
2. Biotic factors
3. Anthropogenic factors

2.3 ABIOTIC FACTORS

The abiotic factors are non-living chemical and physical elements in the environment that aren't living but which are important to sustain the life of the living. Abiotic factors includes: Climatic, Edaphic, Physiographic etc. The sum total of all these factors constitutes the environment of an organism. Every organism has an ecological minimum and maximum for every factor and the range between two limits is known as limit or zone of tolerance. To explain the effect of different limiting factors on living organisms, number of laws and principles has been proposed by different Scientists. The law of tolerance, usually called Shelford‟s law of tolerance presented by American Zoologist Victor Ernest Shelford in 1911. The law states that, the abundance or distribution of an organism can be controlled by certain factors (e.g., the climatic, topographic and biological requirements of animals and plants) where levels of these exceed the maximum or minimum limits of tolerance of that organism. For example- For the proper development and growth of plants, all the soil nutrients are equally important, but anything in excess might limit the uptake of the other nutrient, restricting the proper growth. German Biochemist, Justus Liebig in 1840, presented the Law of minimum; it states that the growth of an organism is dependent on the amount of food stuff which is presented to it in minimum quantity. For example- if the soil is deficient in any one nutrient, it will make the other nutrient metabolically inactive and the proper growth of the plants will get restricted. Liebig‟s Law of minimum is also incorporated with the Laws of limiting factors developed by British Physiologist F.F. Blackman (1905). This law of limiting factor states that a biological process is controlled by a number of factors and the deficiency of any of these factors will affect the process on the whole. For example- Photosynthesis by plants. Blackman listed five factors involved controlling the rate of photosynthesis are amount of water, carbondioxide, chlorophyll, intensity of Solar radiation and temperature of the chloroplast. The same principle of limiting factors applies to animal functions also. The abiotic variables or factors which affect the living things are given below:

2.3.1 Climatic Factors

Climate is the long term pattern of weather in a particular region. Climate is one of the important natural factors which affect the plant life and responsible for determining the climatic conditions of a region. Its study is known as climatology. The climatic factors are grouped under these categories-

1. Light
2. Temperature
3. Water (Humidity and Precipitation)
4. Wind
5. Fire

1. **Light:** Light is one of the most important abiotic factors without which life cannot exist. The chief sources of natural light are sunlight, moonlight, starlight, and the light produced by luminescent organisms. The sun is the main source of light. Light is the part of the electromagnetic spectrum that can be seen by the human eye. Electromagnetic spectrum is the term used by scientists to describe the entire range of light that exists. The electromagnetic spectrum is generally divided into seven regions, in order of decreasing wavelength and increasing energy and frequency: radiowaves, microwaves, infrared, visible

light, ultraviolet, x-rays and gamma rays. Each particle of electromagnetic radiation, called a photon, has certain amount of energy. Types of radiation with short wave length have high energy photons, whereas types of radiation with long wave lengths have low energy photons. Scientists break it electromagnetic spectrum into three separate categories or division. The short wave includes cosmic rays, x-rays and ultra violet rays, which have wavelengths shorter than 0.4 to 0.7 mm. This is also known as photosynthetically active radiation (PAR).

The medium sized waves are called infrared waves (longer than 0.740 mm). Radiant energy reaching the surface of the earth on a clear day is about 10% ultraviolet, 45% visible light, and 45% infrared. It is a form of kinetic energy from the sun that travels in waves in the form of tiny particles called quanta or photons. Sunlight pass through prism disperse in series of wavelength exhibiting seven different colours- violet, indigo, blue, green, yellow, orange and red (VIBGYOR). All these colours make visible spectrum of light that affect physiological processes of plant. e.g., Photosynthesis. On the basis of wave length, there are three types of ultraviolet radiation. These are:

- UV-A radiation (320 to 400 nm)
- UV-B radiation (280 to 320 nm)
- UV- C radiation (100 to 280 nm)

Out of these three radiation types, UV-C is lethal to organisms, and UV-B, is harmful to the organisms. The intensity of light reaching the earth's surface varies with the angle of incidence, degrees of latitude and altitude, season, time of the day, amount absorbed and dispersed by the atmosphere and a number of climatic and topographical features.

Importance of light to plants: Light affect the growth and distribution of plants through its effect upon soil temperature, photosynthesis, transpiration, rate of water absorption etc. Light is essential for the formation and function of chlorophyll. Three properties of this climatic factor that affect plant growth and development are light intensity, light quality and day length or photoperiod. The intensity of light is measured in terms of foot candle is equal to 10.76 Lux and varies according to the latitude and season of the year. An increased light intensity leads to a high rate of photosynthesis and a low light intensity would mean low rate of photosynthesis. At a very high intensity of light, rate of photosynthesis would drop quickly as the light starts to damage the plant. Light quality refers to the colour or wavelength reaching the plant surface. Day length or photoperiod refers to the amount of time that a plant is exposed to sunlight with respect to the night period. Light affects many physiological activities of the plants. Light influences the plants in the following ways:

(i). Photosynthesis: Sunlight acts as the ultimate source of energy for plants. Plants are autotrophic organisms, which need light for carrying out the process of photosynthesis. Photosynthesis is the process by which plant converts light energy into chemical energy (in the presence of chlorophyll) which is subsequently used for the preparation of carbohydrate from carbondioxide and water. The various wavelengths in Sunlight are not all used equally in photosynthesis. Instead, photosynthetic organisms contain light absorbing molecules called pigments that absorb only specific wavelengths of visible light, while reflecting others. The set of wavelengths absorbed by a pigment is its absorption spectrum. The best wavelengths of visible light for photosynthesis fall within the blue range (450-500 nm), and red range (600-700 nm). Therefore the best light sources for photosynthesis should ideally emit light in the blue and red ranges. Green (500-570 nm) light is least effective. Plants look green, it is because the chlorophyll molecules in the plant absorb blue and red light and reflect other colours, resulting in the green colour we see. The rate of photosynthesis is greater in intermittent light than in the continuous light.

(ii). Respiration: The method by which cells get chemical energy by the consumption of oxygen and the liberating of carbondioxide is called respiration. The process of respiration in plants involves using the sugar produced during photosynthesis plus oxygen to produce energy for plant growth. The process of respiration is represented as follows:

$$C_6h_{12}O_6 + 6O_2 \xrightarrow{\text{Enzymes}} 6CO_2 + 6H_2O + 32\ \text{ATP (energy)}$$

Respiration takes place in all type of living cells and generally called cellular respiration. Cellular respiration is a process that takes place inside the cells where energy is released by the breakdown of glucose molecules. Cellular respiration can occur both aerobically (using oxygen), or anaerobically (without oxygen).

Plants respire all the time, whether it is dark or light. There is no direct effect of light on the respiration. Indirect effect is very important because in the presence of light the respiratory substrates are synthesized. Light at which both photosynthesis and respiration become equal is called as light compensation point. This means that the carbondioxide released from respiration is equivalent to that which is taken up during photosynthesis. The compensation point is reached as light intensity increases. If the light intensity is increased beyond the compensation point, the rate of photosynthesis increases proportionally until the point of light saturation is reached, beyond which the rate of photosynthesis is no longer affected by light intensity.

Effect on transpiration and opening and closing of stomata: Transpiration is the biological process by which water is lost in the form of water vapour process from aerial parts, such as stems, flowers and leaves in plants. In the absence of transpiration, excess water will get accumulated in the plant cells, and the cells will eventually burst. The stomata open during the day and close in the dark. Presence of light is directly proportional to the rate of transpiration.

Light affects opening and closing of stomata, influences the permeability of plasma membrane and has heating effect. All these in turn affect transpiration which in turn affects absorption of water.

(iii) Growth and flowering of plants: The day length, the quality and intensity (photoperiodicity) of light are the most important factors which affect growth and flowering of plants. Based on photoperiodic responses plants can be classified into three groups:

(a) Short-day plants: The short day plants in general develop flowers when the days are less than 12 hours long. Example- *Saccharum officinarum* (Sugarcane), *Glycine max* (Soybean), *Xanthium strumarium* (Cocklebur). Day length is critical and varies from species to species.

(b) Long-day plants: The long day plants develop flower when the days are longer than 12 hours. Example - *Daucus carota* (Carrot), *Lactuca sativa* (lettuce), *Spinacea oleracea* (Spinach).

(c) Day neutral plants: Day neutral plants are those whose flowering are not affected by day length, but rather is controlled by age, number of nodes, previous cold treatment etc. for e.g., tomatoes (*Lycopersicon lycopersicum)* are "day neutral" and do not flower based on the length of the day or night. Instead, tomato plants simply flower after they have reached a certain developmental age. Other examples are- *Helianthus annuus* (Sunflower), *Cucumis sativus* (Cucumber), *Gossypium hirsutum* (Cotton).

Plants which grow in bright Sunlight are called heliophytes and those growing in the shades are called Sciophytes. There are some heliophytes which can grow in shade are known as facultative sciophytes and those heliophytes which fail to grow in shade said to be obligate sciophytes. Similarly facultative heliophytes are those sciophytes which may grow in light and obligate heliophytes are those sciophytes which fail to grow in bright Sunlight. The shade plants maintain a high rate of photosynthesis in low light intensities, while the heliophytes are adversely affected by shade.

Movement: Sunlight affects the movement in plants. The effect of Sunlight on the plant movement is called heliotropism or phototropism. The movement of plant parts towards the light source is known as positive phototropism. For example the growth of plant stem in the upward direction in response to sunlight, whereas the movement of plant parts away from light is known as negative phototropism. For example roots are negatively phototropic as they grow downwards into the soil.

Germination: Most plants need light to grow and keep them healthy, but not all plants need light to germinate. Some seeds germinate best in absolute darkness, and others perform well with continuous sunlight. Experts from Thompson and Morgan report that light in the red wavelength range promotes germination, while blue light impedes it. This is because the red light affects a plant pigment, phytochrome, (regulate the germination of seeds (photoblasty), synthesis of chlorophyll, elongation of seedlings, size, shape and number and movement of leaves and the timing of flowering in adult plants) that is within the seeds. But if the plants are below a thick canopy of leaves, blue light may be needed as well. However, in Typha species yellow light has been found to promote germination of seeds and also counters the inhibitory effect of blue light.

Effect of light on animals: Light affects the various phase of animal life such as growth, development, reproduction and diapause (resting phase), migration, locomotion, metabolism etc. Some major effects of light on animals are described below:

(i) Effect on metabolism: The metabolic rate of different animals is largely affected by light intensity. The increased intensity of light results in an increase in enzyme activity, general metabolic rate and solubility of minerals and salts in the protoplasm. The cave-dwelling animals are not affected much by light. Solubility of gases decreases at high light intensity.

(ii) Effect on pigmentation: Formation of pigments depends on light. It is found that higher the intensity of light, higher will be pigmentation. For example the darkly pigmented skins of human inhabitants of the tropical region have higher concentration of melanin in their skin. Cave animals and many inhabitants of deep sea, where light has no ecological significance, have vestigial eyes or are blind.

(iii) Effect on development: Light in some cases accelerates the development, and in some other cases, it retards. For example, Salmon larvae undergo normal development in sufficient light whereas, Mytilus larvae grows larger in darkness.

(iv) Effect on reproduction: In many animals and birds, the breeding activities are induced by light through its inoculating action over the gonads. The gonads of birds are found to become active during summer (increased illumination) and to regress during winter (shorter periods of illumination).

(v) Effect on animal movement: In certain lower animals, the speed of locomotion is regulated by light. The phenomenon is known as photokinesis. They are of two types:

(a) Phototaxis: Oriented locomotory movements towards and away from a source of light is called as Phototaxis. When an animal moves towards the light source, it is called positively photoactic. *Euglena, Ranatra* are the examples of positively photoactic animals. When an animal moves away from the light source, it is known as negatively photoactic. Earthworms, planarians, cope-podes, slugs, siphonophores are negatively photoactic animals.

(b) Phototropism: Phototropism occurs when only a part of organism shows responsive movement to light stimulus. It is seen in sessile animals.

2. **Temperature:** Temperature is one of the most important ecological factors. The moisture and temperature, acting together, determine in large measure the climate of a region and the distribution of plant and animal life (Smith, 1977). Development and rate of plant growth is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a maximum, minimum and optimum. In organisms all metabolic processes necessary for life start at a certain minimum temperature. The temperature at which physiological processes are at their maximum efficiency is called optimum temperature. Minimum temperature is that below which all metabolic processes necessary for life cannot initiate and proceed with lowest motion. The maximum temperature is the temperature above which no biological activity can be observed. The minimum, optimum and maximum temperatures are called cardinal temperature varies from species to species, and in the same individual from part to part. For example, some hot-spring algae can live in water as warm as 73˚C under favorable conditions and some arctic algae can complete their life cycles in places where the temperature barely rise 0ºC. Non-pathogenic bacteria inhabiting hot springs can actively grow at temperatures greater than 90ºC (Bott and Brock, 1969).

   Organisms which can tolerate a very large fluctuation in temperature for growths are called eurythermal plants include jasmine, roses, conifers, daisy, Ashoka tree etc. The organisms who can tolerate only a small variation in temperature are known as Stenothermal organisms. Stenothermal plants include Eucalyptus, Bougainvillea, Plumeria etc. On the basis of temperature tolerance, fungi have also been classified into the following three kinds: thermotolerant, thermophilic and mesophilic fungi (R. Emerson, 1968). Thermophilic fungi require optimum temperature 45^0C for growth. Temperature influences most plant processes, including transpiration, respiration, etc.

(a). Temperature and cell: The minimum and maximum temperatures have lethal effects on the cells and their components. In the extremely low temperature, cell proteins may be frozen to ice. On the other hand; heat coagulates proteins (Lewis and Taylor, 1967). Few organisms survive temperatures above 45°C because of protein denaturation at high temperature. Certain organisms can exist at higher temperature due to heat stable proteins where as some organisms can exist at slightly lower temperatures using antifreezes such as glycerol, salts.

(b). Temperature and metabolism: Usually the various metabolic activities of plants, animals and microbes are regulated by different kinds of enzymes and enzymes in turn are influenced by temperature, consequently increase in temperature, upto a certain limit, brings about increased enzymatic activity, resulting in an increased rate of metabolism. However, the metabolic rate may decrease when there is higher increase in temperature.

(c). Temperature and reproduction: Flowering in plants is affected by temperature through thermoperiodism (the sum of the responses especially of a plant appropriately fluctuating temperatures). Temperature is an important factor, in the phenology of plants. Phenlogy is the study of periodical phenomena of plants, as the time of flowering in relation to climate; colour changing and leaf fall in the autumn, etc.

(d). Temperature and sex ratio: In some animals the environmental temperature determines the sex ratio. For example, the sex ratio in the copepod *Macrocyclops albidus* is determined by temperature. As the temperature rises there is a significant increase in number of males. In Daphina, under normal condition parthenogenetic eggs are produced, which develop into female. But when the temperature is raised, they give rise to sexual eggs, which after fertilization may develop either into females or males.

(e). Temperature and Parasitic infection: Certain diseases develop on plants due to unfavourable temperature i.e., high temperature together with wind and high humidity causes dissemination and development of bacterial diseases.

(f). Temperature and growth: Plant growth and development is dependent on the temperature around the plant. Each species has a specific temperature range. Both very high and very low temperatures can have a negative effect on plant growth. There are two main forms of extreme temperature stress on plants - cold and heat. During high temperature, membrane stability decreases due to excessive fluidity of lipids in the membrane. There is a disruption of the membrane and cell compartment, leading to problems with function. Low temperatures can cause cold injuries such as dehydration, chilling injury, and freezing injury. In desiccation, tissues are dehydrated and injured due to rapid transpiration and slow absorption during winter. Chilling injury can occur at a range of temperatures that are low but not freezing for that species. Chilling has negative effects on cellular function, growth, and colouration. It can also lead to tissue death. Freezing injury occurs when the temperature is below the freezing point of water, resulting in protoplast shrinkage, destruction of chlorophyll, and ice formation in intercellular spaces, resulting in cellular water movement toward ice.

(g). Temperature and colouration: In warm humid climates many animals like birds, insects and mammals bear darker pigmentation than the races of some species found in cool and dry climates. The phenomenon is known as Gioger rule.

(h). Temperature and respiration: Usually, the rate of respiration becomes doubles as per the Vant Hoff‟s law with increase in temperature by 100 C in case of Poikilothermic animals. According to Smith (1974), optimum temperature for photosynthesis is lower than that for respiration.

(i). Temperature and transpiration in plants: Transpiration is the process of loss of water from the aerial surface of plants. Higher temperature increases the capacity of air to hold more moisture in vapour form, which results in difference between vapour pressure defects, hence the rate of transpiration increases. Besides increasing the rate of transpiration if temperature rises above maximum limits, the plant becomes inactive, and may develop choruses.

(j). Classification of organisms according to temperature tolerance: On the basis of the response of plants to temperature of environment, the entire vegetation can be divided into four classes as:

(i). **Megatherms:** Plants which require more or less constant high temperature throughout the year. e.g., tropical rain forests and desert vegetation.

(ii). **Mesotherms**: Plants of habitat which is neither very cold nor very hot. These plants cannot endura extreme high or low temperature. e.g., tropical deciduous forests and aquatic plants.

(iii). **Microtherms:** These plants require low temperature for their growth. These plants cannot endure high temperature. All high altitude plants of the tropical and subtropical regions included in this group.

(iv). **Hekistotherms:** Plants growing in regions with very low temperature. They tolerate long and extremely cold winter months. e.g., alpine vegetation.

3. **Water:** Water is the basis of life for all living beings on the earth. Water makes up a large proportion of the bodies of animals and plants e.g., cytoplasm holds 70-80 percent of water. Water is a compound composed of two atoms of hydrogen and one atom of oxygen. It is the most abundant compound found in all organisms. Water constantly moves around the earth and changes between solid (snow, sleet, hail and ice), liquid (rain, water droplets) and gas (water vapour). The water cycle, also known as the hydrological cycle is manage by Sun’s energy. This solar energy drives the cycle by evaporating water from the lakes, rivers, oceans and even the soil. Other water moves from plants to the atmosphere through the process of transpiration. The water vapour forms clouds in the air by condensation and precipitates back to earth in the form of rain and snow. In plant,

absorption of nutrients, the rate and magnitude of photosynthesis, respiration, growth and other metabolic processes are influenced by the amount of water available. Water plays diverse roles in plants. As it evaporates from the leaf tissue during transpiration, gives cooling to the leaves. It is also a chief component in photosynthesis and respiration. Water act as a solvent for carbohydrates and minerals moving through the plants. In the atmosphere, water is present in the form of water vapours. This is called atmospheric humidity. Humidity is greatly influenced by intensity of solar radiation, wind, water, status of soil, temperature, altitude etc. Evaporation of water from earth surface and transpiration from plants are the main cause of atmospheric humidity. Most of the plants cannot make use of atmospheric humidity, however, several mosses, lichens, filmy ferns and epiphytic orchids can absorb moisture directly from the air. Clouds and fog are the visible forms of humidity. Humidity is measured using a psychrometer and hygrometer and is measured as a percentage. Humidity is described in three different terms:

- **(a). Relative humidity**: Relative humidity is the ratio of the actual amount of water vapours in the atmosphere to the amount that can be held in the air at a particular temperature and pressure.
- **(b). Specific humidity:** It refers to the “amount of water vapours present per unit weight of air”.
- **(c). Absolute humidity:** It refers to the “amount of water vapours present per unit volume of air”.

Effects of humidity on organisms: It influences the rate of transpiration in plants. Higher the humidity, lesser is the rate of transpiration. Low relative humidity increases water loss through transpiration and affects plant growth. It also influences the rate of sweat in humans. So, at high humidity sweating is more. It is an important source of water for epiphytes like lichens, mosses. It plays an important role in the germination of spores of fungi.

Precipitation: Precipitation is the release of water from clouds that falls to the ground as rain, snow, sleet, or hail. Precipitation occurs when a portion of the atmospheric becomes saturated with water vapor (reaching 100% relative humidity), so that the water condenses and ‘precipitates’ or falls. Precipitation depends upon temperature, wind, season and pressure. Precipitation has a significant impact on productivity and species richness of community or perennials and in determines the vegetation of particular region. Precipitation can affect germination, seedling growth and survival, and phenology (the study of recurrent phenomena), thereby altering annual productivity and species richness in many arid and semi-arid ecosystems.

Plant productivity is influenced not only by quantity of precipitation, but also by temporal patterns of precipitation at a given site. The seasonal precipitation has a stronger influence on productivity than total precipitation in arid and semiarid ecosystems, since water is the most limiting resource.

The main types of precipitation include rain, snow, hail, plus a few less common occurrences such as ice pellets, diamond dust and freezing rain. Thus, mist and fog are not precipitation but suspensions, because the water vapour does not condense sufficiently to precipitate. Rainfall is the most common form of precipitation.

Moderate and continuous rains are beneficial instead of heavy rains because in the heavy rains a large amount of water is lost from the surface of soil as runoff and the soil is eroded. The distinction between equatorial forests zones, desert zones near the tropics and temperate forest zones is based upon rainfall. In India the tropical evergreen forest is found with 100 inch rainfall tropical moist deciduous forest are monsoon forest of Western Ghats, Chota Nagpur correspond to a rainfall of 60 to 68 inches, the tropical dry deciduous forest of Sal and Teak occur in regions with only 40-50 inch rainfall. The regions of negligible rainfall consist of deserts. In terrestrial habitats precipitation is the only source of water for growth of most plants.

4. **Wind:** Air is the invisible mixture of gases present in the troposphere. Air in motion is called wind. Wind is the movement of air, caused the uneven heating of the earth by the Sun and the earth's own rotation. Wind traveling at different speeds, different altitudes, and over water or land can cause different types of patterns and storms. They are a giant, spiraling tropical storm. Hurricane- originated over warm oceans and derives energy from the latent heat of evaporation of water sucked into low pressure centre. These tropical storms are known as hurricanes in the Atlantic Ocean, typhoons in the western Pacific Ocean and cyclones in the western Pacific Ocean. Wind is the great equalizer of the atmosphere, transporting heat, pollutants, moisture, and dust great distances around the globe. Landforms, processes, and impact of wind is called Aeolian landforms. Wind is both an ecological provider and disturbance facilitator influences trees and other organisms. The impact of wind on plants largely depends on speed duration, and the extent to which wind can penetrate canopy layers. When the wind is strong, it can carry sand and snow particles, and thus has a considerable abrasive effect on the ground as well as on plants. The effects of wind on plant life and plant environment may be listed as follows:

Physiological impact

(i). Wind affects rate of transpiration. More transpiration occurs in strong wind regions which results water deficiency in their tissues.

(ii). Wind increases the turbulence in atmosphere, thus increasing the supply of carbon dioxide to the plants resulting in greater photosynthesis rates. Beyond a certain wind speed the rate of photosynthesis becomes constant.

(iii). Wind changes the balance of hormones and also increases the ethylene production in barley and rice.

(iv). Dwarfing: Turgidity helps maturing cells of a plant to normal sizes. The plants developing under the influences of drying winds never attain turgidity that enables them to expand their maturing cells. As a result all organs are dwarfed because their cells attain subnormal size.

(v). When wind is hot, desiccation of the plants takes place, because humid air in the intercellular places is replaced by dry air. For example, rice crop during june-july months shows tip drying.

(vi). The wind accelerates transpiration. Plants are able to grow successfully only so long as they can balance their water income with water outgo. When transpiration rate exceeds that of water absorption, partial or complete closure of the stomata may ensure which will restrict the circulation of carbon dioxide into the leaves. As a result, there will be decrease in the rate of photosynthesis, growth and yield.

Mechanical impact of wind

(i). In high winds, leaves can be deprived from plants, and under extreme conditions, plant stems may be broken or plants uprooted. Usually such breakage occurs in soft woods of such plants as cotton woods and river maple.

(ii). Lodging: Lodging is a form of wind injury caused by violent wind in which the crop plants (wheat, maize, and sugarcane) flatted against the ground. But if the stems are not too mature, the prostrated plants become partially erect once more by means of differential growth at the lower node.

(iii). Plants growing at higher altitude show undeveloped growth because of the effects of wind.

(iv). Deformation: When developing shoots are subjected to strong wind pressure from a constant direction, the form and position of the shoot may become permanently altered. This is called deformation. Trees with inclined trunks are commonly observed on ridged. Some trees such as oaks grow flattened against the ground while in others the tree branches developing in a leeward direction.

Other Effects of Wind

(i). When the wind moves the soil from one area to another, this is called wind erosion. It is a natural process that moves soil from one location to another by wind. It can cause important economic and environment damage.

(ii). Wind causes the lifting and transport of lighter particles from a dry soil, leaving behind a surface of coarse grained sand and rocks.

(iii). Wind is a critical means of transportation for seeds, insects and birds, which can travel on wind currents for thousands of miles. The most of gymnosperms are pollinated by the wind and this phenomenon is called as anemophily. Anemophily is the process when pollen is transported by air currents from one individual plant to another.

(iv). The coastal area affected by strong wind brings salt and make the soil unsuitable for growing plants.

(v). Wind also disperses many types of particles (plant propagules, pollen, disease organisms) as well as moving gas molecules (CO_2, Pollutants).

5. **Fire:** Fire is that stage of heat in which things get burned and from them heat and light rays emerges which affect the environment. A fire needs three things: heat, fuel and oxygen. The fire may be caused by (i) volcanic activity, (ii) lighting, and (iii) biological origin. The fire is usually human caused such as campfires, arson, discarding lit cigarettes, not burning debris properly, playing with matches or fireworks and sometimes chiefly in forests develop due to mutual friction between trees (bamboos etc) surfaces. Fire affecting the plants may be of the following types:

(i). **Ground Fire:** This type of fire is flameless and subterranean and usually occurs in deep accumulations of humus, peat and similar dead vegetation that become dry enough to burn. These fire are particularly dangerous as they can 'hibernate' below the surface during a warm winter and re emerge one the weather gets warm again.

(ii). **Surface Fire:** The fire which sweep over the ground surface, their flames consume the litter, living herbs, shrubs and also scorching the trees which in contact. Surface fires are the most fame fire can be put out relatively easily.

(iii). **Crown fires:** The fire which extends from dense, woody vegetation and travels from the canopy of one plant to another. Crown fires pose the highest risk by far due to their fast spreading behavior.

The direct effect of fire on plants is lethal. The different plant organs like leaf, stem etc, have direct effect of fire. Due to higher temperature protoplasm gets destroyed and that plant organs dies. Fire as a destructive force can rapidly consume large amount of biomass and cause negative impacts such as air pollution, post-fire soil erosion and water runoff. Once trees have been removed by fire or logging, infiltration rates become high and erosion low to the degree the forest floor remains intact. Severe fires can lead to significant further erosion if followed by heavy rainfall.

Fire influences both living and physical elements of environment. Fire can become hazardous to surrounding infrastructure and people. It can destroy vegetation, reducing the amount of precipitation absorbed by plants. Major fires can burn off humus in the soil and reduce soil fertility. Indirectly the fire has the following effects on vegetation:

- Fire controls the age of the forest by interrupting and altering succession. Periodic fire limits the number of saplings that survive and hence the number of trees per hectare.
- Fire helps in removal of competition of surviving species.
- Fire impacts on habitats, stimulating flowering and fruiting of species and increasing the availability seeds and berries. The quality and quantity of browse increase after fire and the population of wood boring insects increase. This is important to quail and wood peckers.
- Reduce competition, allowing existing trees to grow larger. To control the encroachment or development of undesirable food plants such as legumes for both forage and soil improvements or shrubs.
- It stimulates seed production or opening of cones and prepares seedbeds for seeding, either naturally or artificially. Some plants like *Populus tremuloides* get stimulated to growth by fire.
- Some plants, such as the Eucalyptus, lodge pole pine, Banksia have serotinous cones or fruits that are completely sealed with resin. These fruits or cones can only open to release their seeds after the heat of a fire has physically melted the resin.
- Fire remove unpalatable growth remaining from previous seasons and stimulate growth during seasons when there is little green grazing. Several grasses such as *Cynodon dactylon, Aristida stride* etc get stimulated by fire to produce large quantities of seeds.
- Fires often remove alien plants that compete with native species for nutrients and space, and remove undergrowth, which allows sunlight to reach the forest floor, thereby supporting the growth of native species.
- Fire removes low-growing underbrush, cleans the forest floor of debris, opens it up to sunlight, and nourishes the soil. Reducing this competition for nutrients, allows established trees to grow stronger and healthier.

2.3.2. Soil (Edaphic Factor)

Soil is one of the most important ecological factors called edaphic factors. Treshow (1970) defined Soil as a complex physical biological system providing support, water nutrient and oxygen for plants. Soil is the loose, friable, unconsolidated top layer of earth’s crust and is a mixture of mineral and organic matter that contains air, water and micro-organism. According to Dokyachev (1879), the first soil scientist, the soil is the result of the actions and reciprocal influences of parent rocks, climate, topography, plants, animals and age of land. Soil is the most important in ecological function as the basis for the growth of terrestrial plants, including supplying nutrient, water, temperature and moderation. It is the outermost layer of the surface of the earth in which roots grow and anchor the plants and from which plant derive water and nutrients. The Study of Soil Science is known as Pedology.

Soil formation: Soil are complex mixture of minerals, water, air, organic matter and countless organisms that are the decaying remains of once- living things. Soil is formed by disintegration and decomposition of rocks by fragmentation or break-down or weathering and the action of soil organisms such as Fungi, bacteria etc and through interactions of various chemical substances present in the soil.

Soil Profile: A soil profile is the term used for the vertical cross-section of the soil, made of layers running parallel to the surface. These layers are known as soil horizons. Each of each varies in thickness, texture, colour, structure, composition, consistency, porosity, and acidity. These layers or horizons are represented by letter O, A, E, B, C, and R. From the surface down ward the following layers can be conveniently made out in these horizons (Fig. 2.1):

O horizon: The uppermost horizon of soil profile is called O horizon or litter zone. It is mainly composed of organic material like dead leaves, grasses, dried leaves, fallen trees, small rocks, twigs, surface organisms and other decomposed organic matter. It includes following two sublayers:
O_1 horizon: It is the top layer of soil which is mainly composed of organic materials such as dead leaves, bark, dried leaves, grasses, small rocks, twigs, fallen trees, fruits, flowers, animal excreta etc. The colour of the soil is generally black brown and dark brown due to the existence of organic matter.
O_2 horizon: O_2 horizon underlies the O_1 or litter horizon and contains blackened unrecognizable decomposed litter. The upper portion of O_2 horizon contains partially decomposed detritus, the duff, so is called duff layer. Its lower part contains completely decomposed, light and amorphous organic matter, the humus. Humus provides nutrients to the soil, therefore, making the soil more fertile. Many living organisms are present in this layer, for example, worms, beetles etc.

A horizon: Underlying the litter zone is the A horizon or topsoil. A horizon includes following three sub zones:
(i) A_1 Horizon: It is the zone of humus incorporation with minerals of soil. It is the uppermost layer of the soil that consists of dark decomposed matter and relatively rich in organic materials thoroughly mixed with the mineral soil. This layer consists of microorganisms such as bacteria, earthworms, fungi etc.
(ii) A_2 horizon: A_2 horizon underlies A_1 horizon and is the zone of maximum leaching. It contains less humus and is a light-coloured horizon from which materials such as aluminium, silicates, clays etc are being removed at the greatest rate.
(iii) A_3 horizon: It is transitional to the subjacent B horizon. It is transition zone between A and B horizons.

E horizon: E horizon is composed of nutrients leached from the O and A horizons. It is present only in the older soils and forest soils.

B horizon- This is known as subsoil lying under A horizon. Roots develop poorly in this zone. Rich in minerals that leached (moved down) from the A horizons and accumulated here. It is also divided into B1, B2 and B3 zones. A and B horizons collectively represent the true soil.

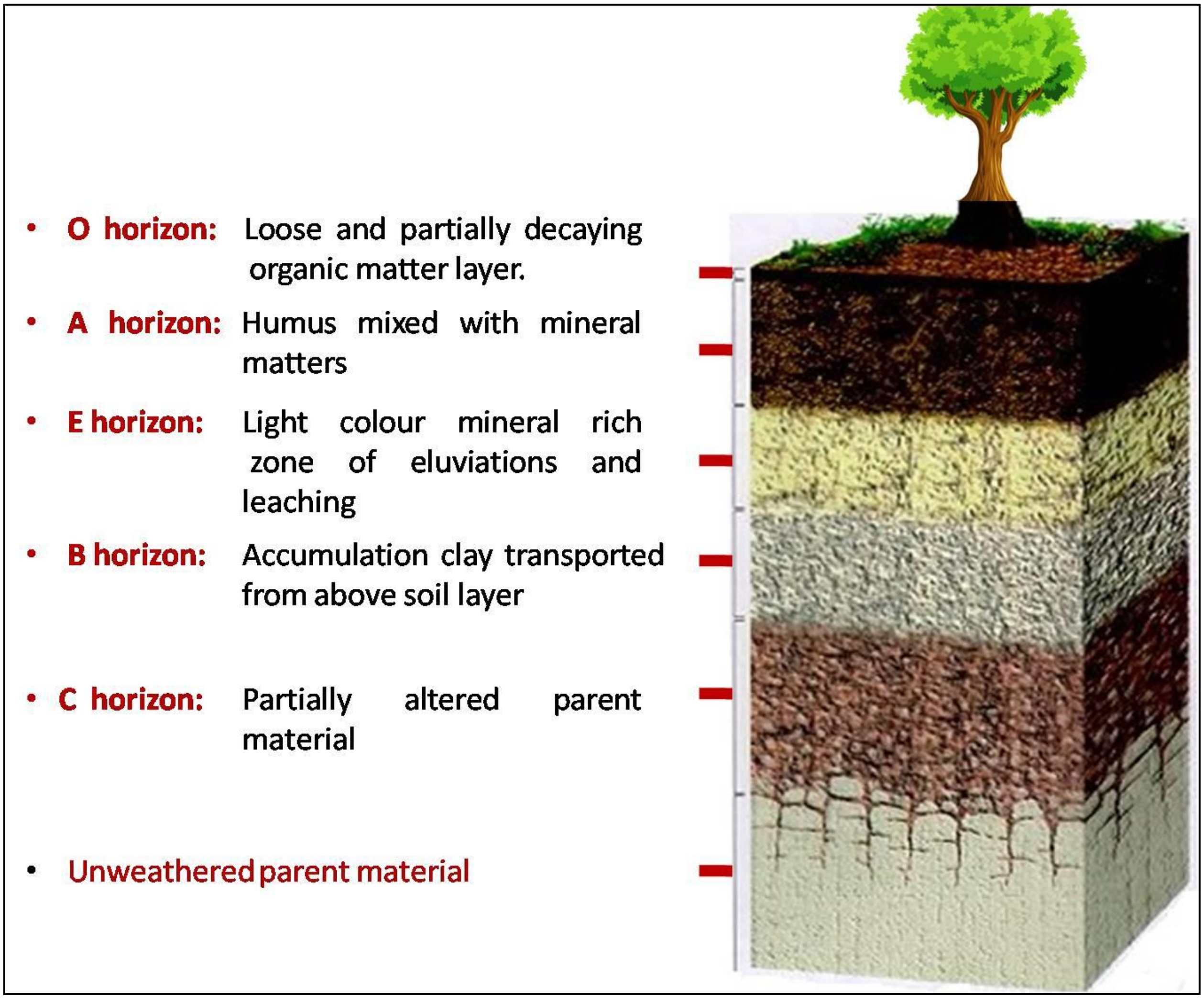

Fig. 2.1 *A representation of the soil horizons within the profile of a typical forest soil. Forests soils tend to have 5 layers, including a surface layer of decomposing plant debris, as well of a zone of leaching. (Image recreated by author, Original source of image: https://www.ctahr.hawaii.edu/mauisoil/a_profile.aspx)*

C horizon: It presents below the B horizons. This layer consists of weathered rock or sediment that serves as the parent material for the mineral fraction of the soil. It is light-coloured and doesn’t contain organic substance in it. This layer is also known as saprolite.

R horizon: C horizon is underlain by un-weathered bedrock which is called R horizon. It is a compacted and cemented layer. Different type of rocks such as limestone, granite etc found here. The important edaphic factors which affect the vegetation are as follows-

1. **Soil moisture:** Soil moisture is the water stored in the soil and is affected by temperature, precipitation, soil characteristics etc. The main source of soil water is precipitation. Types of water in the soil:

   (a). Gravitational water: This is a free form of water which percolates downwardly through the pore spaces between soil particles and accumulates in the pore spaces in the form of ground water. This soil water is ecologically important in the leaching of nutrients.

   (b). Capillary water: The amount of water that is retained in minute interstitial spaces in the form of thin films surrounding the soil particles is known as capillary water. This has a positive water potential and is freely available to plants.

   (c). Hygroscopic water: Some water in the soil forms an extremely thin tightly held film around the soil particles. It is called hygroscopic water. The water is held so tightly by the soil that it cannot be taken up by roots.

   (d). Water vapour: This is water vapour present in air, which can be absorbed by hanging roots of the epiphytes due to presence of spongy velamen tissue and hygroscopic hairs.

   (e). Combined water: In the soil, a small portion of soil water is chemically bound with soil material which is called combined water. This type of water is not available to the plants.

Total amount of water present in the soil is called holard. Chresard or available water refers to the amount of water that can be used by plants. The amount of water that cannot be absorbed by plants is termed as echard or non-available water. The availability of soil moisture is influenced by so many conditions, such as the sizes of soil particles, the quantity, duration and intensity of rainfall, the distribution of precipitation, throughout the year, the rate at which water percolates. The quantity of soil water available to plants is a great determining factor of nature, composition and stature of vegetation at any place.

2. **Soil pH:** Soil reaction, or pH, is a measure of the alkalinity or acidity of the soil solution or of the amount of active hydrogen ions present in the soil. As regards their nature, some soils are acidic; some are neutral and some basic. Any pH reading below 7 is acidic and any pH above 7 is alkaline. A pH value of 7.0 indicates a neutral soil. Normally, pH value of soils lies between 2.2 and 9.6. PH value of soil influences the availability of essential nutrients. For example, some plants require considerable amounts of calcium (Calciphytes) and thus grow on basic soils. Plants requiring low calcium amounts are called Oxylophytes. Highly alkaline or saline and highly acidic soils are often injurious for plant growth and micro-

organisms, etc. At low pH, generally zinc, copper, manganese, aluminium, and iron become toxic. However, most plants grow best in soils with a neutral or slightly acidic pH.

In India, acidic soils (pH below 5.5 to 5.6) occur in the high rainfall areas of Western Ghats, Kerala, Eastern Orissa, Manipur, Assam and Tripura. The saline, alkali or basic soils of India occur in Uttar Pradesh, Punjab, Bihar, Orissa, Maharashtra, Madras, Andhra Pradesh, Madhya Pradesh, Gujarat, Delhi and Rajasthan.

3. **Soil Nutrients:** Soil is a major source of nutrients needed by plants for growth. Nutrient absorption by roots is a process of ion exchange at the surface. Usually, inorganic solutes are absorbed by the plants in the ionic forms. The chief inorganic components of soil are the compounds of Aluminium, Silica, Magnesium, Calcium, Sodium, Potassium and Iron. Soil also contains trace elements like Manganese, copper, Boron, Zinc, Iodine, Cobalt, Molybdenum etc. The chief organic component of soil is humus, a dark coloured amorphous substance formed by partial degradation of dead organic remains. Humus chemically contains amino acids, purines, proteins, aromatic compounds, pyrimidines, hexose sugars, sugar alcohols, methyl sugars, oil, fat, waxes etc.

4. **Soil atmosphere:** Gases found in pore spaces of soil profiles form the soil atmosphere. The spaces between the solid soil particles, if they do not contain water, are filled with air. The soil atmosphere contains three main gases namely nitrogen, carbondioxide and oxygen. The soil air differs from atmospheric air in that it has a higher concentration of CO_2 and moisture and lower concentration of O_2. Soil atmosphere is affected by wind, temperature, rainfall etc. Loam soils with humus contain a normal proportion of water and air (about 66% water and 34 % air) and, therefore, are good for majority of crops.

5. **Soil temperature:** Soil temperature is the measurement of the soil and may be determined with the help of soil thermometer. Soil gets heat energy from different sources such as decomposing organic matter, heat formed in the interior of earth and solar radiation. The factors that affect the amount of heat supplied at the soil surface include, solar radiation, soil colour, soil mulching, slope of land surface, vegetative cover, organic matter content and evaporation. The evaporation of water from the soil decreases its temperature and makes it cooler. Dark coloured soils absorb more radiant heat than light coloured soils. Soil temperature governs the soil chemical, physical and biological processes.

6. **Soil organism:** Organisms present in the soil are called soil organisms. Soil animals (fauna) range in size from macrofauna (earthworms, moles, millipedes) through mesofauna (mites and springtails) to microfauna (protozoan and nematodes. Soil plants (flora) include roots of higher plants, soil fungi, algae, bacteria, and soil actinomycetes. Soil organisms feed on the organic matter of the soil and indulge in various activities such as decomposition of animal

and plant residues, nitrogen fixation in the soil, decaying and cycling organic material, breaking down toxic materials, soil aeration (especially done by earthworms), degradation of toxicants including pesticides, create humus, production of polysaccharides to improve soil aggregation and increase plant nutrients in available forms. In the absence of oxygen some soil microbes secrete chemicals, such as organic acid, aldehydes which may show toxic effects on many plants.

2.3.3. Physiographic factors (Topographic factors)

Physiographic factors are those that are associated with the physical nature of an area. These factors include the topography of the area, the slope of the land, the height of the land above sea level, sand silting and blasting, degree of erosion etc. These factors influence vegetation, which in turn can cause variation in climate throughout a region. This, in turn, gives rise to a localized microclimate. The microclimate represents the climatic conditions that prevail at local scale, e.g., the immediate surroundings of plants and animals. Some of the important physiographic features are discussed below.

1. **Altitude of the place**: Altitude is the height of the land above Sea level. Higher altitudes bring faster winds, lower temperatures and pressure, and higher humidity and light intensity. All these factors together give a definite pattern of vegetational zone. With the increasing altitude, wind velocity also increases thus promoting the rate of transpiration. Plants growing at higher altitudes show stunted growth because of the effects of wind.

2. **Steepness and exposure of the slope:** Slope is the gradient or steepness of a particular surface of the Earth. It affects the amount of solar radiation received during the day. The steep slopes increase the amount of solar radiation, especially at higher altitudes. In the northern hemisphere, the southern slope receives more solar radiation than the northern slope. This is probably because the sunlight hits the steep southern slope almost vertically during the day, while the sunlight hits the northern slope only obliquely in the morning and evening. Slopes play a very important role in determining soil properties. The downward movement of rain water removes soil from a slope and carries it down and may deposit in the valley. The water moving over the slopes causes erosion of the top soil and as a result of this vegetation disappears from the areas.

3. **Direction of mountain chains:** The direction of mountain ranges greatly affects the amount of rainfall in a region. Mountain ranges direct the wind in certain directions, trap moisture from the wind on certain sides, and condense water vapor in the form of clouds and rain in higher areas. This may be the reason that on certain sides of the high mountain, one can see rich vegetation, whereas on the other side, there occurs scanty vegetation.

2.4 BIOTIC FACTORS

Biotic describes a living component of an ecosystem. The term "biotic" is formed by the combination of the two terms, "bio" meaning life and "ic" meaning like. Thus, the term means life-like and related to all the living entities present in an ecosystem. All living beings constitute the biotic components of the ecosystem. Biotic means living, and biotic factors are the other, living things, such as plants, animals, microorganisms. Biotic factors are categorized into three groups: Producers or autotrophs, consumers or heterotrophs, and decomposers or detritivores. Examples of biotic factors include: Grass as producers (autotrophs). Deer, mouse, owl etc as consumers (heterotrophs), and earthworms as decomposers (detritivores). The assemblage of different plants, animals and microorganisms in any given ecosystem or in any given physical environment is a community. The biotic communities may be large such as grasslands, forests, deserts or small such as ponds, rivers, meadows etc. All the organisms of a community share same habitat, live together and influence each other's life directly or indirectly. Various life processes such as reproduction, distribution etc depends very much upon the interactions between organisms. There may be positive or negative interactions of species and can be found in any community. It may be either beneficial to both partners or harmful to both, or beneficial to one and harmful to the other, or it may be neutral for the others. Ecological interactions can be divided as either intra-specific or inter-specific. Intraspecific interaction competition occur between individuals of the same species, while interspecific is competition between individuals of different species. These relationships can be either positive, or they can negative. Positive (+) sign is assigned to beneficial interaction, 'O' sign to neutral interaction and negative (-) sign to negative effect.

Interspecific relationship:

Interspecific relationships between two or more species can be found in any community and belong to two main categories- Symbiosis and antagonism.

1. **Symbiotic Relationships:** Symbiosis means, 'living together'. It is a close relationship between two organisms in which one of the two or both benefits from each other. The perfect example of symbiotic relationship between two plants is lichen. In lichens, the algae and fungi live together in an intimate symbiotic relationship. The alga synthesizes organic food which is utilized by both the algal and fungal components. In return, the fungal component provides moisture and mineral elements to alga. Symbiotic relationships include mutualism, commensalism, proto-cooperation.

   (a). Mutualism: Mutualism is an interspecific interaction between two species that benefits both members. For example, the partnership between nitrogen- fixing bacteria and leguminous plants. The organisms involved in mutual relationship cover a wider range, namely (1) Plant-plant, (2) animal-animal, or (3) Plant-animal associations. Some examples of mutualism are as follows:

(i). **Pollination by animals:** Pollinators such as butterflies, bees, moths etc., transfer the pollen from an anther to a stigma, In turn, the pollinators feed on the nectar that the flower secretes.

(ii). **Role of animals in the dispersal of fruits and seeds**: Generally, the animals are helpful in the dispersal of fruits and seeds from one place to another. Ants are good agents for transporting oily seeds and small grains of cereals.

(iii). **Symbiotic nitrogen fixation:** Symbiotic nitrogen occurs through associations of plant roots with nitrogen-fixing bacteria. The best studied example is the association between legumes and bacteria in the genus Rhizobium. The host plant provides nutrients for the bacteria and the bacteria in return fix atmospheric nitrogen to the host plant in absorbable form.

(b). Commensalism: Commensalism is a relationship where one species benefits and one is unaffected. For example- Bamacles catch a "ride" with whales for protection and food; epiphytes get sunlight and nutrients by living on the host plant. Another example is of lianas. Lianas are woody vascular plants rooted in the soil at ground level and use trees, as well as other means of vertical support, to reach on the top of the plants canopy. *Bauhinia vahlii, Tinospora, Entada gigas* etc are examples of Lianas. This association of lianas with tree is commensalism because tree provides support to the plant without any benefit to the tree.

(c). Proto-cooperation: It is a positive interaction in which both the species benefit but which is not necessary for their survival. Example of proto-cooperation is the removal of ecto-parasites from the back of bovines by some birds that eat the parasites. In this interaction birds get food from the bovines they clean, and in turn the bovines get rid of parasites.

2. **Antagonism or Negative Interaction:** The relationship between members of different species in which one or both are harmed, some (Clarke, 1954) prefer to call such types of associations as "antagonism'. The relationships of antagonism include:

(a). Parasitism: It is a kind of harmful interaction in which one species (parasite) is benefited at the expense of the other species (host). Plants or animals that live on or in their hosts and depend on their host for nutrition. Plants that obtain all or part of its nutritional requirements from another living plant grow either on stem or root of the host plant. Parasitic plants have special sucking roots, called haustoria, which penetrate the host plant connecting them to the conductive system- either the phloem, the xylem or both. Examples of parasitic plants are Cuscuta (total stem parasites), Balanophora, Rafflesia, Orobanche (Total root parasites), Cassytha, Viscum, Loranthus (Partial stem parasites), Striga, *Santalum album* (Partial root parasites).

(b). Predation: Predation is a biological interaction in which one organism, the predator, kills another for food. The organism that is killed for food is the prey. Typical predation occurs when a carnivore kills a herbivore or another carnivore for food. Majority of predatory organisms are animals such as- bats eating the insects, snakes eating mice etc., but there are some plants also, like, nepenthes, *Darlingtonia*, *Dionaea*, *Sarracenia*, *Drosera* etc consume insects and other small species for their food. They are called as Carnivorous plants. Aquatic plants are eaten by animals like duck, fish etc.

(c). Competition: Competition is an interaction between organisms and species in which both require the same limited resources at the same time. Competition can occur within a species (intraspecific) or between different species (interspecific). Plants compete for resources including nutrients, light, water, space, pollinators etc and animals for food and shelter.

(i). **Intraspecific competition:** The interaction between individuals of the same species is intraspecific competition. All species have similar needs when it comes to habitat, food, pollination, etc. There is a lot of competition.

(ii). **Interspecific competition:** The competition between different species is interspecific. There is usually little competition for resources, so a wide variety of grasses can grow in grasslands. During a water shortage, a competition for survival begins between different types of grasslands. The keys to success in this competition are nutrient availability, water availability, and the ability to migrate to new areas. Forest vegetation, such as trees, shrubs, and herbs, compete for sunlight, water, and nutrients. They also compete for pollination and the dispersal of fruits and seeds. The bladderwort (Utricularia) competes with tiny fishes for small crustaceans and insects.

(d). Ammensalism: Ammensalism is the ecological interaction in which one of the species is harmed or destroyed while the other one either benefits or remains unaffected and is denoted by sign ‘O’. For example- Penicillium notatum produces penicillin that inhibits the growth of various bacteria, especially staphylococci, *Trichoderma* inhibits the growth of fungus *Aspergillus*.

Other example- ammensalism is between humans and other species under threat of extinction due to human actions. Such as ecological accidents, habitat devastation by fires etc. In many cases the harmful effects are due to certain chemical substances secreted by one population as specific toxins into the environment.

These chemicals are called allelochemicals. They are of three types: (i) allomones, (ii) depressants, (iii) Kairomones. Allomones are chemicals which give adaptive advantage to the organisms that produce the chemical. Production of allomones is a common form of defense, particularly by plant species against insect herbivores. Depressants released by certain organisms inhibit or poison the receiver without benefit to the releasing organisms. Example is the red tide, Red tide is an algal bloom that can lead to death by intoxication of fish and other water animals. Kairomones are chemicals produced and released by a living organism that benefits the receiver but disadvantages the donar. For example, the chemical released by nematodes stimulates certain fungi to develop traps for nematode worms are used to protect the nematodes from predators.

Interspecific interactions/ Co-evolutionary dynamics

1. **Mimicry:** Mimicry can be defined as a behavioral adaptation in which a living organism modifies its appearance, structure, behavior, form and looks like any other living organism or object as a self defence and survive predation. In plants, mimicry gives protection against herbivores, and also helps in the process of pollination. Types of mimicry in plants:
   - (i). **Batesian mimicry:** In which a non poisonous species (the mimic) resembles a toxic species (the model) and is avoided by the predator in response to the poisonous model species.
   - (ii). **Bakerian mimicry:** This is a type of mimicry whereby the female flowers imitate males of the same species.
   - (iii). **Mullerian mimicry:** In which one toxic species resembles another toxic species and both are avoided by predator in confusion.
   - (iv). **Dodsonian mimicry:** This is a form of mimicry in plants that mimic another species of flower or fruit to lure pollinators. The feeders of the other species are fascinated to a fake fruit to distribute seeds.
   - (v). **Pouyannian mimicry:** This mimicry involves the flowers mimic a female mate visually, but the key stimuli are chemical and tactile.
   - (vi). **Leaf mimicry:** Leaves of a climbing plant mimic the leaves of its supporting trees to protect against herbivory. For example-woody wine *Boquila trifoliolata* mimics the leaves of its supporting trees.
   - (vii). **Cryptic mimicry:** In cryptic mimicry, mimicking plant should resemble its host; this can be done through visual or textural change.
   - (viii). **Pseudocopulation:** Pollination of plants (especially an orchid) by male insects while attempting to mate with flowers that resemble the female insect, carrying pollen to it in the process.

(ix). **Vavilovian mimicry:** Vavilovian mimicry (also weed mimicry or crop mimicry) is a form of mimicry where a weed is unintentionally artificially selected to resemble a crop plant.

2. **Myrmecophily:** Myrmecophily is the term used for beneficial interspecies associations between ants and a number of other organisms, such as plants, certain arthropods, and fungi. Sometimes, ants take shelter on tree (such as Litchi, Jamun, Mango, Acacia etc) and act as body guards of the plants against disturbing agents. The plants in return provide food and shelter to these ants. Example- Acacia and acacia ants.

3. **Co-evolution:** The interaction between two or more species, continues for generations, involves reciprocal changes in genetic and morphological characters of both the species. This type of evolution is called co-evolution. The evolution of one species depends on the evolution of another species. Many flowering plants have a close relationship with pollinating insect species. For example flowers and bees have evolved to have a close symbiotic relationship. Bees get pollen and nectar from flowers while bees fly around collecting pollen, they are helping the flowers reproduce by spreading pollen from flower to flower. An extreme example of co-evolution between plant and insect species is the relationship between Ficus (fig tree) and fig wasp.

2.7 ANTHROPOGENIC FACTORS

Men made activities are termed as anthropogenic activities. Anthropogenic can refer to any changes in nature that are caused by human beings. It is evident that humans are an integral part of the complex ecosystem ‘the ecosphere’ and anthropogenic activities disrupted the ecological processes leading to degradation of the environment that affected the humans as much as other forms of life, animals, plants, and microbes. It has arisen from human activities constricting the environment and depleting the natural resources of biosphere.

The term is sometimes used in reference to pollutant emissions caused by human activity, but it also applies broadly to major human impacts on the environment. Human activities have caused a number of changes in a variety of ecosystems through agriculture, forestry, urbanization and industry.

Factors responsible for Anthropogenic activities

1. **Human overpopulation:** The term human overpopulation refers to the relationship between the entire human population and its environment. Human overpopulation occurs when the ecological footprint of a population at a particular geographic location exceeds the carrying capacity of the space occupied by that group. Overpopulation is associated

with adverse ecological and economic consequences, ranging from the impacts of over-farming, global warming, deforestation, and water pollution to eutrophication.

2. **Over consumption:** Overconsumption describes a situation where the use of renewable natural resources exceeds its capacity to regenerate. A prolonged pattern of overconsumption leads to the eventual loss of resource bases.
3. **Technology:** The applications of technology often results in unexpected and unavoidable environment impacts. Environmental impacts caused by the application of technology are often perceived as unavoidable for several reasons.
4. **Light pollution:** Light pollution is the presence of unwanted inappropriate or excessive artificial lighting. Poorly designed commercial, residential and industrial outdoors lights contribute significantly to light pollution. It disrupts the natural patterns of wildlife, contributes to the increase in carbondioxide in the atmosphere, obscures the stars in the night sky. Three main types of light pollution include sky glow, glare and light trespass.
5. **Introduction of species:** Introduced species is, any nonnative species that significantly modifies or disrupts the ecosystems it colonizes. Introduced species that have profound effects on their new ecosystems have been termed invasive species. These effects include out competing native species, sometimes causing their extinction, and altering ecosystem functioning.
6. **Energy: Harvesting and consumption-** Energy harvesting is the process by which energy is derived from external sources (e.g. wind energy, solar power, thermal energy, kinetic energy and salinity gradients), captured, and stored for small wireless autonomous devices, like those used in wearable electronics and wireless sensor networks. Energy source examples include vibration or pressure (captured by a Piezoelectric element), light (captured by photovoltaic cells), radio energy (captured by an antenna), temperature differentials (captured by a thermoelectric generator) and even biochemically produced energy (such as cells that extract energy from blood sugar). Energy consumption refers to all the energy used to perform an action, consumption of fossil fuel resources leads to global warming and climatic change.
7. **Mining:** Mining is the process of extracting useful materials from the earth**.** Mining activities produce the potential toxic element accumulation, which lead unnatural enrichment, ecological pollution, and environmental degradation.
8. **Transport:** Transportation systems, from infrastructures to vehicle operations, have environmental impacts ranging from noise, the emission of pollutants to climate change. For instance, vehicular pollution over the last few decades has increased the global concentrations of N_2O, a very potent greenhouse gas.
9. **Environmental degradation:** Environmental degradation is the deterioration of the environment through depletion of resources such as quality of air, soil and water; the destruction of ecosystems; the extinction of wildlife, habitat destruction, pollution and processes such as improper land use and natural disasters.

10. **Human impact on the nitrogen cycle:** The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among atmosphere, marine and terrestrial ecosystems. Anthropogenic activities have drastically affected the nitrogen cycle. Burning fossil fuels, application of nitrogen-based fertilizers, and other activities can dramatically increase the amount of biologically increases available nitrogen in an ecosystem. For example- the important nitrogenous fertilizer is urea, which supplements the exhausted nitrogenous supply in the soil. It is first synthesize organic in the laboratory. The use of nitrogenous fertilizer impacts the natural nitrogen cycle.
11. **Ozone depletion:** Ozone depletion, gradual thinning of earth's ozone layer in the upper atmosphere caused by the release of chemical compounds containing gaseous chlorine or bromine from industry and other human activities. The main causes of the destruction of ozone molecules comprise the reactions with various substances of anthropogenic and natural origin, the absence of solar radiation during the polar winter, stable polar vortex, which prevents the penetration of ozone from the polar regions, and the formation of polar stratospheric clouds (PSO). These factors are especially observed in the Antarctic area.
12. **Global warming:** Global warming is the increase in the temperature of the earth's atmosphere, caused by the increase of certain gases. It may be natural, but human activities have been the main driver of climatic change, primarily due to the burning of fossil fuels, which produces heat trapping green house gas levels in earth's atmosphere.
13. **Mass extinction, defaunation, and decline in biodiversity:** A mass extinction event is when species vanish much faster than they are replaced and a considerable portion of the world's diversity is lost. Defaunation is the global, local or functional extinction of animal or species from biological communities. Biodiversity decline encompasses more than just species loss. It also includes the loss of genetic diversity within species and loss of ecosystems. Biodiversity loss is caused by five primary drivers: invasive species, habitat loss, pollution climate change associated with global warming, over exploitation (over fishing, over hunting and overharvesting) for things like food, medicines and timber. In each case, human beings and their activities play direct roles.
14. **Habitat destruction:** Habitat destruction is the process by which natural habitats becomes incapable to support the native species, resulting in the displacement or destruction of its biodiversity.
15. **Land degradation:** Land degradation is defined as the reduction or loss of the biological or economic productivity and complexity of rainfed cropland, woodlands, irrigated cropland, pasture, forest, resulting from natural processes, land uses or other human activities.
16. **Ocean acidification:** Ocean acidification refers to a reduction in the pH of the ocean over an extended period time caused primarily by uptake of carbondioxide.

17. **Manufactured products:** Manufactured products such as pesticides, cleaning agents, paper, paint, leather, plastics, pharmaceuticals and personal care products etc contribute to the environment pollution.
18. **Agriculture:** The environmental impact of agriculture varies based on the wide variety of agricultural practices employed around the world. Ultimately, the environmental impact depends on the production practices of the system used by farmers.

Impact of human activities

1. Humans can accidentally or intentionally introduce a non-native species into an ecosystem. They can damage native habitats, spread diseases and cause extinctions. This can have a negative impact on the ecosystem as introduced species can compete with native organisms and displace them.
2. Humans may destroy natural landscapes as they urbanize. This is a bad thing as it reduces habitats and food sources.
3. Contaminated water from large factories, lack of adequate sanitation, and numerous human interventions along water sources greatly contribute to water pollution. Industrial wastewater and sewage are discharged directly into rivers, is getting polluted. Seas and oceans are also hostile to aquatic life, sometimes facing oil spills with long-lasting effects on the water.
4. Overpopulation is one of the main factors causing air pollution. Harmful factory gases are released into the atmosphere, causing us to breathe air containing harmful substances and pollutants, contributing to various medical conditions, including respiratory and cardiovascular disease.
5. The major impacts on agriculture are deforestation, soil erosion, and the depletion of nutrients. There have been both positive and negative consequences on the environment in order to increase production. There are a number of fertilizing problems, with micronutrient imbalances being the most common. Nitrate pollution is also a problem, as is the overuse of fertilizers. There can be various problems caused by pesticides, including herbicides, insecticides, fungicides, and biocides.
6. Global warming refers to the rapid increase in the average surface temperature of the earth over the past 100 years, largely due to greenhouse gases emitted by people burning the fossil fuels needed for industrialization. This is believed to be a result of the warming of the Earth due to human actions associated with the greenhouse effect. Ice caps melt and sea levels rise, causing tsunamis, hurricanes, and other natural disasters.
7. Ozone is a toxic gas which plays a critical role in the atmosphere and is dangerous on earth. Humans and animals are harmed by the UV rays emitted by the sun. Ozone protects us from UV damage by preventing UV radiation from entering the planet. The defensive layers have been eroded across the world over the years. This serious deterioration was discovered in 1980s due to CFCs (chlorofluorocarbons) used in

refrigerators and fire extinguishers. Now manufacturing companies are required to manufacture CFC-free devices worldwide.

8. Marine life is threatened by over fishing and loss of biodiversity. Water degradation continues to impede marine life and make their lifespan uncertain.

9. Wildlife protection is getting difficult as their habitat are constantly threatened and destroyed. The main causes of habitat loss are water pollution and deforestation. Deforestation provides abundant land for humans, but for animals it means losing their homes.

10. The poor housing situation causes directly measurable effects on the physical and mental health of the citizens. The modern high-tech buildings can cause health problems due to indoor air pollution. The manufacture of plastics causes the production of greenhouse gases such as carbon dioxide, volatile organic compounds and polyvinyl chloride. The production of metals from their ores has several environmental impacts, some of which may be carcinogenic (cancer-causing).

11. Mining is the process of extracting valuable minerals and metals from the earth. The environmental damage caused by mining activities can include deforesting and damaging of the landscape, groundwater contamination, surface water pollution, air pollution, and workplace health hazards.

12. The activities of the transportation industry release millions of tons of gas into the atmosphere each year. These include lead (Pb), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), perfluorocarbons (PFC), heavy metals (zinc, chromium, copper, cadmium) and particulate matter (ash, dust). Acid rain affects construction, reduces agricultural production and leads to forest decline.

2.5 SUMMARY

Ecology is the scientific study of interactions between organisms and its environment. Ecological factor is any factor biotic or abiotic that influences plants and organisms. Ecological factors can be classified into five divisions- climatic factors, physiographic factors, edaphic factors, biotic factors and anthropogenic The climatic factors are grouped as: Light, temperature, precipitation and atmospheric humidity, wind, fire. Edaphic factors are those which act upon plants through soils. Physiographic factors are those associated with the physical nature of the area. Such factors include topography of the area, slope of the land, land elevation from Sea level, silting and blowing up of sand, degree of erosion etc. Biotic factors are the other, living things, such as plants, animals, microorganisms. All the human activities, responsible for a number of changes in a variety of ecosystems is termed as Anthropogenic factors. Anthropogenic factors constitute the primary deterministic causes of species declines and extinction.

2.6 GLOSSARY

ATP: The energy released during oxidation of energy rich compounds is made available for activities of cells through an intermediate compound called Adenosine triphosphate.
Topography: Topography is the land scale shape which is determined by the aspects of slopes and elevations.
Ecology: The study of interactions between organisms and their environment.
Predation: The preying of one animal on others.
Phototropism: Plants in response to light stimulus.
Phototaxis: An organisms movement in response to light.
Soil Profile: The vertical layered structure of soil.
Precipitation: A form of water, such as rain, snow, or sleet, that condenses from the atmosphere and falls to the earth’s surface.
Humidity: It is defined as the amount of wetness or water vapour in the air.
Transpiration: The process of water movement through a plant and its evaporation from aerial parts, such as leaves, stems, and flowers.
Heliophytes: Plants which grow in bright Sunlight.
Sciophytes: Plants which grow in the shades.
Edaphic factor: The physical or chemical composition of the soil found in a particular area.
Stratum: A layer or a series of layers of rock in the ground.
Humus: The organic components of soil, formed by the decomposition of leaves and other plant material by soil microorganisms.
Capillary water: Water that remains in the soil after gravitational water is drained out.
Gravitational water: Free water that moves through the soil due to the force of gravity.

2.7 SELF ASSESSMENT QUESTION

2.7.1 Multiple Choice Questions:

1. Which of the following interaction is beneficial to both the parents?
   (a) Competition (b) Mutualism
   (c) Commensalism (d) Parasitism
2. Environmental factors which deal with the structure of soil are termed as-
   (a) Biotic factors (b) Edaphic factors
   (c) Topographic factors (d) Climatic factors
3. Ecosystem has two components:
   (a) Biotic and abiotic (b) Frogs and lizards
   (c) Plants & animals (d) Man and animals
4. Plant group growing in zones where high temperature alternates with low temperature are called:

(a) Mesotherms (b) Microtherms
(c) Hekistotherms (d) Megatherms

5. The branch of biology that deals with the study of interaction between organisms and environment is called-
(a) Morphology (b) Metrology
(c) Ecology (d) Physiology
6. Plants which blooms when the light duration is more than 12 hours per day is known as:
(a) Long day plants (b) Short day plants
(c) Day neutral plants (d) Long day and short night plants
7. The plant of cold or temperate habitat require low temperature for their growth are called-
(a) Megatherms (b) Mesotherms
(c) Microtherms (d) Ekistotherms
8. Edaphic factors are included in:
(a) Abiotic components (b) Biotic components
(c) Producers (d) Consumers
9. Which of the following is an abiotic component?
(a) Plants (b) Animals
(c) Soil (d) Microorganisms
10. The Law of tolerance presented by which of the following Scientists:
(a) Victor Ernest Shelford (b) Justus Liebig
(c) F.F. Blackman (d) None
11. The science dealing with soil is called
(a) Pedology (b) Aerology
(c) Geology (d) Palaeontology
12. Plants absorb from the soil
(a) Hygroscopic water (b) Capillary water
(c) Gravitational water (d) Both hygroscopic and gravitational water

2.7.2 True and False

1. An ecosystem is a community of living organisms interacting with each other and their non-living environment.
2. A.G. Tansley coined the term “ecosystem” as a biological assemblage interacting with its associated physical environment and located in a specific area.
3. The environment includes only physical and biological components, not the chemical.
4. The biotic (living) environmental factors which include interactions between different populations and instinctive control mechanism.
5. Flowering in plants is affected by temperature through thermoperiodism.
6. The sex ratio in the copepod *Macrocyclops albidus* is determined by temperature.
7. Humidity is greatly influenced by intensity of solar radiation, wind, water, status of soil, temperature, altitude etc.

8. The tropical storms are known as hurricanes in the Atlantic Ocean, typhoons in the western Pacific Ocean and cyclones in the western Pacific Ocean.
9. The wind does not affects rate of transpiration.
10. The fire influences only the living component but not physical elements of environment.

2.7.3 Fill in the blanks

1. _____ is one of the most important ecological factors called edaphic factors.
2. Soil are complex mixture of minerals, water, air, organic matter and countless _____ that are the decaying remains.
3. The uppermost horizon of soil profile is called _____.
4. In the soil, a small portion of soil water is chemically bound with soil material which is called _____.
5. Soil pH is a measure of the amount of _____ present in the soil.
6. Nutrient absorption by roots is a process of _____ at the surface.
7. _____ factors are those that are associated with the physical nature of an area.
8. _____ between two or more species can be found in any community.
9. The perfect example of symbiotic relationship between two plants is _____.
10. _____ is an interspecific interaction between two species that benefits both members.

Answer Key:

2.7.1- 1. (b), 2. (b), 3. (a), 4. (a), 5. (c), 6. (a), 7. (c), 8. (a), 9. (c), 10. (a), 11. (a), 12. (b)

2.7.2- 1. True; 2. True; 3. False; 4. True; 5. True; 6. True; 7. True; 8. True; 9. False; 10. False

2.7.3- 1. Soil; 2. Organisms; 3. O horizon; 4. combined water; 5. hydrogen ions; 6. ion exchange; 7. Physiographic; 8. Interspecific; 9. Lichen; 10. Mutualism

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2.10 TERMINAL QUESTIONS

2.10.1 Short answer type questions

1. Briefly describe the biotic factors.
2. Write a note on the classification of organisms according to temperature tolerance.
3. Categorize the different type of forest fire.
4. Write a note on the soil moisture
5. Write a note on the antagonism.

2.10.2 Long answer type questions

1. Define Ecology. Discuss in detail about the climatic factor.
2. What is soil profile? Describe it in detail.
3. Differentiate between:
   (a) Parasitism and Predation
   (b) Competition and ammensalism
4. Give a detailed note on importance of light factor.
5. Explain about the physiographic factor.

UNIT-3- ECOSYSTEM STRUCTURE AND FUNCTIONING

Contents:

3.1 OBJECTIVES

The present topic provides an overview of structure, organization, composition and functioning of the ecosystem. After reading this topic you will be learn about:

- Structure of ecosystem and their components.
- Able to distinguish abiotic and biotic factors of ecosystems.
- Homeostasis of ecosystem.
- Tropical level and food chain.
- Ecological pyramids and their types.
- Ecological energetic and energy flow in the ecosystem.
- Biogeochemical cycles

3.2 INTRODUCTION

The ecosystem refers to as a community of life forms interacting with non-living components in a same system. In a basic form environment means the surroundings. It refers to those circumstances around the organisms which influence their life, development, evolution and populations through directly or indirectly. Living component and environment component, which are non separable, construct the ecosystem and the ecosystem cannot exist if one of these components is absent. The living components interact with each other along with their prevailing environmental conditions.

A.G. Tansley for the first time put forth the concept of ecosystem in 1935. He described that ecosystem is the major ecological unit which have their own specific structure and functions. The structure of ecosystem depict about the species diversity. This indicates that the ecosystem structure will be more complex if the species diversity is high. The functioning of ecosystem is associated with energy flow and cyclic of nutrients in ecosystem through the structural components. The ecosystem has been defined by the various scientists from time to time. According to Clarke the living component and the physical features of the habitat form an ecological complex or more briefly an ecosystem. Woodbury describes the ecosystem as a complex structure in which habitat, plants and animals are considered as one unit, the materials and energy of one passing in and out of the others. According to E.P. Odum, the ecosystem is the basic functional unit of organisms and their environment interacting with each other and with their own components.

The earth contains many ecosystems and all these ecosystems are interlinked to one another, for example the ecosystem of river is connected with the ecosystem of ocean. A complete self-sufficient ecosystem is rarely found in nature but situations approaching self-sufficiency may occur. As mentioned above that each ecosystem has its own structure and functions, so in this chapter we will discuss all these components in detail.

3.3 STRUCTURE OF ECOSYSTEM

The structure of an ecosystem principally gives the information regarding the living components (organisms) and physical factors (temperature, moisture, pH etc) of the environment as well as the allocation of nutrients in a meticulous habitat. It also provides information concerning the climatic conditions existing in that particular environment. Ecosystems are controlled or influenced in a very extensive way by these external and internal factors. From the structural point of view, the ecosystem can be divided into two components i.e., Abiotic and biotic components (Fig. 3.1).

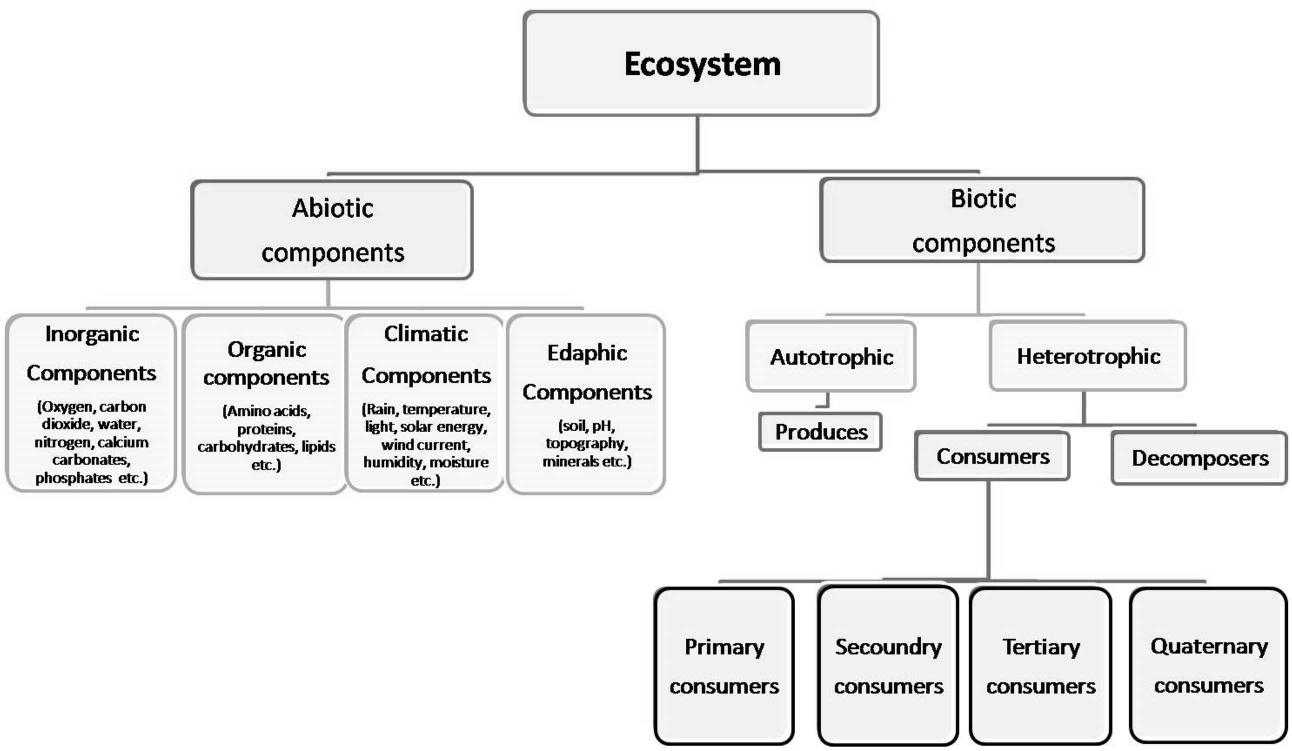

Fig. 3.1: Composition of ecosystem on the structural point of view

3.3.1 Abiotic components:

Abiotic components of the ecosystem include those components which are non living. These are basically the inorganic and organic elements and compounds of the environment or habitat of the organism. The inorganic components of the environment are oxygen, carbon dioxide, water, nitrogen, calcium carbonates, phosphates etc, all of which are involve in the biogeochemical cycles. On the other hand, the organic components listed as amino acids, proteins, carbohydrates, lipids and all of which are synthesized by the flora and funna (biota) and are reached to ecosystem after decomposing their remains by the microorganisms.

Abiotic components also include the physical factors such as temperature, soil etc. These physical factors can be categorized as climatic factors and edaphic factors. Climatic factors incorporated the rain, temperature, light, solar energy, wind current, humidity, moisture etc. Radiant energy of the sun is the only significant energy source for any ecosystem. The edaphic factors integrated with the soil, pH, topography, minerals etc.

Functions of abiotic components:

1. Soils, a complex mixture, supply nutrients and water, serve as growing medium and habitat of many organisms. The vegetation is closely linked to the soil through nutrient cycling.
2. The atmosphere provides CO_2 to plants for the process of photosynthesis and oxygen to living organisms for respiration. The processes of evaporation, transpiration and precipitation take place between the atmosphere and the Earth's surface.
3. Solar radiation is utilized in an ecosystem for heating the atmosphere and to evaporate the water into the atmosphere. Sunlight is required to plants for photosynthesis.
4. Water is essential for the living activities of all the organisms. It has the great importance for the various metabolic functions of living cells because most of them require the exclusively aqueous media. It is used by the cell as a transporting media for the food, nitrogen waste and other necessary substances. It is the main component of the process of photosynthesis in the plant and without it plant cannot synthesized their food. It is also necessary for the maintenance of leaf turgidity. Both the plants and animals receive water from the Earth's surface and soil. The original source of water is precipitation from the atmosphere.
5. Climatic and topographic conditions also regulate the type of vegetations in an ecosystem. For example the vegetation of tropical ecosystem differs from the dessert ecosystem and the vegetation of hill region is quite different from the plain region. These differences in vegetation occur due to the climatic and topographic conditions, respectively prevailing on that particular ecosystem.

3.3.2 Biotic Components:

Biotic components included all the living organisms present in the environment of ecosystem. The biotic components can be categorized into two components according to their nutrition point of view:

1. **Autotrophic components:** All the green plants, which synthesized their own food from the simple inorganic compounds (CO_2 and H_2O) with the help of sun light by the process of photosynthesis in which carbon dioxide is assimilated and the light energy is converted

into chemical energy and oxygen is evolved as by-product, are grouped under the autotrophic components. These are also called the producers. Apart from the chlorophyll bearing green plants, chemosynthetic bacteria and purple bacteria also belong to this category.

2. **Heterotrophic components:** All the living organisms (non-green plants and all animals) which are not capable to synthesize their own food and depend on the autotrophs for their food requirement are grouped under heterotrophic components of ecosystem. They may be consumers and decomposers.

a) Consumers: The consumers further divided into four categories;

(i). Primary consumers: This group of consumers is principally the herbivorous animals which are dependent on producers to obtain their food. Elton (1949) termed the herbivores as "key industry animals". All the insects, rabbit, rodents, deer, goat, cow, buffalo etc are some of the common herbivores in the terrestrial ecosystem, and small crustaceans, molluscs, etc. in the aquatic habitat. The herbivores animals serve as the food source for secondary consumers.

(ii). Secondary consumers: This group of animals consumes the primary consumers as food source and simply called carnivores and omnivores. Carnivores are only predator, flesh eating animals while the omnivores are adapted to consume both plants and herbivores for the source of energy. Some examples of secondary consumers for aquatic ecosystem are frog, krill, small fish etc and for terrestrial ecosystem are spider, snake, crow, sparrow, fox, wolves, dog, cat etc.

(iii). Tertiary consumers: These are the large size animals that depend on secondary consumers for their food. These are strictly omnivore in nature. Example: wolf, eagle for terrestrial ecosystem and big fish, seals and sea lions, jellyfish, eels, turtles etc for aquatic ecosystem.

(iv). Quaternary consumers: These are also called fourth order consumers which are present in some food chains. These animals prey on tertiary consumers for energy. Furthermore, they are usually at the top of a food chain as they have no natural predators. Examples are lions and tigers for terrestrial ecosystem and shark, whale etc for aquatic ecosystem.

Apart from these different classes of consumers, the scavengers, parasites and saprobes are also placed in the consumer category. The parasites (including animals and plants) live on and in the other organisms (called host) and get their nutrition from the host to survive. The saprobes and scavengers consume debris of plants and animals as their foodstuff.

b) **Decomposers:** Decomposers are also known as transformers. They are chiefly microscopic or very small in size (fungi and bacteria) which decompose the dead residue of producers and consumers. They convert the complex organic substances into simpler compounds and finally convert into the inorganic forms which are easily reused by producers in the ecosystem. They play a significant role in maintaining the nutrients dynamic in nature.

3.4 HOMEOSTASIS

Every ecosystem sustains a biological balance between its various components and this phenomenon is known as homeostasis or biological equilibrium or balance of nature. This process is controlled by the numerous factors including carrying capacity of the system, capability of recycling and the reproduction potential of the organisms (Fig. 3.2). The individual constituent ensures the population of the other constituent in ecosystem which referred as feedback system. The feedback system can categorize into two systems:

(i). **Positive feedback system:** Increasing the population of organisms at any level when impose the positive effects on other level organisms is known as positive feedback system. For example, if the population of plants increases it promotes the population of primary consumers which ultimately increases the numbers of secondary consumers and so on.

(ii). **Negative feedback system:** When growing populations of organisms compel the negative effects on the population of others. This process is known as negative feedback system. For example, if the insectivorous population exceeds beyond the caring capacity of the system it leads to impose the negative impact on the insect population.

Homeostatic Mechanisms

Due to the disperse nature of ecosystem, the negative feedback control more diffusely than in physiology. There is no central dispensation element to apply or organize a negative feedback. Instead, it frequently appears from interactions among species and individuals, and among species, individuals and their environment. In ecosystem, negative feedbacks that established system characteristics are usually referred to as homeostatic mechanisms.

Stabilizing effects of limiting resources

In general, mechanism of homeostatic controls many properties of the systems including the interaction between resources and their consumers. An extensively mentioned example of interaction between prey and predators demonstrate how resource and consumer dynamics can result in the negative feedbacks which balanced the system. We can understand it better with the help of an example. Let suppose, if rat is a prey and owl is its predator. In this case, a population of prey initially increases consequentially increasing in the populations of predators because of resources accessibility for their predator. Because the increase in the population of predators is a consequence of breeding and survival in prey, therefore, the increasing population of prey initially provides the motivation to increase the predator population. As number of predator increases, the need for hunting increases simultaneously and the increase in mortality for prey leads to a declines in their populations. As resources shrink, predator population decreases with high mortality and there is no longer support for maintain a high predator load in the system, which ultimately reduces predator population. The above discussed model is a particular case of a common procedure that takes place across the systems. When food resources is limited, they place strong stabilization constraints on community dynamics. In any system, when utilization of resources via one constituent increases, it must be harmonized by reduce in consumption by other constituents because availability of resources are inadequate.

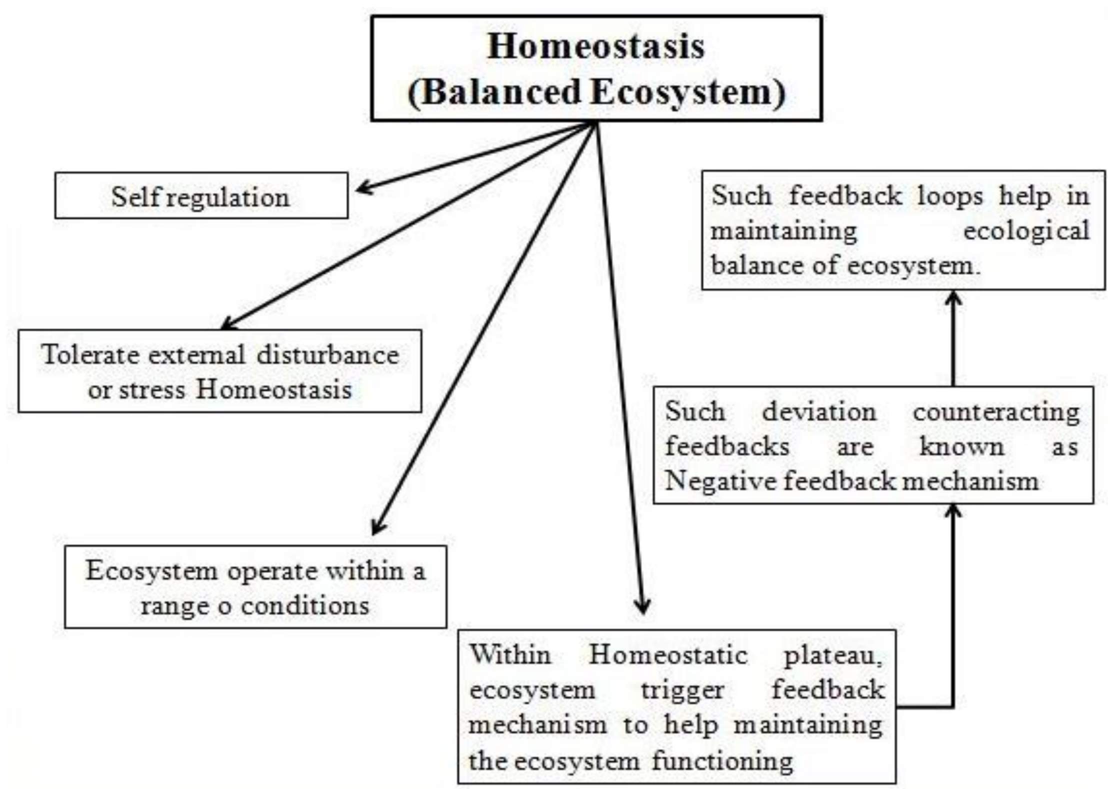

Fig. 3.2: Mechanism of homeostasis in the ecosystem

Often, the primary resource plays a role in limiting factor where the system initially counters to enhance that resource. However, with the main resource limitation, some additional resources become a limiting factor on the system. For example, in a dense tropical forest ecosystem, short heighted plants are primarily limited by availability of sunlight but when the sunlight limitation is released nitrogen can turn into a limiting resource restraining plant response. Various resource constraints can cause discrepancy between short-term and long-term responses to change as initial changes are slowed or even reversed by the implementation of new constraints.

Sometime the ecological stabilization regulated by more than one potential limiting factors. Environment alterations are occur either by natural or manmade resulted increases in the resource. Consequential prompt alterations in state characteristics since present system equilibrate to the new limitations. Example: Carbon and nitrogen are considered as macronutrients which are essential for the plant growth and productivity but sometimes both the elements serve as limiting factors for productivity in an ecosystem. Here, the system could be prevented from responding to an increase in single resource except both limiting resources change.

Compensatory dynamics

It is a fundamental homeostatic mechanism and takes place when exploitation of resources of some species is coordinated by decreases in other species. While resource limitations produce the circumstances for negative feedbacks, compensatory dynamics are often required for keeping a stable state between resource use and resource accessibility. Without compensatory dynamics, strong fluctuations in only a few dominant species would result in large changes in system properties, regardless of the presence of constraints on the system. This balance between increases and decreases in species populations is often referred to as species compensation or compensatory dynamics. The inadequacy of resources impels a negative feedback to intensifying consumption by the community. Because the resources are utilized by species for their survival, reproduction, maintenance and the resource constriction control mortality, birth rate and net production. So, resource limitations are crucial for stabilizing overall consumption as well as for stabilizing system-level properties such as total abundance, standing, and biomass production.

3.5 TROPHIC LEVELS AND FOOD CHAIN

When we consider the function of an ecosystem, we must describe the flow of energy and the cycling of nutrients. That is, we are interested in things like how the plants trapped the solar energy and how much plant martial is eaten by herbivores, and how many herbivores are eaten by the carnivores.

The word trophic derives from a Greek word (trophē) meaning food or nourishment. The concept was first developed in 1942 by Raymond Lindeman, based on the terminology of August Thienemann (1926) "producers", "consumers" and "reducers" (modified to "decomposers" by Lindeman) (Thienemann 1926; Lindeman, 1942). The trophic level in an ecosystem may be defined as a position occupied by an organism in a food chain. The food chain is a sequence of organisms which eat other organisms and may, in turn, be eaten themselves. The trophic level of an organism is the number of steps it is from the start of the chain. Therefore, the number of trophic levels is equal to the number of steps in a food chain. The various trophic levels in a food chain are;

- Level 1: Primary producers (e.g., all the green plants synthesize their own food)
- Level 2: Herbivores or primary consumers (eat plants).
- Level 3: Carnivores or secondary consumers (eat herbivores).
- Level 4: Carnivores of higher level or tertiary consumers (eat other carnivores).
- Level 5: Apex predators: have no predators and are at the top of their food chain.

Any food chain necessarily starts from trophic level 1 with primary producers and proceeds to herbivores at level 2, than carnivores at level 3 or higher, and terminates with apex predators at level 4 or 5. For example: Let's consider a food chain of the terrestrial ecosystem (Fig. 3.3), in this food chain four trophic levels are present. Grass form the first trophic level and hawk forms the last (forth trophic level) or top consumer. Grasshopper and frog are the intermediated trophic levels between these two.

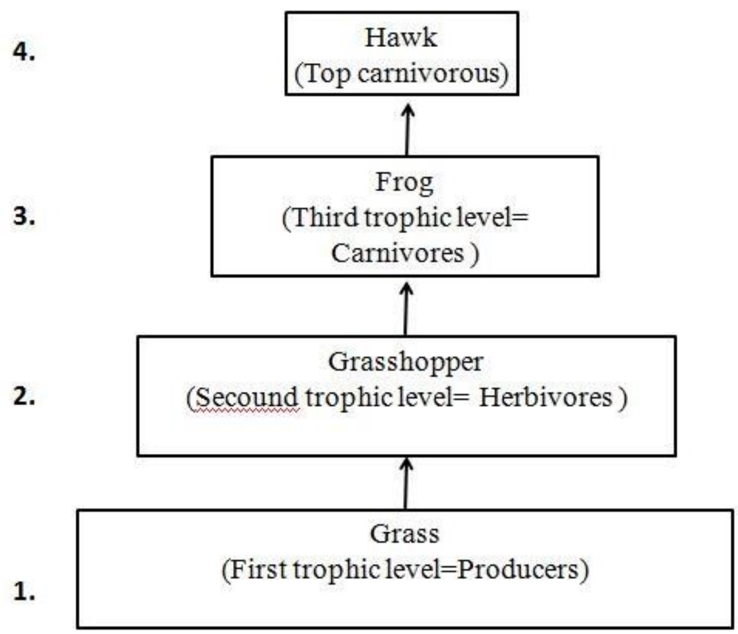

Fig. 3.3: Diagram showing the various trophic levels in a food chain

Limited number of trophic levels in a food chain

A large portion of energy is lost at each trophic level in a food chain. This results in lesser amount of energy being transfer on by the organisms at one trophic level to the next trophic level. This is why the number of trophic levels in a food chain is limited. As the numbers of trophic levels in a food chain increases, organisms at the extreme right side of the food chain received least amount of energy. This limits the number of trophic levels or steps in a food chain to five or six.

Organisms of one trophic level have the same food habit but may have several food resources like leaves, seeds, fleshy food, grasses etc. thus, a group of species belonging to a trophic level which consumes a common resource base is known as guild, e.g., nectar feeding birds, grazing animals etc. Thus an ecosystem has a limited number of trophic levels because:

1. There is a loss of food energy at each transfer.
2. Food is not completely utilized by the organisms of a trophic level and some part of the food goes waste.
3. A large amount of energy is used in respiration.

Food chain

There is passage of material from producers through primary, secoundry, tertiary to top consumers. Individuals related in this manner constitute a food chain. Thus a food chain can be defined as a group of organisms in which there is a transfer of food energy through a series of repeated eating and being eaten.

Composition of food chain

A food chain being with producers green plants and ends with the top consumers, which is not preyed upon by anyone. In general, a food chain may be represented as:

Producers ⟶ Herbivores ⟶ Carnivores

For the producers, the Sun is the source of the energy. Green plants along are able to trap the solar energy which they use to reduce the carbon from CO_2. This carbon forms carbohydrates, fats and proteins. Energy trapped in these compounds is stored in the plants and forms the primary source of energy supply to all other living organisms. Thus plants are the producers of the ecosystem.

In animal community, the herbivores are the primary consumers. These organisms are eaten by the secoundry consumers which may include carnivores or omnivores.

Ecological principles of food chain

Following important ecological principles emerge from the study of food chain:

1. A food chain always begins with photosynthesis by following a series of consumers and end with decomposition. Thus the flow of energy from the sun to producers is unidirectional.
2. The more steps in food chain lead to wastage of energy. Therefore, the shorter food chain is more efficient.
3. The size of the population is determined by the number of trophic levels in a food chain. With the decrease in useful energy at each step, there is a decrease in the population size. Thus the size of the population of quaternary consumers is less than that of tertiary consumers and that of tertiary consumers are smaller than secoundry consumers.

Types of food chain

Basically there are two types of food chain has recognized in an ecosystem: grazing food chain and detritus food chain.

1. **Grazing food chain:** It is a normal type of food chain which starts from the green plants and ends at carnivores by passing through herbivores. In herbivores, the assimilation of food can be stored as carbohydrates, proteins ad fats. The ultimate disposition of energy in herbivores occurs by three routes: respiration, decaying of organic matters by the microorganisms and consumption by the carnivores. Primary carnivores or secoundry carnivores eat herbivores or primary consumer. Similarly, secoundry carnivores or tertiary carnivores eat primary carnivores. The total energy assimilated by the primary carnivores is derived entirely from the tissues of herbivores. Its disposition into respiration, decay and further consumption by other carnivores is analogous with that of herbivores. The energy flow the grazing food chain can be described in term of trophic level as:

Autotrophs (Primary producers) → Herbivores (Primary consumers) → Primary carnivores (Secoundry consumers) → Secoundry carnivores (Tertiary consumers)

The food chain demonstrated that the amount of energy found at any trophic level, the transfer of energy from one trophic level to the next, and the amount of energy lost from this food chain. Further, the predator food chain starts with herbivores and goes from smaller to large predators. i.e., herbivorous are primary consumers and predators are the secoundry and tertiary consumers. The size of the predators increases at ah level in the food chain. Predators of the first level are smaller than those of secound level.

The parasitic food chain also starts with the herbivores but food energy passes from large to smaller organisms. Therefore, the larger animals are the host and the smaller organisms which fulfill their nourishment from the host are described as parasitic.

2. **Detritus food chain:** The food chain that passes through dead organic matter is known as detritus food chain. It represents an important component in the energy flow of an ecosystem. In some ecosystems, considerably more energy flows through the detritus food chain as compare to the grazing food chain. Here, the energy flow is continues passage rather than a stepwise flow between different trophic levels. Detritus organisms ingest partially decomposed organic matter, digest them partially after utilizing some of the energy in the food to run their metabolism, excrete the remains in the form of simpler organic molecules. The waste for one organism is immediately utilized by the secound one which repeats the process.

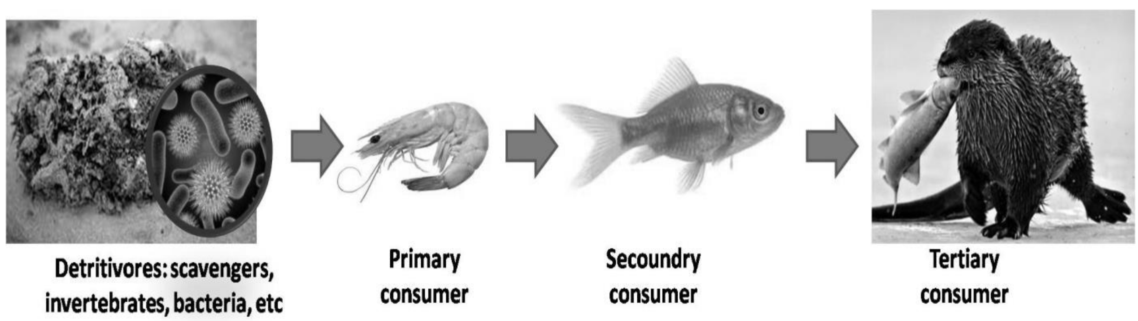

Fig. 3.4: Different trophic levels of a detritus food chain

Detritus food chain operates in the decomposing, accumulating litter in temperate forest and mangroves. For example, in mangroves, leaves of *Rhizophora* fall into the warm, shallow waters. The fallen leaves are acted upon by saprophytic fungi, bacteria and protozoa etc. and are eaten by a group of small animals, e.g., crabs, insect larvae, shrimps, amphicpodes etc. All these animals are called detritus consumers. These organisms are eaten by other organisms (game fish etc) which in turn are eaten by the large fish and fish eaten otter or birds etc. Such animal are referred to as the top consumers. Thus a detritus food chin ends up like a grazing food chain. However, in this food chain, the detritus consumers are mixed population of various trophic levels. These include herbivorous, omnivores and primary consumers. These detritus feeders obtain some of their energy directly from plant material, most of it from microorganisms and some through carnivores.

Detritus organisms ingest pieces of particular decomposed organic matter, digest them partially, after extracting some of the chemical energy in the food to run their metabolism, excrete the remainder in the form of slightly simpler organic molecules. The waste from one organism can immediately be utilized by a secound which repeats the process. Gradually, the complex molecules present in the organic wastes or dead tissue are broken down to much similar compounds, sometime all the way to carbon dioxide and water. In most instances, however the organic material is broken down until all the easily biodegradable material has been degraded, and all that is left are some refractory organic substances termed humic acid or simply, humus. In a normal environment the humus is quite stable and will form an essential part of the soil.

Links between grazing and detritus food chain

Just as the energy enters the detritus food chain from the grazing food chain as leaf litter or dead organisms, energy can re-enter the grazing food chain from the detritus food chain if organisms from the latter are composed by grazers (Verma and Agarwal 2008). Considering the diversity of the detritus community, it is not surprising that many of these serve as prey for carnivores in the grazing food chain. A common example is robins eating earthworms. In addition, many insects among them beetle and files spend their larval period in the detritus food chain and their adulthood in the grazing food chain. But through such links where energy passes from detritus food chain basic into grazing food chain, very little amount of energy is passed in comparison to the amount of energy which flow from grazing food chain to detritus food chain.

Food Web

The food chain, as a matter of fact, does not occur in isolation. Since many animals eat more than one kind of food, different kinds of food chains exist in an ecosystem. This network of interconnected food chain is called food web. Thus food web may be defined as the network of a number of food chains existing in an ecosystem.

Unlike a food chain, food web as several alternative pathways for the flow of energy. In the food web shown in Fig. 3.4, there are several food chains operating in a food web. The food web starts from the plants which are producers and ends with the top carnivore.

Characteristic features of a food web

1. In a food web, no food chain is independent and no liner arrangement of food chain is occurs.
2. It is formed by the interlinking of three types of food chains: predators chins, parasitic chains and saprophytic chains.
3. Food web provides alternative pathways of food availability, i.e., if a particular crop fails the herbivorous graze on other type of crop. Thus, greater the number alternative pathways, more stable the ecosystem.

4. Food web helps in checking over population of highly fecundative species of animals and plants.
5. The position of n animal in a food web is determined by the age and the size of the species and availability of the food source.
6. A food web operates according to taste and food preferences of the organism at each trophic level. Availability of food source is also very important i.e., In Sunderban of India, in the absence of its natural prey, tiger eats fish and crabs.

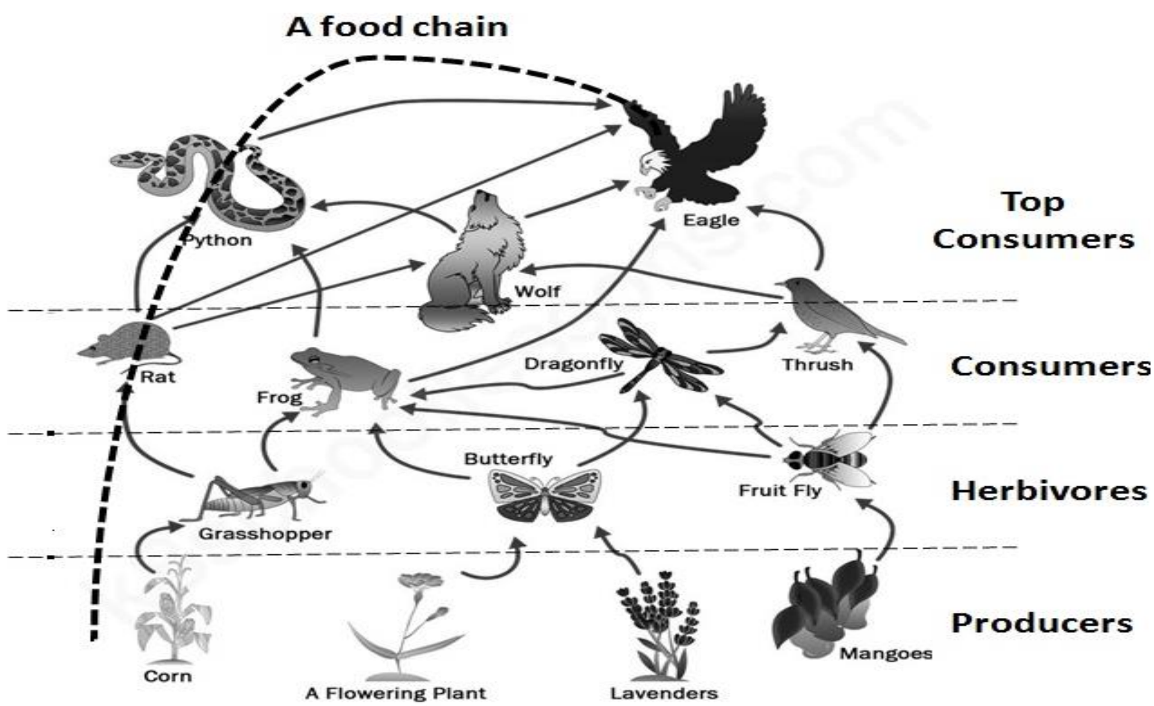

Fig. 3.4: Diagram showing the food web in an ecosystem where a number of food chains interlinked to construct a food web

3.6 ECOLOGICAL PYRAMID

In the successive steps of grazing food chain- photosynthetic autotrophs, herbivorous heterotrops, carnivorous heterotrops, decay bacteria- a number and mass of organisms in each step is limited by the amount of energy available. Since some energy is lost as heat, in each transformation the step become progressively smaller near to the top. This relationship is sometimes called “ecological pyramid”. The ecological pyramids represent the trophic structure and also trophic function of the ecosystem. In many ecological pyramids, the producers from the base and the successive trophic levels make up the apex.

Thus, communities of terrestrial ecosystems and shallow water ecosystems contain gradually sloping ecological pyramids because these producers remain large and characterized by an accumulation of organic matter. This trend however, does not hold for all ecosystems. In such aqatic ecosystems as lakes and open sea, primary production is concentrated in the microscopic algae. These algae have a short cycle, multiply rapidity, accumulate little organic matter and are heavily exploited by herbivorous zooplankton. At any one point in the time the standing crop is low. As a result, the pyramid of biomass for this aquatic ecosystem is invert: the base is much smaller than the structure it supports.

Types of Ecological pyramids

The ecological pyramids (Fig. 3.5) may be the following types:

1. **Pyramids of number:** It depict the number of individual organisms at different trophic levels of food chain. This pyramid was advanced by Charles Elton in 1927, who pointed out the great differences in the numbers of the organisms involved in each step of the food chain. The animals at the lower end (base of the pyramid) of the chain are the most abundant. Successive links o carnivores decreases rapidly in the number until there are very few carnivores at the top. The pyramids of number ignore the biomass of organisms and it also does not indicate the energy transfer or the use of energy by the group involved. The lake ecosystem provides a typical example for the pyramid of number.

2. **Pyramids of biomass:** the biomass of the members of the food chain present at any one time forms the pyramid of the biomass. It indicates decrease of biomass in each trophic level from base to apex. For example: the total biomass of producers ingested by herbivores is more than the total biomass of the herbivores in an ecosystem. Likewise, the total biomass of the carnivores will be less than the herbivores and so on.

3. **Pyramid of energy:** When production is considered in terms of energy, the pyramid indicates not only the amount of energy flow at each level, but more important, the actual role the various organisms play in the transfer of energy. The base upon which the pyramid of energy is constructed is the quantity or organisms produced per unit time, or in other words, the rate at which food material passes through the food chain. Some organisms may have a small biomass but the total energy they assimilate and pass on may be considerably greater than that of organisms with a much larger biomass. Energy pyramids are always slopping because less energy is transferred from each trophic level than was paid into it. In case such as in open water communities the producers have less bulk than consumers but the energy they store and pass on must be greater than that of the nest level. Otherwise, the biomass that producers support could not be greater than that of the producers themselves. This high energy flow is maintained by a rapid turnover of individual plankton, rather than an increase of the total mass.

Importance of ecological pyramid

1. It shows the trophic levels of diverse organisms in different ecosystems.
2. The existing situation of any ecosystem can be examined with the help of ecological pyramids.
3. Ecological pyramids are important in estimating the efficiency of energy transfer in an ecosystem.

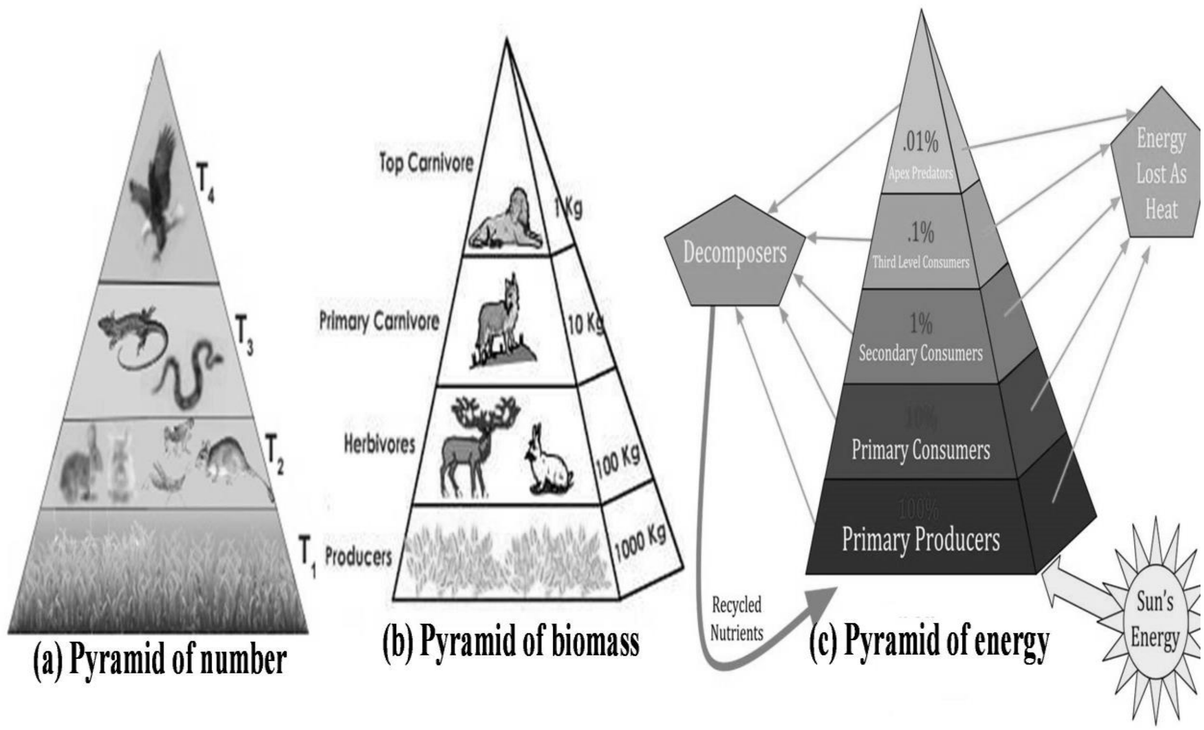

Fig. 3.5: Ecological Pyramids; (a). Pyramid of number, (b). Pyramid of biomass, (c). pyramid of energy

Limitations of the ecological pyramid

1. These pyramids are applicable only to simple food chains, which usually do not occur naturally.
2. More than one species may occupy multiple trophic levels as in case of the food web. Thus, this system does not take into account food webs.
3. They do not consider the possibility of the existence of the same species at different levels.
4. The saprophytes are not considered in any of the pyramids even though they form an important part of the various ecosystems.
5. These pyramids do not deliver any concept in relation to variations in season and climate.

3.7 FUNCTIONING OF ECOSYSTEM

When we consider the function of an ecosystem, we must describe the flow of energy and the cycling of nutrients .That is why, we are interested in thinks like how much sunlight is trapped by plants in the year, how much plants material is eaten by herbivores, and how many herbivores are eaten by carnivores. Ecosystem functions are conceived as a subset of ecological processes and ecosystem structures. Natural processes, in turn, are the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy. The flow of energy in an ecosystem and nutrient cycle (biogeochemical cycle) discuss in this chapter in detail.

3.7.1 Ecological energetics and energy flow

Living organisms can use energy in several forms. But all can be grouped under one of the two headings: radiant energy and fixed energy. Radiant energy occurs in the form of electromagnetic waves such as light. Fixed energy is potential chemical energy bound up in various organic substances which can be broken down or reached with something else in order to release their energy content.

Only a small fraction of the light energy reaching the earth is trapped; considerable areas of the earth have no plants and plants can utilize in photosynthesis only about 3% to 10% of the incident energy. This radiant energy of sun is converted into chemical or potential energy by photosynthesis in plants, the photosynthetic autotrophs:

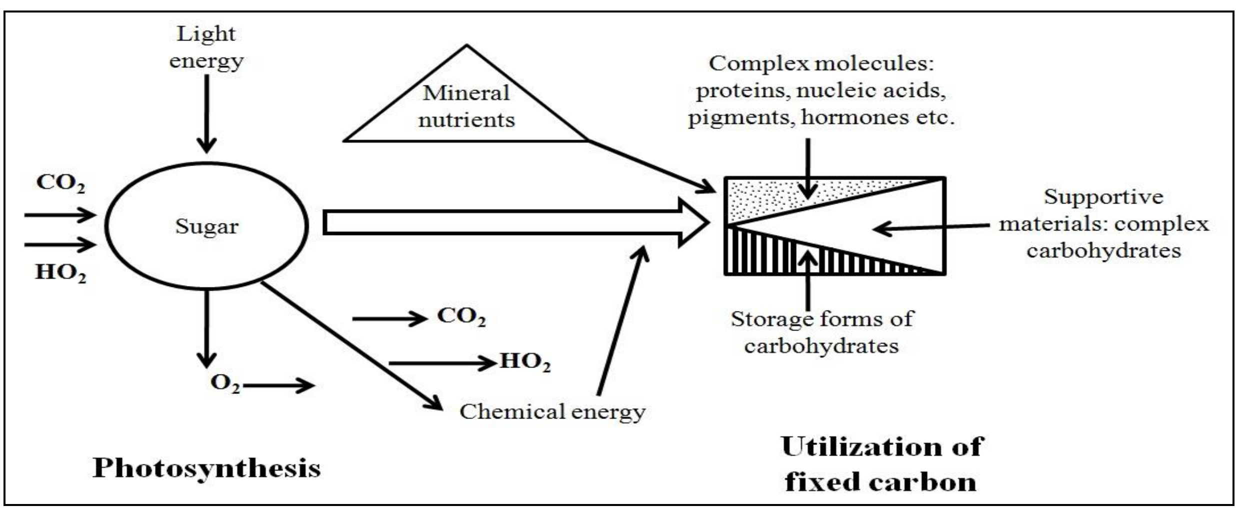

Fig. 3.6: Diagram showing the production and utilization of fixed carbon by photosynthetic plants (After Clapham Jr. 1973)

The reaction is catalyzed by certain pigments (e.g., chlorophylls) in the cells. The product of this reaction is carbohydrate such as sugar (glucose) shown above. This sugar can have several destinations: it can be converted to a relatively inert energy rich organic substance such as starch, and stored; it can be combined with other sugar molecules to form specialized such as starch and stored; it can be combined with other sugar molecules to form specialized carbohydrate such as cellulose, which are used by the plants for specific purposes; and it can be combined with other substances-such as nutrient substances such as nitrogen, phosphorus and sulphur to build complex molecules like proteins, nucleic acids, pigments and hormones. All these types of reactions are necessary for normal growth and maintenance of body tissues and functions of the plants (Fig. 3.6). All required energy which is provided by oxidation of some of the sugar produced by photosynthesis to give CO_2, H_2O and usable chemical energy. Oxidation of sugar or any other organic molecule to get usable energy by organism is called respiration. The energy released by respiration is lost permanently to the ecosystem.

Primary Production

All the energy that the plant actually fixes results in the formation of sugar. Conversely, all the sugar produced in the leaves of green plants is derived from carbon dioxide and water which have been combined by the solar energy. Thus, one can speak of the energy incorporated into living tissue either in terms of the light energy utilized or in term of sugar produced. Because all the energy used by the plant is converted into chemical energy, it should theoretically be possible to determine the entire energy uptake by the plants by measuring the total amount of sugar produced. This quantity is termed gross primary production or gross productivity. Because it is not easy to measure gross primary production in most ecosystem because some of the sugar produced by photosynthesis is lost immediately through respiration. So, if one measures the total organic material actually present in the plant (biomass) then indirectly will measure the gross primary production less the respiration or net primary production. In addition, there are direct measurement techniques involving the rate of uptake of radioactive carbon ^{14}C. Productivity is generally express in term of grams or kilo-grams per sq meter per day or per year. It can be also be expressed as $P_g=P_n+R$, where P_g is the gross productivity or energy used to do work, P_n is net productivity and R i the respiration or energy to do the work. Net production is an increase of stored energy with time, while biomass is total stored energy at any time. If gross production equals to the respiration ($P_g=R$) no change in energy content results. But when P_g is less than R biomass decreases and when P_g is greater than R there is an accumulation of biomass.

The gross productivity is dependent on many things, including climatic conditions such as temperature, rainfall and total solar radiations and other abiotic factors as the availability of nutrients material essential for life. Following Table 3.1 lists the gross primary production or gross productivity over one year for several different environments.

Table 3.1: Estimated annual gross primary production of a range of ecosystem (Odom 1971; Clapham Jr. 1973).

	Ecosystems	Area (10^6 km^2)	Gross primary productivity (ly./Yr.)
	Marine		
1.	Open Ocean	326.0	100
2.	Costal zones	34.0	200
3.	Up welling zones	0.4	600
4.	Estuaries and reefs	2.0	2000
	Terrestrial		
1.	Desert and Tundras	40.0	20
2.	Grasslands	42.0	250
3.	Dry forests	9.4	250
4.	Boreal coniferous forests	10.0	300
5.	Cultivated lands	10.0	300
6.	Moist temperate forests	4.9	800
7.	Mechanized agriculture	4.0	1200
8.	Wet tropical, sub tropical forests	14.7	2000

Secoundry Production

The potential energy resulting from primary production furnishers the energy required by the other trophic levels in an ecosystem. Some energy, in the form of food is consumed by herbivores or omnivores who may be eaten by carnivores that in turn may be eaten by the other carnivores. However much of this ingested food is not assimilated; herbivores may assimilate only 10 percent their ingested food, whereas the assimilation coefficiency of carnivores is typically higher. For example various species of fish absorbed between 86 to 96 percent of the ingested food but the efficiency absorption of different classes of food substances varied: about 92-98% of the ingested protein was absorbed, while only 80 percent of the fat and about 63-79% of carbohydrates was the absorbed by the fish (Pandian, 1967). The unassimilated materials leaves the animal’s body as waste material to serve as an energy source for other organisms (for initiation of detritus food chain). Assimilated energy is used by these consumers species for various metabolic process, such as respiration, excretion and secretion. The resultant amount of energy stored in the tissues of heterotrophs is termed as net secoundary production. The gross secoundary production is equivalent to the total plant material ingested by the herbivores, less the materials lost as faeces. That is it is the food that actually possess through the walls of the gut. Unlike gross primary production, gross secoundary production can be measured directly by determining the amount of material defaecated.

Patterns of flow of energy through the ecosystems

In the ecosystem one can observe the transfer or flow of energy from one trophic level to other in succession. A trophic level can be define as the number of links by which it is separated from the producers, or as the next position or the organism in the food chain. The patterns of eating and being eaten from a linear chain called the food chain which can always be traced back to the producers. Thus, the primary producers trap radiant energy of the sun and transfer that the chemical or potential energy of organic compounds such as carbohydrates, proteins and fats.

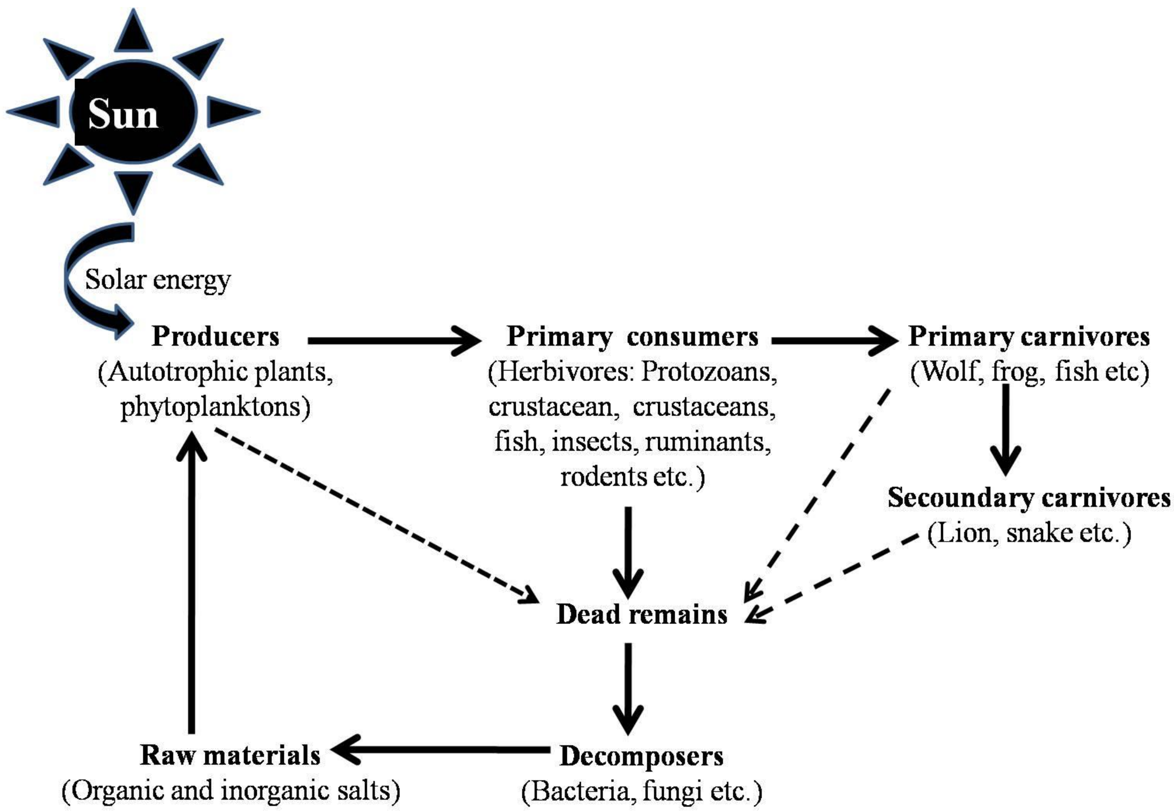

Fig. 3.7: A generalized food chain of the ecosystem

When a herbivore animal eats a plant and these organic composed are oxidized the energy librated is just equal to the amount of energy used in the synthesizing the substances (first law of thermodynamics), but some of the energy is heat and not useful energy (secound law of thermodynamics). If this animal, in turn, is eaten by another animal, along with the transfer of energy from a herbivore to carnivore a further decrease in useful energy occurs as the secound animal (carnivore) oxidizes the organic substance of the first (herbivore) lo liberate energy to synthesize its own cellular constituents. Such transfer of energy from organism to organism sustains the ecosystem and when energy is transferred from individual to individual in a particular community, as in the pound or lake or river, we come across the food chain (Fig. 3.7).

The number of steps in a food chain is always restricted to four or five, since the energy available decreases with each step. In other words, the energy fixed in organisms such as in aquatic plants in pound passes through the ecosystem in the form of plant to herbivore to carnivore, where only three steps are encountered in the chain. But very often, the chain are very complicated with several steps includes plant to herbivore to carnivore$_1$ to carnivore$_2$ to carnivore$_n$.

3.7.2 Biogeochemical cycles

According to the law of conservation of matter, matter is neither created nor destroyed; obviously the carbon and nitrogen must have been used over and over again in the course of time. The earth neither receives ant great amount of matter from other parts of the universe nor does it loss significant amount of matter to outer space. The amount of each element such as carbon, nitrogen, hydrogen, oxygen, phosphorus, calcium etc are taken from the environment, made a part of some cellular component of an organisms and finally, perhaps by a quite circuitous route involving several other organisms, are returned to the environment to be used over again. The cyclic movements of chemical elements of the biosphere between the organism and environment are referred to as biogeochemical cycle (Vernadsky 1934). Here, bio refers to the living organisms and geo to the rocks, soil, air and water of the earth.

Types of Biogeochemical cycle

There are two types of biogeochemical cycles, the gaseous and sedimentary. In gaseous cycles the main reservoir of nutrients is the atmosphere and the ocean. In sedimentary cycles the main reservoir is the soil and the sedimentary and other rocks of the earth's crust. Both involve biotic and abiotic agents, both are driven by the flow of energy and both are tried to the water cycle.

Water cycle:

The atmosphere, ocean and masses from a single gigantic water system that is driven by solar energy. The presence and movement of water in any part of the system affects the presence and movement in other parts. In fact, the atmosphere has great significance in words water system. At any one time the atmosphere holds no more than a 10 to 11 day supply of rainfall in the form of vapour, clouds and ice crystals. Thus the turnover of water molecules is rapid. Because the source of water in the atmosphere is evaporation from land and sea, there are global differences in the amount of evaporation and the amount of moisture in the atmosphere at any given point. Evaporation at lower altitudes is considerably greater than higher altitudes, showing the greater heat budget produced by the direct rays of the sun. Evaporation is greater over ocean than over land.

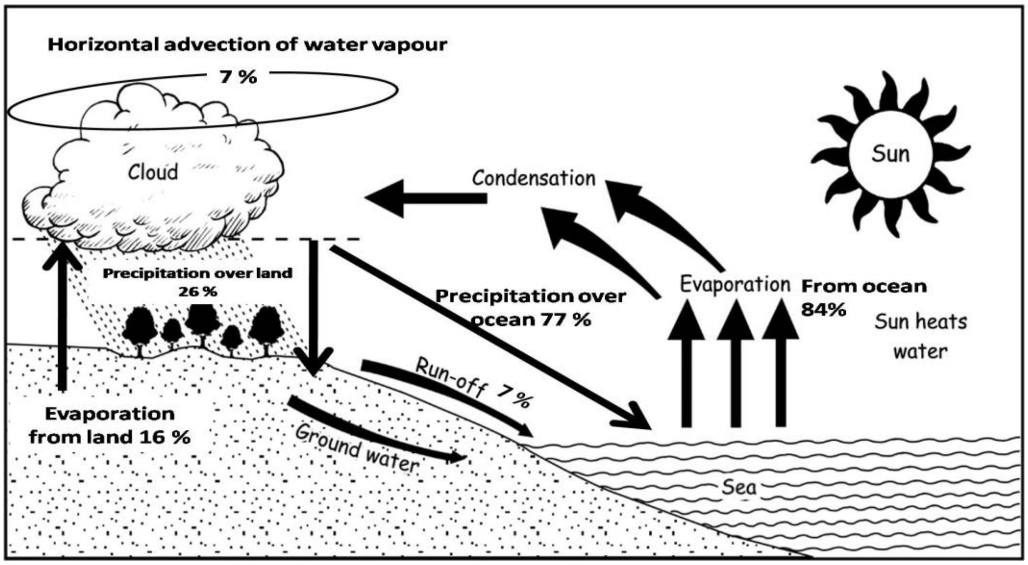

Fig. 3.8: The global budget of water. The mean annual global precipitation of 83.6 cm has been converted into 100 units (after Smith, 1977)

Thus, evaporation, precipitation, detention and transportation maintain a stable water balance on the earth. Consider the amount of water that falls on the earth terms as 100 units (Fig. 3.8). On the average, 84 % of water is lost from the ocean by evaporation, while only 77% of water is gained by it from precipitation. Land area loss 16 % of water by evaporation and gain 23 % of its by precipitation. Water runoff through rivers from land to oceans makes up 7 %, which balance the evaporation deficit of the ocean. The remaining 7 % of water circulate as atmosphere moisture.

(A). Gaseous cycles

The gaseous cycles geochemical cycles are following types:

1. **Carbon cycle:** All organic compounds that enter into the composition of living matter contain carbon. There are three main source of carbon in the living world:

- Carbon dioxide of the air and that dissolve in ocean.
- Carbonate rocks in the earth curst.
- Fossil fuel like coal and petroleum.

The atmosphere contains 0.03 % carbon dioxide. This comes to about 1.3×10^{12} tonnes. Ocean contains about 1.3×10^{13} tones of carbon dioxide. The atmosphere ocean system continuously exchanges carbon dioxide with the biosphere and the lithosphere. Most of the carbon dioxide enters the living world through photosynthesis. Plants fixed nearly 1.3×10^{10} tonnes carbon dioxide annually.

Inside the biosphere, the movement of carbon through the food chain from the producers to the consumers and from both these group to the decomposers. Carbon goes back the surrounding medium as carbon dioxide for cycling in following ways:

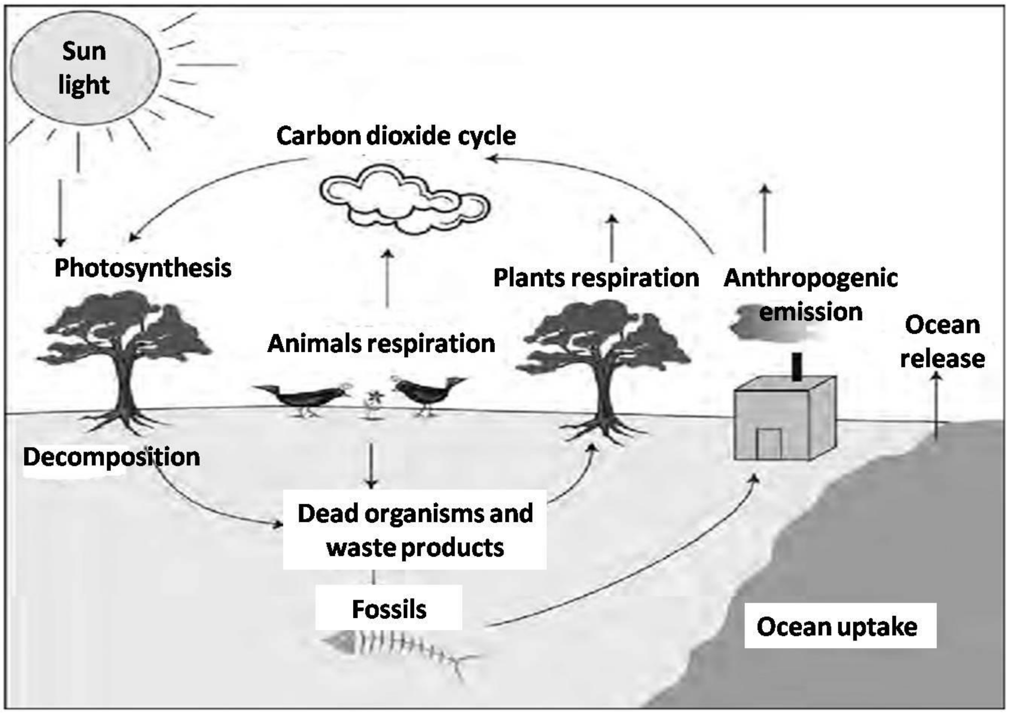

Fig. 3.9: The carbon cycle of the earth

- By biological process of the respiration in plants and animals.
- By decay and decomposition of the dead animals and plants by the decomposers.
- By burning of wood and fossil, petroleum substances and by the dissolution of the carbonate rocks.

The graphic representation of the carbon cycle of the earth is describe in Fig. 3.9. Animal remains like molluscan shells and protozoan tests are deposited as carbonate rocks. Calcium carbonate as a byproduct of photosynthesis assimilation is released by plants living in alkaline waters. In due course of time, calcium carbonate mixed with clay turns into limestone. Also about 100 million tons of CO_2 is annually released by weathering of rocks. Hot springs and volcanic activities also release substantial quality of CO_2 in the atmosphere. About $40{,}000\times 10^9$ tonnes of $CO_2$from the atmosphere of the past geological period is lying buried as fossil fuels. Humans are returning about billion tons of CO_2 in each year by burning the fossil fuels in homes and factories.

2. **Nitrogen cycle:** Nitrogen is an essential constituent of different biologically significant organic molecules such as amino acids, protein, pigments, nucleic acids and vitamins. It is also a major component of the atmosphere, comprising about 78.08% of it. The

paradox is that in its gaseous state, N_2 abundant through it is unavailable to most life. Before, it can be utilized it must be converted to some chemically usable form. So nitrogen cycle can define as **"**A biogeochemical process which transforms the inert nitrogen present in the atmosphere to a more usable form for living organisms". The process of nitrogen cycle (Fig. 3.10) takes place in the following stages: nitrogen fixation, nitrification, assimilation, ammonification and denitrification.

a) Nitrogen fixation: In nitrogen fixation, atmospheric inert nitrogen gas (N_2) is converted into the usable form ammonia (NH_3). During this process, atmospheric N_2 is deposited into soils mostly through the precipitation and converted into NH_4^+ by separating two nitrogen atoms and combined with hydrogen. The nitrogen fixation is take place by the several methods:

(i). **Atmospheric fixation or electro-chemical or photochemical fixation:** This is a natural phenomenon where the high energy fixation like cosmic radiation, meteorite trails and lightning provides the high energy needed to combine nitrogen to oxygen and hydrogen of water. The resulting ammonia and nitrates are brings them down to the earth surface by precipitation.

(ii). **Industrial nitrogen fixation:** Is a man-made alternative that aids in nitrogen fixation by the use of ammonia. Ammonia is produced by the direct combination of nitrogen and hydrogen and later, it is converted into various fertilizers such as urea.

(iii). **Biological nitrogen fixation:** Biological agencies which fix free nitrogen of the atmosphere are many soil and water bacteria. These may be free living or symbiotic bacteria. Most of the atmospheric nitrogen fixation takes place by the biological fixation. Some of these nitrogen fixing organism may be free living, either in the soil (*Azobacter* and *Clostridium*) or in water (bule green algae: *Nostoc*, *Calothrix* and *Anabaena*) and produce vast quantities of fixed nitrogen. In other case, some symbiotic bacteria of genus *Rhizobium* although unable to fix atmospheric nitrogen themselves and only can do this when in combination with cells either from the root of legumes and of other angiosperms such as *Alnus*, *Myrica* etc. Further both free soil bacteria produce ammonia as the first stable product and like the symbiotic bacteria, they require molybdenum as an activator and are inhibited by an accumulation of nitrates and ammonia in the soil.

Recently, certain lichens (*Collema tunaeforme* and *Peltigera rufescens*) were also implicated in nitrogen fixation. Lichens with nitrogen-fixing ability possess nitrogen fixing blue green species as their algae component.

b) **Nitrification:** In this process, the ammonia is converted into nitrate by the presence of bacteria in the soil. Nitrites are formed by the oxidation of Ammonia with the help of *Nitrosomonas* bacterium species. Later, the produced nitrites are converted into nitrates by *Nitrobacter*. This conversion is very important as ammonia gas is toxic for plants. The reaction involved in the process of Nitrification is as follows:

$$\mathbf{2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O}$$

$$\mathbf{2NO_2^- + O_2 \rightarrow 2NO_3^-}$$

c) **Assimilation:** Primary producers (plants) take in the nitrogen compounds from the soil with the help of their roots, which are available in the form of ammonia, nitrite ions, nitrate ions or ammonium ions and are used in the formation of the plant and animal proteins. This way, it enters the food web when the primary consumers eat the plants.

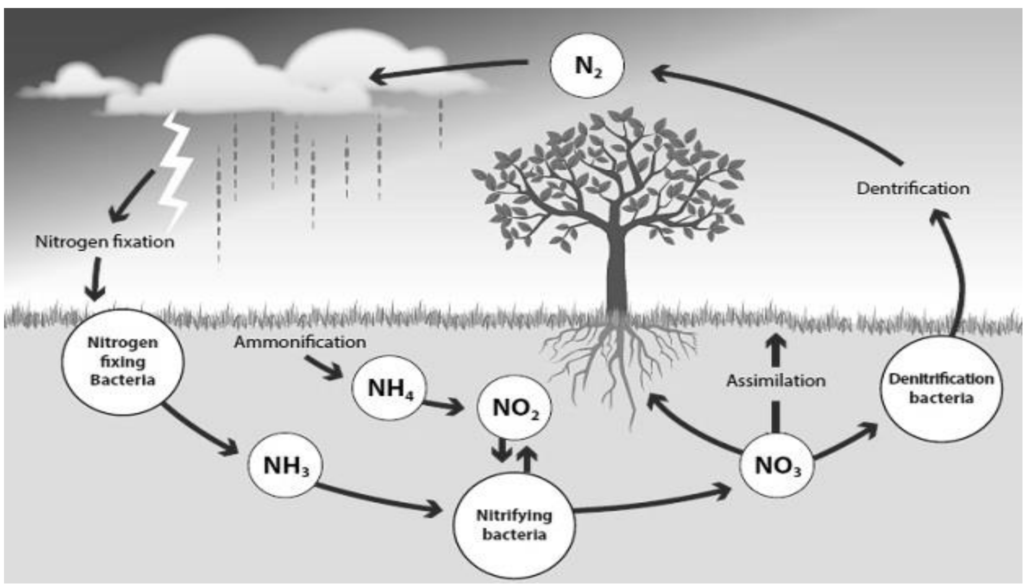

Fig. 3.10: Nitrogen cycle

d) **Ammonification:** Proteins of animals are excreted out in the form of urea, uric acid and ammonia. Proteins of dead plants and animals are broken into ammonium ions and the process is called ammonification. This process of decomposition produces ammonia, which is further used for other biological processes.

e) **Denitrification:** Denitrification is the process in which the nitrogen compounds makes its way back into the atmosphere by converting nitrate (NO_3^-) into gaseous nitrogen (N_2). This process of the nitrogen cycle is the final stage and occurs in the absence of oxygen. Denitrification is carried out by the denitrifying bacterial species like *Pseudomonas*, which will process nitrate to gain oxygen and gives out free nitrogen gas as a byproduct.

(B). Sedimentary cycles

Plants and animals fulfill their mineral requirements from mineral solutions in their environments. After the death of the living organisms the minerals are returns to the soil and water through the process of decomposition by the microorganisms. There are different kinds of sedimentary or mineral cycles, depending on the kind of elements, but following two cycles are very significant to the ecosystem.

1. **Sulphur cycle:** The sedimentary phase of sulphur cycle (Fig. 3.11) is long termed and in it sulphur is tied up in organic and inorganic deposits. From these deposits, it is released by weathering and decomposition and is carried to terrestrial and aquatic ecosystem in a salt solution. Atmospheric phase of sulphur cycle is less pronounced and it permits circulation on a global scale.

   Sulphur enters the atmosphere from the several sources: the combustion of fossil fuels, volcanic eruption, the surface of oceans and the gases released by the process of decomposition. Initially sulphur enters the atmosphere as H_2S which quickly oxidizes into another volatile form SO_2. It is soluble in water and carried back to earth in rainwater as weak sulphuric acid. The soluble form of sulphur is absorbed by the plant roots, where it incorporated into certain organic molecules such as amino acids and proteins. From producers the sulphur in amino acids is transferred to the consumers with excess being excreted in the faeces.

   Excretion and death carry sulphur in living material back to the soil and to the bottom of ponds, lakes and seas where the organic material is acted upon the bacteria of detritus food chain. The sulphydryl group (–SH) of amino acids is separated from the rest of the molecules as hydrogen sulphide (H_2S) by the decomposing bacteria. In aerobic condition, the H_2S is oxidized to sulphate by bacteria specially adapted to perform this conversion:

$$H_2S + 2O_2 \longrightarrow SO_4^- + 2H^+$$

   The sulphate produced then can be reuse by the autotrophs. In anaerobic environment, it is impossible to oxidize sulphide by this means because the process of oxidation required oxygen. But if infra red radiation is present, there are photosynthetic bacteria that can use it to manufacture carbohydrates and oxidize sulphide either to elemental sulphur or to sulphate:

$$6CO_2 + 12H_2S + hv \longrightarrow C_6H_{12}O_6 + 6H_2O + 12S$$

$$6CO_2 + 12H_2O + 3H_2S + hv \longrightarrow C_6H_{12}O_6 + 6H_2O + 3SO_4^- + 6H^+$$

Elemental sulphur can also be utilized by other bacteria to form sulphate. If oxygen is present, the reaction is quite rapid.

$$2S + 3O_2 + 2H_2O \longrightarrow 2SO_4^- + 4H^+$$

Under anaerobic conditions, elemental sulphur can still be oxidized to sulphate by certain bacteria if nitrate is present:

$$6NO_3 + 5S + 2CaCO_3 \longrightarrow 3SO_4^- + 2CaSO_4 + 2CO_2 + 3N_2$$

None of these bacterial reactions is unidirectional; under certain conditions, sulphate can also be reduced either to sulphide or to elemental sulphur by bacteria. This series of reactions operating within the organic phase of the sulphur cycle provides a rather finely turned mechanism for regulating the availability of the sulphur to autotrophs.

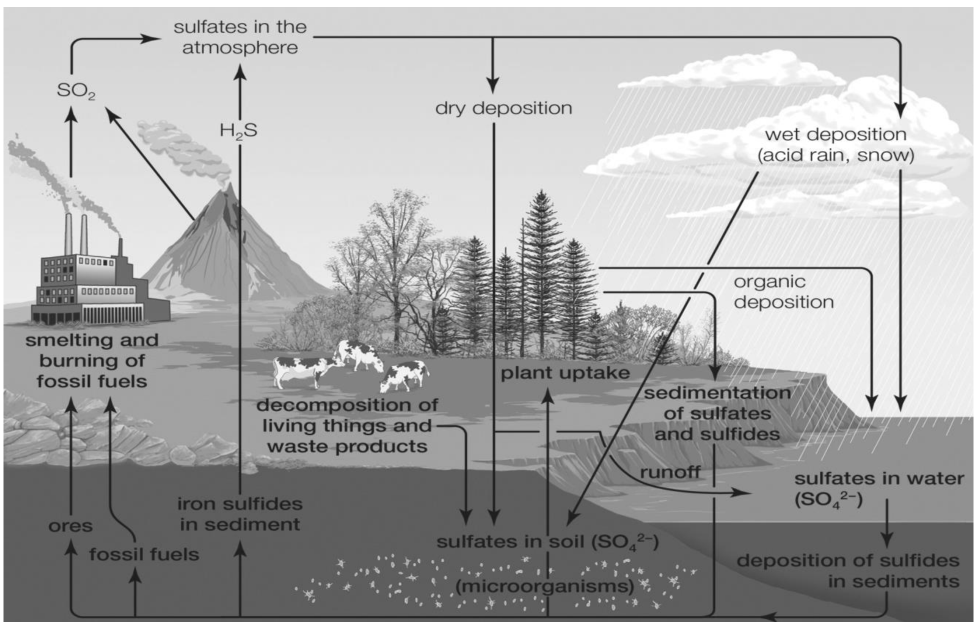

Fig. 3.11: Sulphur cycle in the atmosphere (Source: Encyclopedia Britannica, Inc.)

The sulphur is removed from the organic phase in the form of elemental sulphur which is insoluble and accumulates in sediments. If iron is present in the sediment, it can combine with sulphide to form iron sulphides, all of which are highly insoluble:

$$Fe^{++} + S^- \longrightarrow FeS$$

$$Fe\ (ionic) + 2S\ (ionic) \longrightarrow FeS_2\ \text{(Ferrous sulphide or pyrite)}$$

FeS_2 is highly insoluble under neutral and alkaline conditions and is firmly held in mud and wet soil. Some ferrous sulphide is contained in sedimentary rocks overlying coal deposites. Exposed to the air in deep and surface mining, the ferrous sulhate oxidizes and in the present of water produced ferrous sulphate and sulphuric acid.

In this manner, sulphur in pyrite rocks, suddenly exposed to weathering by man, discharge heavily slugs of sulphur, sulphuric acid, ferric sulphate and ferrous hydroxide into a aquatic ecosystems. These compounds destroy aquatic life and cause acidic water.

2. **Phosphorus cycle:** Phosphorus cycle has no atmospheric phase (Fig. 3.12). It occurs naturally in environment as phosphate (PO_4^- or one of its analogous HPO_4^- or H_2PO_4), either as soluable inorganic phosphate ions, as soluble organic phosphate (as a part of a soluble organic molecule), as particulate phosphate (as part of an insoluble organic or inorganic molecules) or as mineral phosphate (as part of mineral grain as found in a rock sediment). The ultimate source of phosphate in the ecosystem us crystalline rocks.

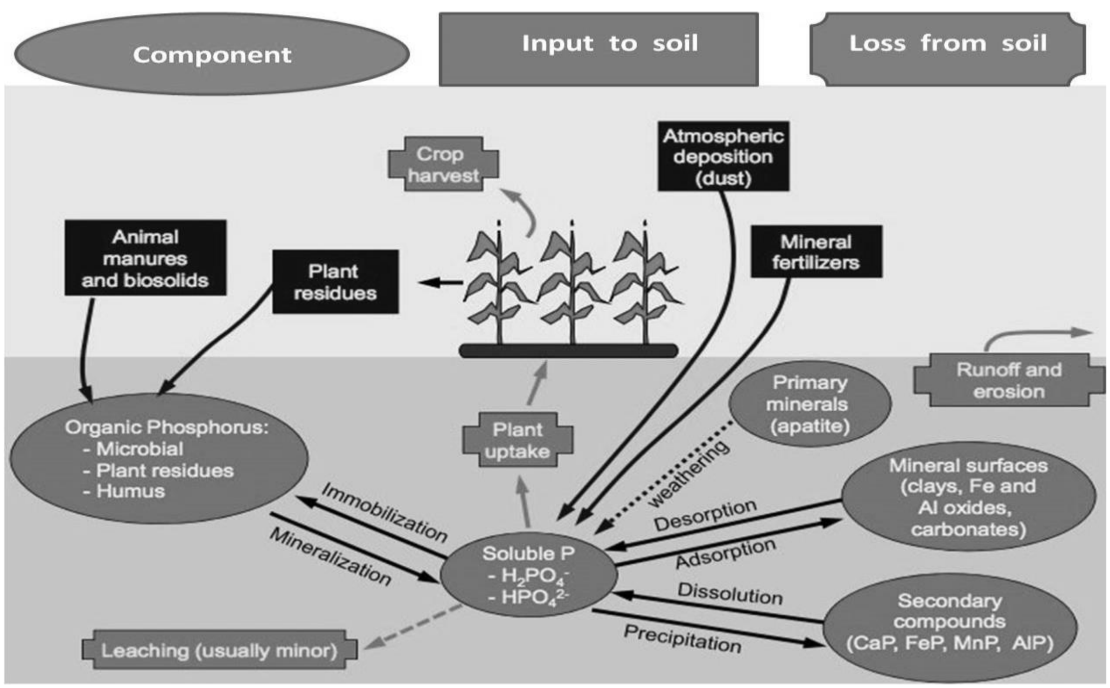

Fig. 3.12: Phosphorus cycle in the environment

As there are eroded and weathered phosphate is made available to living organisms, generally as ionic phosphate. This is introduced into autotrophic plants through their roots, where it is incorporated into living tissues. From autotrophs, it is passed along the grazing food chain in the same fashion as nitrogen and sulphur, with excess phosphate being excreted in the faeces. An extreme example of faecal phosphate is the tremendous guano deposit build up by birds on the desert west coast of South America. Phosphates can also be released as particulate matter from forest and grassland fires.

In the detritus food chain, a large organic molecules containing phosphate are degraded, the phosphate is liberated as inorganic phosphate. In this form it can be immediately be taken up by autotrophs, or it can be incorporated into a sediment particle, either in the soil of a terrestrial ecosystem or in a sediment of an aquatic ecosystem. The sedimentary phase of phosphorus cycle remains comparatively slow than the organic phase.

3.8 SUMMARY

In this chapter we have learned about the overall structure of ecosystem and how it works. The ecosystem is the major ecological unit which has their own specific structure and functions. It refers to as a community of life forms interacting with non-living components in a same system. The earth contains many ecosystems and all these ecosystems are interlinked to one another. The structure of an ecosystem principally gives the information regarding the living components (organisms) and physical factors (temperature, moisture, pH etc) of the environment as well as the allocation of nutrients in a meticulous habitat. From the structural point of view, the ecosystem can be divided into two components i.e., **abiotic** and **biotic components**. Abiotic components of the ecosystem include those components which are non living. These are basically the inorganic and organic elements and compounds of the environment or habitat of the organism. Biotic components included all the living organisms present in the environment of ecosystem. The biotic components can be categorized into two components according to their nutrition point of view i.e., **autotrophic components** (all green plant which synthesized their own food) and **heterotrophic components** (non-green plants and all animals including human). They may be consumers and decomposers. Consumers further divided into four categories: Primary consumers, Secondary consumers, Tertiary consumers and Quaternary consumers. The decomposers are chiefly microscopic or very small in size (fungi and bacteria) which decompose the dead residue of producers and consumers.

The biological balancing between various components of ecosystem is known as homeostasis or biological equilibrium or balance of nature. This process is controlled by the numerous factors including carrying capacity of the system, capability of recycling and the reproduction potential of the organisms. The nature adopts positive feedback (increasing the population of organisms at any level when impose the positive effects on other level organisms) and negative feedback (when growing populations of organisms compel the negative effects on the population of others) mechanism to balance the ecosystem.

When we consider the function of an ecosystem, we must describe the flow of energy and the cycling of nutrients. That is why, we are interested in things like how the plants trapped the solar energy and how much plant martial is eaten by herbivores, and how many herbivores are eaten by the carnivores. The concept of trophic levels was first developed in 1942 by Raymond Lindeman which means food or nourishment. The trophic level in an ecosystem may be defined as a position occupied by an organism in a food chain. The food chain is a sequence of organisms which eat other organisms and may, in turn, be eaten themselves. There are two types of food chain occurs naturally in ecosystem. First is **grazing food chain** (It is a normal type of food chain which starts from the green plants and ends at carnivores by passing through herbivores) and secound is **detritus food chain** (The food chain that passes through dead organic matter).

The food chain, as a matter of fact, does not occur in isolation. Since many animals eat more than one kind of food, different kinds of food chains exist in an ecosystem. This network of interconnected food chain is called **food web**. Thus food web may be defined as the network of a number of food chains existing in an ecosystem.

The **ecological pyramids** represent the trophic structure and also trophic function of the ecosystem. In many ecological pyramids, the producers from the base and the successive trophic levels make up the apex. The ecological pyramids may be three types: **Pyramids of number** (the number of individual organisms at different trophic levels of food chain), **Pyramids of biomass** (the biomass of the members of the food chain at each trophic level) and **Pyramid of energy** (It indicates not only the amount of energy flow at each level).

Living organisms can use energy in several forms. But all can be grouped under one of the two headings: radiant energy and fixed energy. Only a small fraction of the light energy reaching the earth is trapped. This radiant energy of sun is converted into chemical or potential energy by photosynthesis in plants, the photosynthetic autotrophs. All the energy that the plant actually fixes results in the formation of sugar. The energy used by the plant is converted into chemical energy, it should theoretically be possible to determine the entire energy uptake by the plants by measuring the total amount of sugar produced. This quantity is termed gross primary production or gross productivity. The gross productivity is dependent on many things, including climatic conditions such as temperature, rainfall and total solar radiations and other abiotic factors.

The biogeochemical cycle refers to the cyclic movements of chemical elements of the biosphere between the organism and environment is referred to as biogeochemical cycle. The biogeochemical cycle are can broadly divided into: **gaseous cycle** (includes carbon, nitrogen cycle etc) and **sedimentary cycle** (includes sulphur and phosphorus cycle etc). The geochemical cycle of different chemical substances are closed: the atoms are used over and over again. To keep the cycles going does not require new matter but it does require energy. Further, the patterns of flow, both the energy and the chemical substances are of great significance.

3.9 GLOSSARY

Abiotic: Nonliving factors of the environment includes light, temperature, soil, climate and atmospheric gases etc.

Absorption: The taking in of water and dissolved minerals and nutrients across cell membranes.

Aerobic: Pertaining to the presence of free oxygen. Aerobic organisms require oxygen for their life processes.

Anaerobic: Pertaining to the absence of free oxygen. Anaerobic organisms do not require oxygen for their life processes, in fact oxygen is toxic to many of them. Most anaerobic organisms are bacteria or archaeans.

Autotroph: Any organism that is able to manufacture its own food.

Biodiversity: The variety of plant and animal life in a habitat.

Biotic: All living component of the ecosystems including plant animal and microorganisms.

Carnivore: Organism that eats meat for energy.

Chemical energy: That part of the energy in a substance that can be released by a chemical reaction.

Consumer: Organism that consumes another organism as food for energy.

Decomposer: Organism that breaks down organic material.

Detritivore: Organism that obtains its energy by feeding on dear organisms or wastes.

Detritus: Accumulated organic debris from dead organisms, often an important source of nutrients in a food web.

Ecological pyramid: A graph that illustrates the trophic level in food chain.

Ecosystem: A system formed by the interaction of a community of organisms with their physical environment.

Food chain: An interconnected chain of organisms that indicate which predators are and which are prey in relation to one another.

Food web: A network of interconnected food chains in an ecosystem.

Herbivore: Organism that eats plants for energy.

Herbivore: Organisms that eats only plants or algae.

Heterotrophy: An organism that feeds on complex organic substances.

Litter: Leaf litter, or forest litter, is the detritus of fallen leaves and bark which accumulate in forests.

Omnivore: Organism that eats plants and meat for energy.

Photosynthesis: Process that producers use.

Phytoplankton: Tiny, free-floating, photosynthetic organisms in aquatic systems. They include diatoms, desmids, and dinoflagellates.

Plankton: Very small, free-floating organisms of the ocean or other aquatic systems, including phytoplankton, which produce their own nutrients through photosynthesis, or zooplankton, which get their nutrients from organisms.

Predator: An animal that hunts and kills other animals for food

Predator: Organism which hunts and eats other organisms. This includes both carnivores, which eat animals, and herbivores, which eat plants.

Prey: Animal hunted or caught for food.

Prey: Organism hunted and eaten by a predator.

Primary productivity: The amount of organic material that the photosynthetic organisms of an ecosystem produce.

Producer: Any organism which brings energy into an ecosystem from inorganic sources.

Saprophyte: Organism which feeds on dead and decaying organisms, allowing the nutrients to be recycled into the ecosystem. Fungi and bacteria are two groups with many important saprophytes.

Scavenger: An organism that feeds upon dead and dying organisms.

Solar radiation: Radiation emitted by the Sun.

Zooplankton: Tiny, free-floating organisms in aquatic systems that cannot produce their own food.

3.10 SELF ASSESSMENT QUESTIONS

3.10.1 Multiple Choice Questions

1. Ecosystem is smallest unit of
   (a) Ionosphere (b) Lithosphere
   (c) Biosphere (d) Mesosphere

2. Which one of the following is not a functional unit of an ecosystem?
   (a) Productivity (b) Stratification
   (c) Energy flow (d) Decomposition

3. The source of energy in ecosystem is
   (a) AMP (b) ATP
   (c) NADP (d) Sunlight

4. Energy in an ecosystem is
   (a) Released (b) Absorbed
   (c) Flows (d) None of the above

5. The ratio between energy flow at different points in a food chain is known as:
   (a) Ecological capacity (b) Ecological efficiency

(c) Ecological assimilation (d) Ecological potential

6. In an ecosystem, the energy flow is always
(a) Always unidirectional (b) Always bidirectional
(c) In any direction (d) Always down directional

7. Name the organisms that manufacture organic compounds from simple inorganic compounds without using sunlight?
(a) Detrivores (b) Organotrophs
(c) Phototrophs (d) Chemotrophs

8. "The pyramid of energy is always upright" states that
(a) The energy conversion efficiency of herbivores is better than carnivores
(b) The energy conversion efficiency of carnivores is better than herbivores
(c) Producers have the lowest energy conversion efficiency
(d) Energy conversion efficiency is the same in all trophic levels.

9. What type of food chain is it: dead animals → blowfly maggot → maggots → frog → snake
(a) Detritus food chain (b) Decomposer food chain
(c) Predator food chain (d) Grazing food chain

10. Which of the following type of productivity counts the total fixation of energy by photosynthesis?
(a) Secondary productivity (b) Primary productivity
(c) NPP (d) GPP

3.10.2 Fill in the blanks

1. Vertical distribution of different species occupying different levels in an ecosystem is called…………
2. The rate of production of biomass is termed as………..
3. The degradation of humus by some microbes to release the inorganic nutrients is called……..
4. The ………….of organisms are the beginning of the detritus food chain.
5. The …………are the saprotrophs (heterotrophs) which meet their energy requirements by degrading the detritus.
6. The amount of energy ………… at each successive trophic level.
7. The pyramid of number in a grassland ecosystem is…………
8. The …………. for the first time put forth the concept of ecosystem.
9. All the living organisms are ………….. component of ecosystem.
10. From the structural point of view, the ecosystem can be divided into ……… and ……….. components

3.10.3 True and False

1. In an ecological pyramid, the amount of energy available at the lower trophic level is always more than that at a higher trophic level.
2. The functioning of ecosystem is associated with energy flow and cyclic of nutrients in ecosystem through the structural components.
3. Algae are eaten by insects, and insects are eaten by the fish. In this food chain system; the algae is primary consumer, insect is secondary consumer, and the fish is tertiary consumer. False.
4. Birds and animals are the examples of abiotic environment.
5. An organism that breaks down dead and decaying matter is called omnivore.
6. Many feeding relationships that are linked together are called a food web.
7. When an animal is hunted by its predator, this is called parasitism.
8. The living and nonliving factors in an environment and all their interactions called ecology.
9. Phosphorus cycle occur in the nature in the form of gaseous cycle.
10. If gross production equals to the respiration ($P_{g=}R$) no change in energy content results.

Answer Key:

3.10.1: 1 (c), 2 (b), 3 (d), 4 (c), 5 (b), 6 (a), 7 (d), 8 (a), 9 (a), 10 (d)
3.10.2: 1. Stratification, 2. Productivity, 3. Mineralisation, 4. Death, 5. Decomposers, 6. Decrease, 7. Upright, 8. A.G. Tansley, 9. Heterotrophic, 10. Abiotic and biotic.
3.10.3: 1. True, 2. True, 3. False, 4. False, 5. False, 6. True, 7. False, 8. False, 9. False, 10. True

3.11 REFERENCES

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3.13 TERMINAL QUESTIONS

3.13.1 Short answer type questions

1. Briefly describe the abiotic components of ecosystem.
2. What do you understand by positive and negative feedback of ecosystem balancing?
3. What are the differences between grazing and detritus food chain?
4. What is food web? Explain with example.
5. What are the importance and limitations of ecological pyramids?
6. What are biogeochemical cycles?
7. What is biological nitrogen fixation?
8. Discuss the water cycle in brief.

3.13.2 Long answer type questions

1. What do you understand by the structure of ecosystem?
2. Describe the concept and mechanism of homeostasis in detail.
3. Discuss the trophic level and food chain in an ecosystem.
4. Explain the ecological pyramid in detail.
5. Discuss the ecological energetic and flow of energy in an ecosystem in detail.
6. Discuss the nitrogen cycle in detail.
7. Discuss the sulphur cycle in detail.
8. Discuss the cycling of phosphorus in environment.

UNIT-4- ECOSYSTEM DEVELOPMENT AND ECOSYSTEMS OF THE WORLD

Contents:

4.1 OBJECTIVES

The present topic provides an overview of ecosystem development and outlines the world's major ecosystems. After reading this topic, learners will be able to answer the:

- Concept of succession
- Types of succession
- Process of succession
- Major ecosystem of the world
- Ecosystem of India based upon the altitude variations

4.2 INTRODUCTION

As we have already discussed in the previous chapter that the biotic community of the ecosystem is very unstable and they change regularly over time. The lifespan of an individual organism is affected by the many circumstances including the natural phenomena. In addition, there are other levels of community change that function longer and are the cause of considerable changes in the structure of the community. These include ecological succession and community evolution.

You have usually seen forest landscape containing complex diversity of flora and fauna but have you wondered ever how it come to be or how did that forest constructed here? May be once upon a time that land must have been empty rock or a pond, yet today, it contain a community comprising a rich biodiversity of plants and animals which interact with each other on the same piece of landscape. This conversion did not happen overnight while it's a long, slow and gradual process of change in ecological communities. Such an orderly and progressively replacement of one community by another until a relatively stable community (i.e., climax community), occupies the area is called ecological succession. In a simple sentence, Ecological succession may be defined as the process of change in the species structure of an ecological community over time. The time scale can be decades (for example, after a wildfire), or even millions of years after a mass extinction (Sahney and Benton 2008).

In the process of succession, the community begins with relatively few simplest plants or animals species, collectively known as pioneering species which ultimately increases the complexity of the system until or unless it becomes stable or self-perpetuating as the climax community. Succession may be initiated either by formation of new, unoccupied habitat, such as from a lava flow or a severe landslide, or by some form of disturbance of a community, such as from a fire, severe wind throw, or logging. The changes in the structure and composition of the community are rapid at first, slowing gradually until a point of dynamic equilibrium is reached, and the community is more or less stable.

Let us take some examples to understand the concept of succession more thoroughly. Suppose, a lake is filled with silt that gradually transforms from a deep lake into a shallow pond, then into a marsh and in some cases into a dry land which eventually converts into forest. In this case, the principal cause of the change in the community was a physical process i.e., the filling in the lake with silt. Suppose, a forest has turned into a bare ground due to severely forest fire. Now a series of changes take place. Diverse plant communities invade and grow up there and replace one another: first annual weeds, then perennial weeds or grasses, then shrubs and trees-until or unless a forest ends the development. Here, a principal cause of succession was the growth of plants on an existing soil. Likewise, if a landslide exposes a surface of rock in the mountains, the surface may be successively occupied by a spare cover of lichens; a spreading moss mat; grasses, which enter and become a meadow; a shrub thicket, which overtops and suppress the grasses; a first forest stage of smaller tress, which seed into the shrub thicket, grow through it, and replace it; and a final stage form a large and potentially permanent forest community. Here, the process of succession proceeded by a back and forth interplay between organism and environment: as one dominant species modified the soil and microclimate in ways that made possible the entry of a third dominant species, which in turn altered it environment.

In all the mentioned above three examples, the causes of the successional changes are of varying degrees, external to the community or internal to the community, many successions involve both kinds of causes and reciprocal influences (Whittaker, 1970).

Succession was among the first theories advanced in ecology. Ecological succession was first documented in the Indiana Dunes of Northwest Indiana and remains at the core of much ecological science (Smith and Mark 2009). The basic idea of succession was first of all forwarded by Anon Kerner in his book “Plant life of the Danube Basin” during the regeneration of a swamp forest. However the term “ecological succession” was first of all used by Hult (Verma and Agarwal 2008).

Factors affecting the process of succession

The process of succession influenced by the various factors including the site conditions, events initiating succession (perturbations), interactions between species and stochastic factors (availability of colonists or seeds or weather conditions) at the time of disturbance. Nowadays, two main important disturbances are listed as: anthropogenic activities and climatic change (Bazzaz 1996).

During the process of succession, invader communities dominated by fast-growing, well-dispersed species (opportunist, fugitive, or r-selected life-histories). As succession proceeds, these species will tend to be replaced by more competitive (k-selected) species. Species diversity necessarily increases during early succession as new species arrive, but may decline in later succession as competition eliminates opportunistic species and leads to dominance by locally superior competitors. Net Primary Productivity, biomass, and trophic properties all show variable patterns over succession, depending on the particular system and site.

Ecological succession was formerly seen as having a stable end-stage called the climax, sometimes referred to as the 'potential vegetation' of a site, and shaped primarily by the local climate. This idea has been largely abandoned by modern ecologists in favor of non-equilibrium ideas of ecosystems dynamics.

The development of some ecosystem attributes, such as soil properties and nutrient cycles, are both influenced by community properties, and, in turn, influence further successional development.

4.3 TYPE OF SUCCESSION

The first organisms to become established in an ecosystem undergoing succession are known as pioneers; the stable community that ends the succession is termed the climax community. The whole series of communities which are involved in the ecological succession at a given area, such as from grass to shrub to forest, and which terminates in a final stable climax community, is called a sere and each of the changes that take place is a seral stage. Each seral stage is a community, although temporary, with its own characteristics and it may remain for a very short time or for many years. Seres are sometimes classified according to the predominant force that is bringing them about. These forces are biotic, climatic, physiographic and geologic and their resultant seres are commonly called bioseres, cliseres, eoseres and geoseres.

The succession may be of the following two types in any of the basic environments such as terrestrial, freshwater or marine:

4.3.1. Primary Succession: It is the process of species colonization and replacement in which the environment is initially virtually free of life. That is, the process starts with base rock or sand dune or river delta or glacial debris and it ends when climax is reached. The sere involved in primary succession is called presere.

4.3.2. Secondary succession: In this process, the changes occur after an ecosystem is disturbed but does not completely disintegrate. In this situation, organic matter and some organisms from the original community with remain: thus the successional process does not start from scratch. Consequently, secondary succession is more rapid than primary. It is seen in areas burned by fire or cut by farmers for cultivation. The sere involved in secondary succession is called subsere.

The primary and the secondary succession may be the following type depending upon the moisture contents:

(i). **Hydrach or hydrosere:** The succession when starts in the aquatic environment such as ponds, lakes, streams, swamp, bogs etc.

(ii). **Mesarch:** The succession when began in the area where adequate moisture is present.

(iii). **Xerach:** The succession when starts in xeric or dry habit having minimum amount of moisture. Example: dry dessert, rocks, etc. A temporary community in an ecological succession on dry habitat is called xerosere. It may be of three types: Lithosere (succession initiated in the rocks); Psammosere (succession initiated on sand); and Halosere (succession initiated on saline water or soil).

Further, a succession progressing entirely as a result of interactions of the organisms and their environment (i.e., driving force is internal to the community) is known as autogenic community. Example: succession on sand dunes. The succession moving under the influence of external factors, as input of nutrients is called allogenic community. Example: succession in a small pond.

4.4 PROCESS OF SUCCESSION

The complete process of a primary autotrophic ecological succession involves the following sequential steps which follow one another.

1. **Nudation:** The formation of the bare zone or nudation take place by many natural phenomena (such as volcanic eruption, landslide, flooding, erosion, fire, disease or other catastrophic agency etc) leads to beginning of succession. Humans have also created some new lifeless bare land (i.e., Walls, stone quarrying, flooding large land areas under reservoirs etc).

2. **Invasion:** It is the process of entering reproductive bodies (seeds, propagules etc) of various organisms and their establishment in bare land. In any bare land plant must be considered as pioneer invaders because the animal depends on the plants for their food requirements. Invasion include the following steps:

   (i) **Dispersal or migration:** The seeds, spores or the other propagules of the species reach the bare area through the air, water and animals. The process starting from the time a propagule leaves the parent plant to the time it arrive on the bare area is called migration**.**

   (ii) **Ecesis:** This is the successful establishment of migrated plant species into the new area. It includes the germination of seeds or propagules, growth of seedlings and starting of reproduction by adult plants. Only a few immigrant propagules are capable of doing this under primitive hard conditions and thus most of them disappear.

(iii) Aggregation: In this final stage of invasion, the successful immigrant individuals of a species increase their number by reproduction and aggregate in a large population in the area and in consequence individuals of the species come close to each other.

3. **Competition and reaction:** As the number of the individual increase, they aggregated at the limited space, now the competition started due to the similar requirements (intraspecific competition) of food, reproduction, shelter etc. They also compete with individuals of other species that may enter the area (interspecific competition). All individuals also compete with the environmental stress. All these combined effects of stress due to intraspecific and interspecific competition along with the abiotic stress, the environment of the ecosystem modified and progressively becoming unsuitable for the existing community which sooner or later is replaced by the new invaders.

4. **Stabilization or climax:** Eventually a stage is reached when the final terminal community becomes more or less stabilized for a longer period of time and it can maintain itself in the equilibrium. The vegetation is tolerant of the environment conditions it has imposed upon itself. It has a wide diversity of species, a well-developed spatial structure and complex food chains and its living biomass is in a steady state. This final stable community of the sere is the climax community and the vegetation supporting it is the climax vegetation. A climax community therefore, refers to as stable ecosystem in its final stage of ecological succession.

4.5 HYDROSERE

In a simple word it can be called aquatic succession. It occurs in the fresh water bodies, pool, pond, lake etc. There are several stages take place during the process of succession. The fresh water was dried out succeed by swamp and marsh and ultimately tuned into woodland. It is a very slow procedure and takes centuries or millennia to reach its climax stage, although, intermediate stages may be shorter or longer than others. The whole process of aquatic succession comprises the subsequent stages describe in below (Fig. 4.1):

Stage 1: Phytoplankton stage: During the early stage of succession the spores of the phytoplanktons (cyanobacteria), green algae, diatoms, etc. are carried out wind or water and deposited into the fresh water bodies. The simplest, unicellular and colonial microorganisms (bacteria, diatoms, phytoplanktonic algae etc) are the first invaders, therefore, this stage is called phytoplankton stage. Sooner or later, to get the favorable conditions of temperature, moisture and nutrients, large algal blooms appear.

Zooplankton makes their appearance after phytoplankton including *Amoeba*, *paramecium*, *Euglena* etc. If the growth of the phytoplankton and zooplankton become sufficient enough, the pond support the other forms of large animals. All these organisms add large amount of organic matter and nutrients throughout their life span by various activities. They settle at the bottom of the pond after death, and decay into humus that mixes with silt and clay particles brought into the basin by runoff water and wave action and form soil. As soil builds, the pond becomes shallower and further environmental changes follow.

Stage 2: Submerged stage: The muddy bottom and increasing light penetration in the shallower water of the pond provide the suitable conditions for the establishment of rooted submerged hydrophytes plants like branching green algae, *Chara*, *Hydrilla*, *Myriophyllum*, *Potamogeton*, *Vallisneria*, *Ceratophyllum* etc. These plants reproduced and colonize which ultimately bind the loose bottom sediment into a firmer matrix and add the organic matter on it. The organisms common to the barren pond floor cannot exist under submerged vegetation conditions. Already living species have now been replaced by other species that are able to creep over submerged flora. Dragonflies, mayflies and some other small crustaceans like *Asellas*, *Cypris*, *Cyclops*, *Daphnia*, *Gammarus* etc. inhabit the pond at this stage.

Stage 3: Floating stage: Continuously deposition of sediments and organic matter on the bottom reduce the depth of the pond. The roots of floating hydrophytes embedded in bottom while the leaves float on the surface of water (e.g., *Nelumbo, Nymphaea, Marsilea*, *Limnanthemum*, *Aponogeton*, *Trapa*, *Monochoria* etc). Some plants may occur free floating on the surface of the water without having substratum (e.g., *Azolla*, *Lemna*, *Wolffia*, *Pistia*, *Spirodella*, *Salvinia* etc.).

In this stage the faunal diversity of the ecosystem is also increase. Frogs, salamanders, gill breathing snail, beetles are capable of utilizing the under surfaces of floating leaves appear. Sometime snakes and turtle also invade.

Stage 4: Reed swamp stage: As the water body reduced in area, the marsh vegetation encroaches upon newly exposed shallow water areas and a reed swamp is reached. In this stage the pond is now invaded by emergent plants such as *Ranunculus*, *Saggittaria*, *Phragmites*, *Typha*, *Rumex*, *Cyperus*, and *Zizania*. Shoots of these plants are partially or completely exposed to air. These plants have creeping rhizomes which knit the mud together to produce large quantities of leaf litter. This litter is resistant to decay and reed peat builds up, accelerating the autogenic change.

Animal diversity progressively changes by those that inhabit the vegetation. Gill breathing snails give way to lung breathers like *Lymnea*, *Physa* and *Gyraulus*. Different species of mayflies, dragonflies, water scorpion, giant water bug etc. are present at this stage.

Stage 5: Sedge meadow stage: Since the root system and the annual deposition of leaf growth add great quantities of organic matter to the bottom and entrap sediments, the substrate build up rapidly after the emergent have appeared. Much of the old open water area is covered by the species of Cyperaceae and Graminae, such as numerous species of sedges as *Juncus*, *Carex*, *Eleocharis*, *Polygonum* etc. and many species of forbs like *Mentha*, *Colha*, *Campanula* etc. to form marsh or swamp.

Further as the level of the pond increase the ground water level, the remnant of the open pond dries up in summer. It has now become a temporary pond drying in summer and freezing in winter. In a gradual manner as land builds higher, drainage improves, emergent disappear and the soil lies above the water table and grasses accompanied by land animals invade to form a marsh meadow in forest regions and a prairie in grass country. With the approach of mesic conditions the herbs and woody plants invade the area.

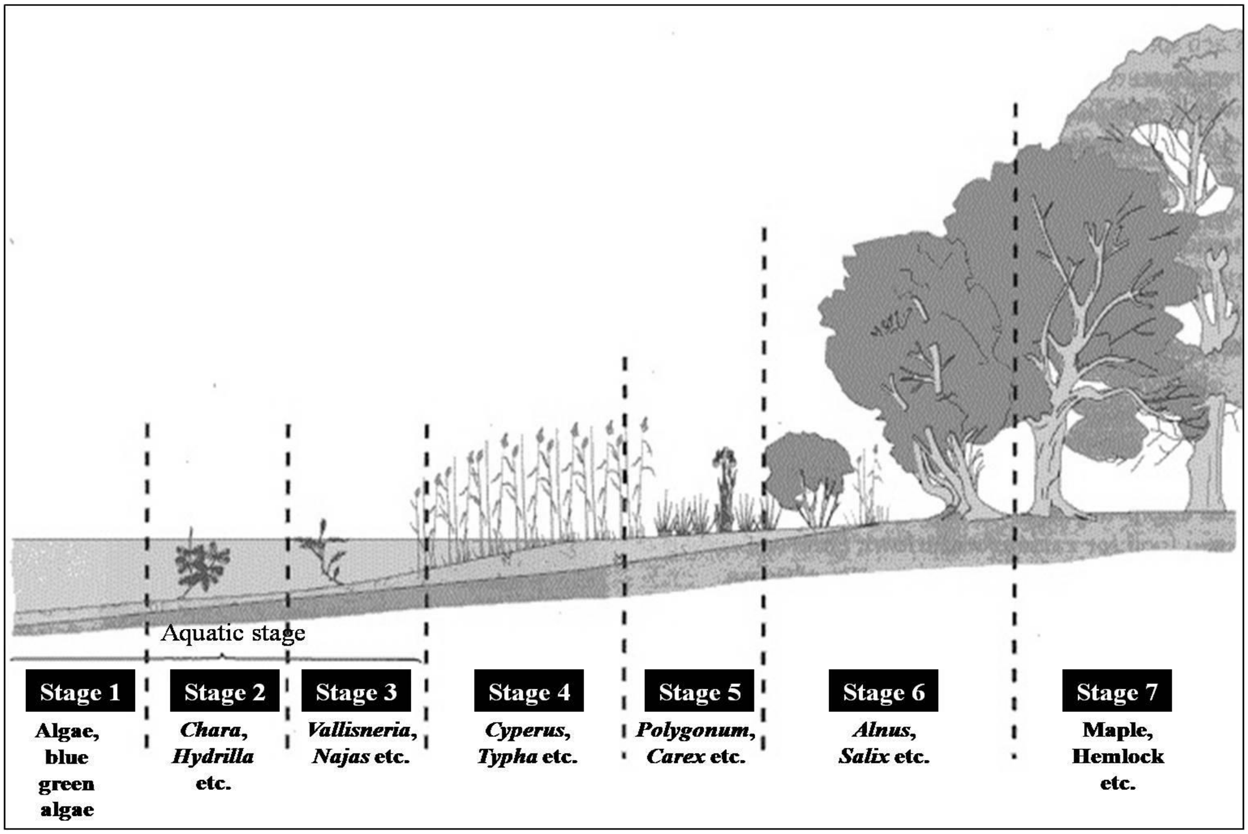

Fig. 4.1: Process of succession in hydrosere. (Stage 1= Phytoplankton, Stage 2= Submerged, Stage 3= Floating, Stage 4=Reed-swamp, Stage 5= Sedge-meadow, Stage 6= Woodland, Stage 7= Forest)

Stage 6: Woodland stage: This stage is characterized by the plants that can tolerate water logged soil around their roots. Some common plants species of this stage include *Salix*, *Cornus*, *Cephalanthus*, *Alnus*, *Populus*, Willows tree etc. The root system of these tree species spread horizontally instead of vertically in the soil due to high water table. These plants react upon the habitat by producing shade, lower the water table still further by transpiration, build up the soil, and lead to the accumulation of humus with associated microorganisms. This type of wet woodland is also known as carr. By this time there is much accumulation of humus with rich flora fauna of micro organisms. Thus, mineralization of soil favours the arrival of new tree species.

Stage 7: Forest stage: This is the climax community. The wood land community is rapidly invaded by several trees. In tropical climates with heavy rainfall, there develop tropical rain forest whereas in temperate region, there develops mixed forests of aspen, elm, red and silver maples, ash, oak, white pine etc. in regions of moderate rainfall, there develops tropical deciduous forests. A forest is characterized by presence of all types of vegetation including herbs, shrubs, mosses, shade-loving plants and trees. Decomposers are frequent in climax vegetation.

Moreover, as the forest floor becomes drier and the crown closes, seedlings of intolerant forest trees are unable to develop, but seedlings of sugar maple, hemlock, spruce and cedar able are able to grow low light intensities of a temperate forest and dominate the understory and subsequently replace the intolerant trees. Since these trees tolerate the environmental conditions they create, the forest cover becomes stabilized.

4.6 XEROSERE

The ecological succession which is limited by the water availability is called xerosere. It initiates in extremely dried conditions including sand dunes, salt and rock disserts etc (Fig. 4.2). According to Cooper (1913) xerosere may contain on rock (lithoseres) and on sand (psammoseres).

Stage 1: Bare rocks: The bare rocks form after a volcanic eruptions or recede of glaciers. The rainwater along with atmospheric CO_2 creates crevices into the surface of the rocks, which eventually lead to the expansion of the boulders. Now, due to some natural phenomena (i.e., gravitational force, blowing the wind etc) these boulders wear some partials from surroundings and accelerate the formation of a little soil on bare rock surface. Some algal and fungal spores reach the rock through the air and sporulate over it and form symbiotic association. This association is termed as lichen which acts as pioneer species of bare rocks. The process of succession starts when autotrophic organisms start living in the rocks. Animals such as spiders which can hide between boulders or stones invade these rocks.

Stage 2: Foliose and fruticose lichen stage: The foliose and fruticose lichens do not completely cover the soil because they are attached to the substratum only at a point. Lichens are able to accumulate soil moisture and therefore retain more water. They built humus from its dead remains due to their massive foliage structure. The humus mixed with the soil particles provides a suitable substratum for invader species.

Stage 3: Moss stage: In this stage, the lichen species is being succeeded by moss. The spores of some xerophytic mosses (e.g., *Grimmia, Polytrichum Tortula* etc.) are brought to the rock by various means, sprouting and flourish their communities. As the mosses develop in patches, they capture soil particles from the air and help increase the amount of substrate. Due to containing organic and inorganic compounds in it, mosses also enhance the soil fertility. The altering conditions of environment lead to migration of lichens and facilitate the growth of small herbaceous flora that can be able to replace mosses completely.

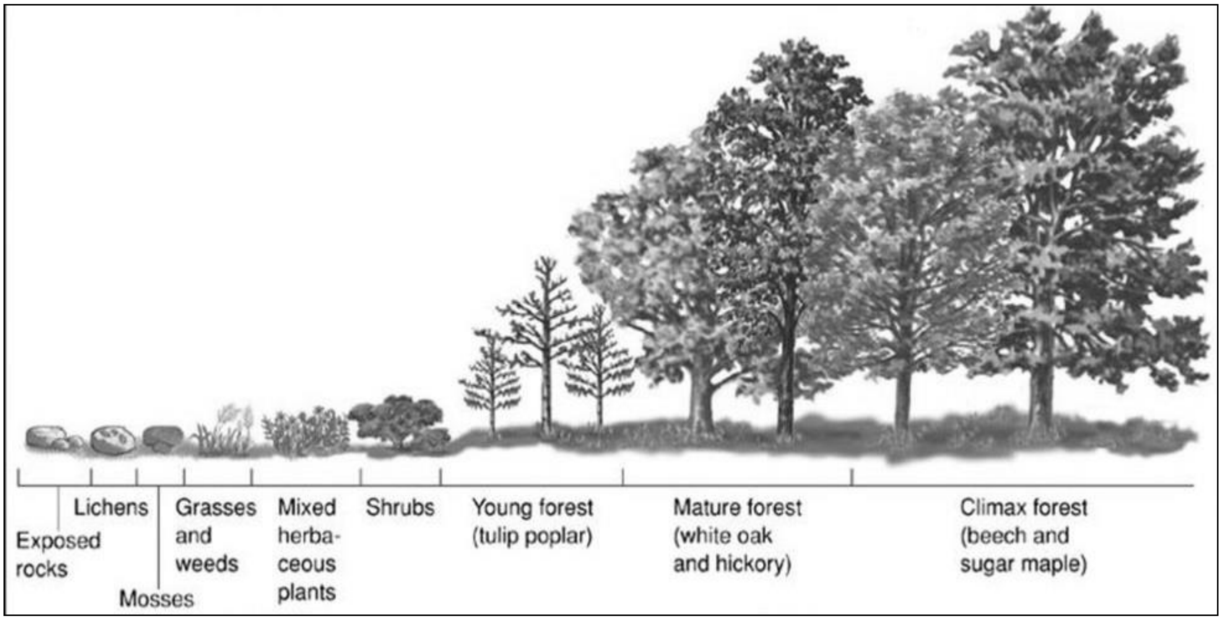

Fig. 4.2: Process of succession in xerosere. (Source: Kaufman and Franz 2000)

Stage 4: Herb stage: Some annuals weeds, such as evening primroses, asters, milk weeds etc. invade the rock. Roots of these plants promote the weathering of rocks by root secreting substances. Ground vegetation cover reduced the evaporation from the soil. Consequently, the xeric conditions begin to change and biennial and perennial herbs and xeric grasses such as *Aristida*, *Festuca*, and *Poa*, begin to inhabit.

Stage 5: Shrub stage: Sooner the grasses invaded by the shrubs (*Physocarpus*, *Rhus* etc.). However, this invasion is slow, but once shrubs are established in this fragile ecosystem, they invite the aves for their shelter and food, which helps in the dissemination of shrub seeds. These outcomes a dense shrub cover begins to migrate the herb cover in the newly established microclimate. The soil continues to form and soil moisture increases due to shading.

Stage 6: Tree stage: Prolonged changes in environmental conditions favor the colonization/ aggregation of tree species. The tree saplings begin to raise and establish themselves among the shrubs. This establishment depends on the soil conditions, for example, pine established in acidic soil etc. The tree canopy support the growth of shade loving shrub as secoundry vegetation, while the sun loving shrubs are eliminated by this newly developed ecosystem. Litter decomposition adds humus continuously so that it can encourage other trees to grow. Mosses and ferns make their appearance and fungi population grows in abundance.

Stage 7: Forest stage (Climax stage): The succession concludes in a climax community, the forest. Many intermediate tree stages extend prior to establishment of a climax community. The forest type depends upon climatic conditions.

- Oak-hickory climax forest in dry habitat with ferns, mosses, herbs and shrub as ground cover vegetation.
- Beech-hemlock climax forest in mesic climates comprises ferns, mosses and herbs as ground cover vegetation
- Spruce-alpine fir climax forest at high altitude having ferns, mosses, herbs and grasses etc as vegetation cover vegetation.

4.7 COEVOLUTION

Coevolution is the process of evolutionary changes which happen between pairs of species or among different group of species in natural environment. Every activities of each species that participates in interaction with other species apply selection pressure on the other. For example, in prey-predator interaction, the appearance of faster prey may select against individuals in the predatory species that are unable to keep pace. Thus, only fast individuals or those with adaptations allow them to capture prey using other means, which will pass on their genes to the next generation. So, coevolution is also a method to organized biological communities. The diverse species interact with one another and these ecological interactions contain:

1. **Parasite-host and Predator-prey:** It is the relationship called parasitism between two individuals wherein one individual called parasite receives benefits at the expense of other individual called host. It is a kind of harmful coordination between two species. A parasite usually parasitizes a host that is larger in body size than it. Further a parasite does not ordinarily kill its host at least not until the parasite has completed its reproductive cycle. However, some secondary infection can cause host death.

   The relationship between predator and prey is called predation. It is a form of disoperation, at least in point of immediate effects, as one species kills another for food. Like parasitism, predation is important in community dynamics, but both differ in the point that a predator trends to be larger than its prey, and it catches its prey from without, while a parasite is smaller than its host and consumes if from within.

2. **Competitive species:** Competition refers to the type of interaction in which two individuals or species compete for limited resources. This can occur between the individuals of the same species called intraspecific competition or between the individuals of two or more species of community called interspecific competition. Both types of competition have population regulating and evolutionary roles.

3. **Mutualistic species:** Mutualism is an obligatory interaction that is beneficial to both species. The term symbiosis has often been applied to this relationship but symbiosis properly refers to intimate association of two or more dissimilar organisms, regardless of benefits or the lack of them and hence includes mutualism, commensalism and parasitism. Mutualism may be facultative, when the species involved are capable of existence independent of one another, or obligate, when the relationship is imperative to the existence of one or both species. Mutualism in plant is demonstrated in the association of fungi and algae to form lichen, of nitrogen fixing bacteria with the roots of legumes, and of fungal mycorrhizae with the roots of many flowering plants.

4.8 TROPICAL ECOSYSTEM

In the world map, the tropical regions lie in between tropic of Cancer and tropic of Capricorn where the daylight, temperature and humidity are never experienced very low (Fig. 4.3) The seasonality is not clearly marked, while the region has wet and dry seasons driven by the tropical rain belt.

There are many different habitats within the tropics including: tropical rainforest, cloud forest, wetlands, dry deciduous forest, spiny forest, desert and even alpine habitat on the highest mountains. For each 1,000 foot rise in altitude, there is a 4°F drop in temperature. This has a dramatic effect on plant and animal distribution.

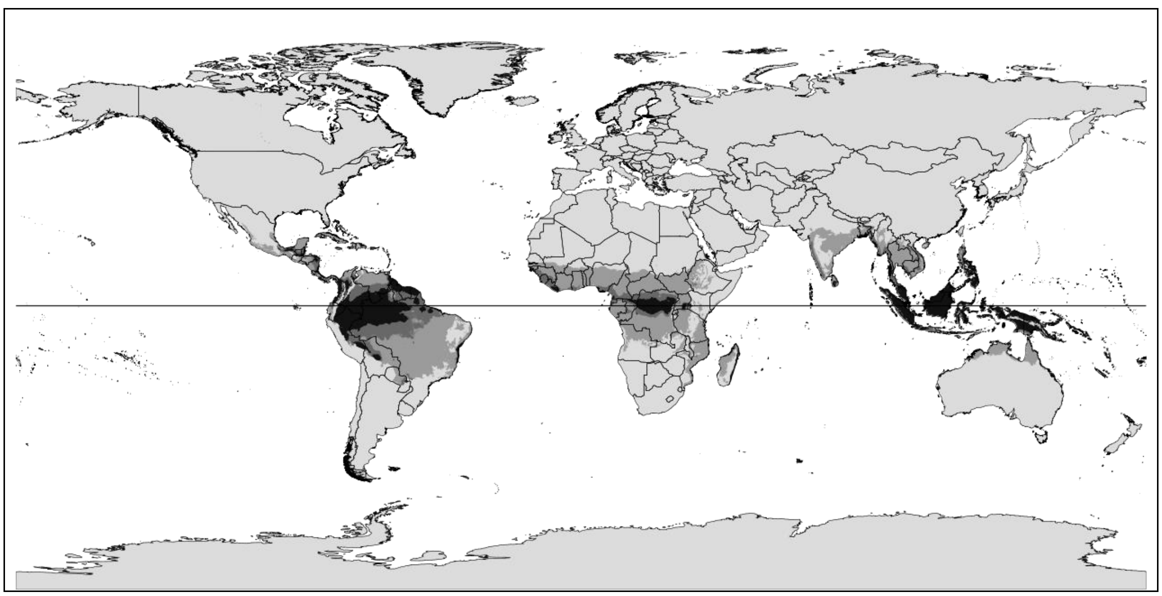

Fig. 4.3: Distribution of tropical zone across the world (Source: Beck et al. 2018)

A. Tropical Rainforests

Distribution and climate conditions: Tropical rainforest occur near the equator in Central and South America, Central and Western Africa (Cango, Zambesin river), Southeast Asia (Part of India and Malaysia), Malaya, Borneo, New Guinea and Northwest Australia. Both temperature and humidity are high and constant. The annual rainfall which exceeds 200 to 225 cm in generally evenly distributed throughout the year.

Floral diversity: Tropical rainforest contain the high biodiversity of flora and fauna. The highly diversified and dense vegetation of the forests remains vertically stratified with tall trees. The vegetation of the forest can be divided into following layers:

(i). Emergent layer: These giant trees rise above the dense canopy layer. They contain vast mushroom-shaped crowns and obtain the greatest amount of sunlight due to their height. but must also withstand high temperatures, low humidity, and strong winds. The leaves are thick, waxy and smaller than lower down. E.g., *Ceiba pentandra.*

(ii) Canopy layer: The broad, irregular crowns of these trees form a tight, continuous canopy 60 to 90 feet above the ground. The branches are often densely covered with other plants (epiphytes) and tied together with vines (lianas). The canopy is home to 90% of the organisms found in the rainforest; many seeking the brighter light in the treetops.

(iii) Understory: It is a dark place receiving only 2-15% of the sunlight. It is relatively open and contains young trees and leafy herbaceous plants that tolerate low light, with larger, thinner leaves to catch as much light as possible

(iv) Forest floor: The forest floor receives less than 2% of the sunlight and consequently, little grows here except plants adapted to very low light. On the floor is a thin layer of fallen leaves, seeds, fruits, and branches that very quickly decomposes.

Soil: The soil is red latosols and they may be exceedingly thick. The high rate of leaching makes soil virtually useless for agriculture purpose, but if they are left undisturbed the extremely rapid cycling of nutrients within the litter layer can compensate for the natural poverty of the soil.

Fauna diversity: Invertebrate density and abundance are very high in tropical rainforests but while vertebrates are diverse, they are not as abundant as in many other communities.

B. Tropical seasonal forests

Distribution and climate conditions: Tropical seasonal forests occur in region whose total annual rainfall is very high, but segregated into pronounced wet and dry periods. Tropical seasonal forests are found in Southeast Asia, Central and South America, Northern Australia, Western Africa and the tropical islands of the pacific as well as India and Southeast Asia. In exceedingly wet tropical seasonal forests, commonly known as monsoon forests, the annual precipitation may be several times that of the tropical rainforests.

Flora and fauna diversity: They are also containing high diversity of flora and fauna. Trees may reach heights over 40 m, but are more commonly 20-30 m high. Stratification is of a relatively simple type with a single understory tree layer, canopy is deciduous and understory is evergreen. Teak is often a major large tree in the best known tropical seasonal forests, those of India (Central India) and Southeast Asia.

Soil: Soil fertility is the primary influence on forest structure and wood production. On poorer soils, trees are designed to minimize waste of mineral nutrients, and they devote more of their resources to root-making.

4.9 TEMPERATE ECOSYSTEM

The interacting system of a biological community and its non-living environmental surroundings in regions of or related to moderate climates, intermediate between tropical and polar zones and having distinct warm to hot summer seasons and cool to cold winter seasons.

A. Temperate deciduous forest: The temperate forest are characterized by a moderate climate broad leaved deciduous trees, which shed their leaves, are bare over winter and grow new foliage in the spring.

Distribution: These forests are the characteristics of North America, Europe Eastern Asia Chile, some parts of Japan and Australia (Fig. 4.4).

Climate: This zone has experienced a cold winter and a annual rainfall of 75-150 ºC cm and a temperature of 10-20 ºC. In this region, the precipitation may be fairly uniform throughout the year. In India, at elevations of 9009-12000 feet in Himalayas occurs temperate vegetation including pines, fir, yew and juniper trees with an undergrowth of scrubby *Rhododendrons*.

Soil: Soils of temperate forests are podozolic and fairly deep.

Floral diversity Trees are quite tall about 40-50 m in height and their leaves are thin and broad. The predominant genera of this zone are *Acer*, *Fagus*, *Quercus*, *Carya*, *Tilia*, *Castnea*, *Populas*, *Platanus*, *Ulmus*, *Salix* etc. In some locations, coniferous vegetation may be quite prominent and that includes *Pinus strubos*, *Tsuga Canadensis*, *Juniperus virginianus*. The understory of shrubs and herbs in the deciduous forest is typically well developed and richly diversified, with a considerable portion of the photosynthesis and flowering attuned to the short days of the spring season, prior to the leafing out of and consequent shading by the tree canopy.

Fauna diversity: The diverse amount of fauna are present in this region includes the vertebrates and non vertebrates. All these animals and plants show a profound seasonality: some may even hibernate throughout the winter. The range of animal size and adaptations is wide: the largest animals include such forms as the deer and black bear. The dominant carnivores are large, including the wolf and mountain lion, although smaller carnivores such as fox and skunk are also common. Diversity of fauna is lower than in any of the rain forest and a few species seems clearly to be dominant.

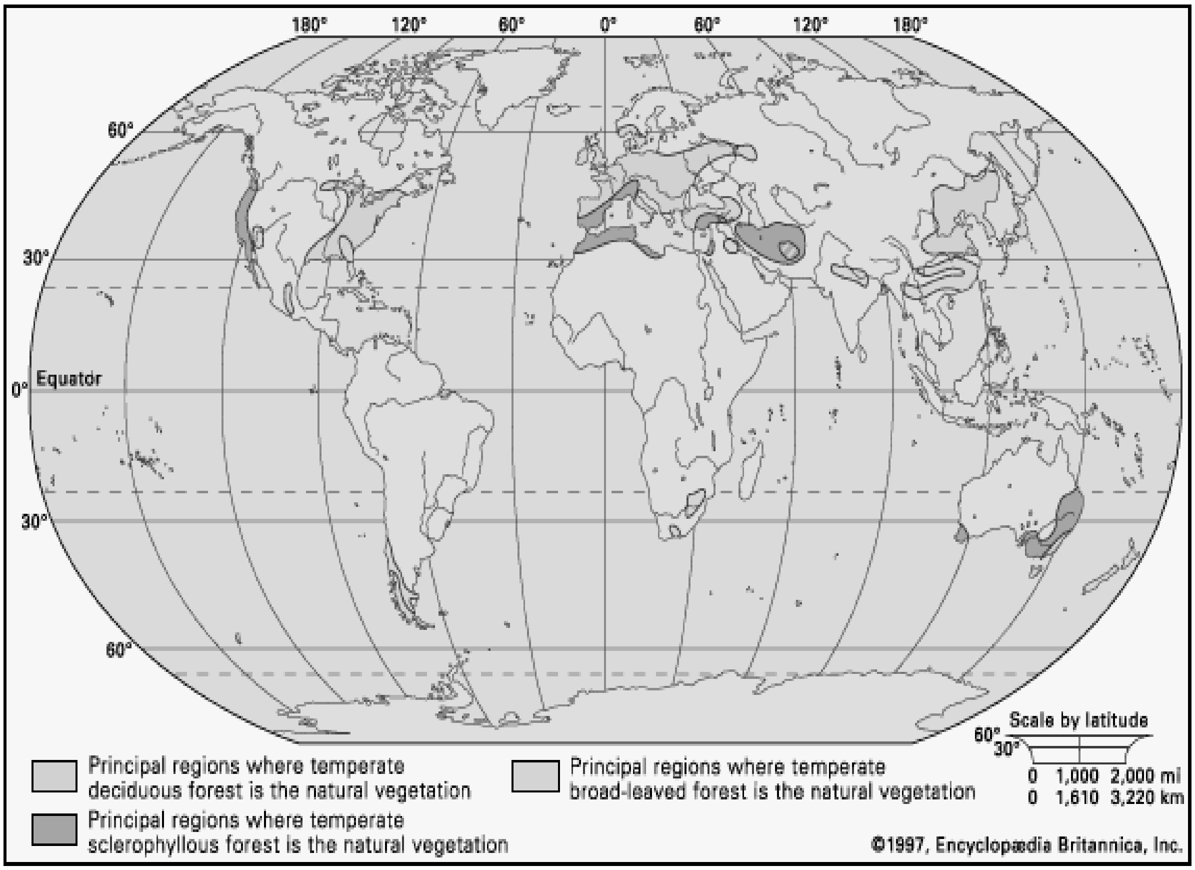

Fig. 4.4: Distribution of temperate zone across the world (Source: Encyclopedia Britannica 1997)

B. Temperate rain forest: The temperate rain forest is a colder ecosystem than any other rainforest. Such a forest has a definite seasonality, with both temperature and rainfall varying throughout the year. Rainfall is high but fog may be very heavy and actually more important as a source of water than rainfall. The diversity is much lower, both in plants and animals, in comparison to warmer rainforests, yet it remains still higher than other temperate forests. The dominant trees are coast redwood of the Pacific coast of North America and the alpine ash of

Australia and Tasmania both of which reach more than 100 m in height. The animals of temperate rainforests are similar to those of deciduous forests, but show a somewhat higher diversity.

C. Temperate evergreen woodland: Many parts of the world have a Mediterranean type climate with warm, dry summers and cool, moist winters. These are commonly inhabited by low evergreen trees with small hard needles or slightly broader leaves. St important area of the temperate evergreen woodland in North America is the "Chaparral" of the Pacific Coast, the Mediterranean "Maquis", Spanish "encinar" and "melle scrab" on Australia's South Coast are the some type of community. In such woodland, trees are essentially lacking although shrub may range up to 3-4 m in height. Species diversity is roughly intermediate between that of a temperate deciduous forest and drier grassland. Fire is an important factor in this ecosystem and the adaptations of the plants enable them to regenerate quickly after being burned.

The characteristic animals of temperate evergreen woodland or chaparral are mule deer, brush rabbits, wood rats, chipmunks, lizards wem-tits and brown towhees. Small-hooved cursorial ungulates are the dominant herbivores. Saltatorial (jumping) animals and many fast moving ungulates are also common in the fauna.

4.10 BOREAL ECOSYSTEM

Distribution: The boreal ecosystem distributed in Northern Hemisphere in between 50° to 70°N latitude across the world. The climate is subarctic having long winters. These ecosystems are located in Boreal forests which are commonly known as the taiga, particularly in Europe and Asia (Fig. 4.5).

Climate: Cold region with high rainfall and strongly seasonal climates with long winters and fairly short summers are characterized by boreal conifer forest which is transcontinental.

Soil: Boreal forest soils are thin podozols and rather poor both because the weathering of rock proceeds slowly in the cold environment and because the litter derived from conifer needle is broken down slowly and is not particularly rich in nutrients. Theses soils are acidic and mineral deficient, the result of the movement of a large amount of water through the soil: in the absence of a significant counter upward movement of evaporation, soluble essential nutrients like calcium, nitrogen and potassium are leached sometimes beyond the reach of roots thereby leaving no alkaline oriented cations to encounter the organic acids of the accumulating litter (Padalia et al 2018).

Floral diversity and fauna diversity: For example adjacent to the tundra region either at latitude or high altitude is the northern boreal forest or coniferous, which stretches across both North

America and Eurasia just south of the tundra (i.e., Canada, Sweden, Finland, Siberia and Mussoories). The term taiga is applied to the northern range of coniferous forests. This is characterized by evergreen plant species such as *Picea*, *Abies balsamea*, *Pinus resinosa*, *Pinus strobus* etc. Species diversity is low, and pure stands of trees and shrubs are common. Understory trees are uncommon as a result of the continual low light penetration. Among common understory associates are orchids and ericaceous shrubs like the blue berry. The thalloid mosses and lichens being very rich understory vegetation. The animals such as snow shoe hare, the lynx, wolf bears, red fox, porcupines, squirrel, amphibians like *Hyla* and *Rana* etc.

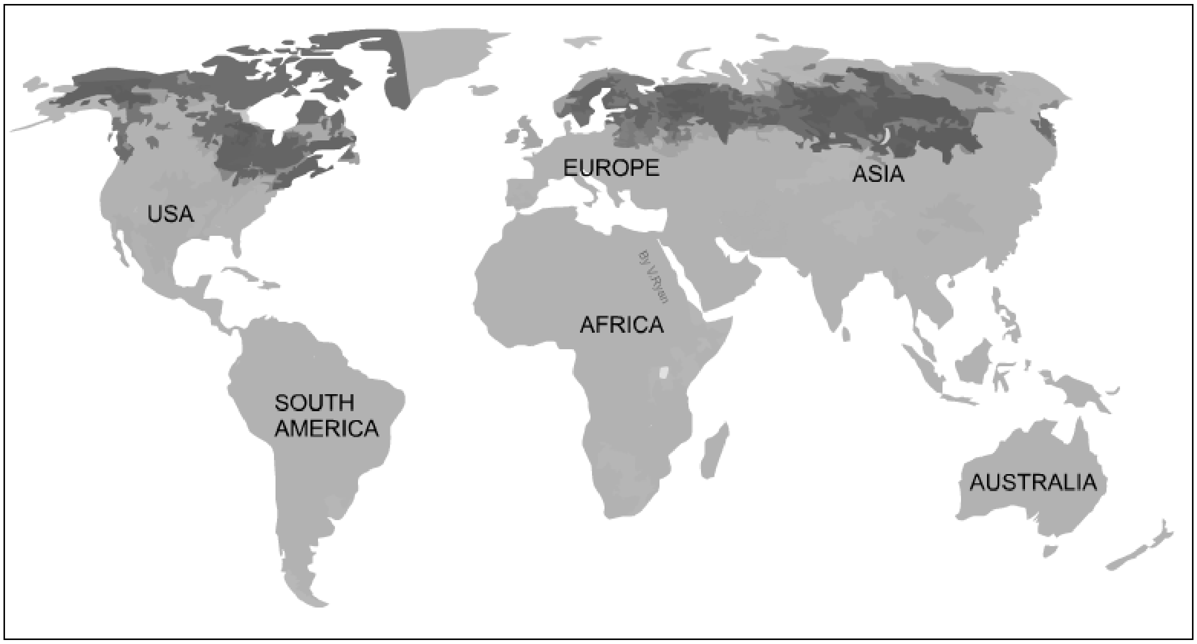

Fig. 4.5: Distribution of Boreal ecosystem across the globe

4.11 INDIAN ECOSYSTEM

India is a home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained winter snowfall. According to the climate, vegetation and altitude the Indian terrestrial ecosystem can be divided into the following zones (Fig. 4.6):

A. Tropical wet region

The tropical region experience constant warm, humid and high temperatures throughout the year. The temperature usually does not fall below 18 °C and the winters are pleasant. This region contains the high biodiversity of flora and fauna. In India, tropical region can be divided into two climatic subtypes:

i. Tropical monsoon region

Distribution: It covers up a stripe of southwestern lowlands adjoining the Malabar Coast, southern Assam and the Western Ghats. Lakshadweep and the Andaman & Nicobar Islands are also falls under this region.

Climate: The climate is moderate and experiences the high temperature throughout the year, even in the foothill region. The rainfall is high about 2000 mm annually and most of the precipitations occur during the months of monsoon seasons (May to November).

Vegetation: The high moisture content and rainfall favoure the growth of diverse type of vegetation. It sustains the evergreen forest and other vegetation. There is not any particular time for leaves shedding. The forest are well stratified and can be divided into three zone: shrubs and creepers; short height trees and; tall trees more than 60 m. mahogany, ebony, aini, rosewood etc are the dominant forest vegetation.

Fauna: The fauna diversity is high including many herbivore and carnivore. Many varieties of invertebrates are also reported in this region.

ii. Tropical wet and dry region:

Distribution: This is a drier region with tropical monsoon climate, it dominates most inland peninsular India except for a semi-arid rain shadow east of the Western Ghats.

Climate: In an annual cycle, the region experiences long and dry winter and early summer on an average 18 °C air temperature. The summers are extremely hot and sometime temperature reach beyond 50°C during May and June. Heat waves are common during summer season. The region experiences yearly shower between 750-1,500 mm annually from June to September.

Vegetation: Due to deficit of regular rainfall, tree species prevents from surviving in this region. The abundant vegetation of this region are shrubs and grasses with some scattered distributed tree species. Vegetation has adopted many practices to withstand the long and dry conditions of prevailing climatic conditions.

Fauna: The grasslands sustain herbivores animal that survive in the grasses. These animals live in herds for safety and migrate in search of food and water. The carnivores hunt the herbivores.

B. Arid and semi-arid region

Tropical arid and semi-arid are those zones where the rate of evapotranspiration is higher than the precipitation. These can be divided into three regions: (i). tropical semi-arid steppe, (ii). arid climate, tropical and (iii). sub-tropical steppe climate.

i. Tropical semi-arid steppe climate:

Distribution: This region falls under south of Tropic of Cancer and east of the Western Ghats and the Cardamom Hills. The region includes Central part of Maharashtra, Western part of Andhra Pradesh, inland Tamil Nadu and some part of Karnataka.

Climate: The climate is prone to drought, as it receives less rainfall due to failure of the southwest monsoon or sporadic lateness. The Krishna river is responsible for the most of precipitation during the summer season in North, while in South, post monsoonal shower occurs in October and November. Climate is dry and hot. The mean monthly temperature during summer is accounted 32 °C with 320 mm rainfall. The winter is not so cold and maintains the temperature of 21-22°C.

Vegetation: Semi-arid climates tend to support short or scrubby vegetation and are usually dominated by either grasses or shrubs.

ii. Arid climatic:

Distribution: Most of western part of Rajasthan falls under arid climatic region.

Climate: This region received very less amount of precipitation about 300 mm annually from July to September therefore, the survival in this region is very harsh. Summers (especially April to June) are very hot where temperatures reach beyond 50°C. Temperature fall below freezing point during winter due to cold air waves from Central Asia.

Vegetation: The dominant forest is dry deciduous forest, broad leaved hill forest, Dhauk forest, thorn forest, Riverine forest and Teak mixed forest.

Fauna: Camel, Chinkara, deer, leopard, asses, calves and goats, and many species of birds in which great India bustard is most noticeable.

iii. Thar Desert:

Distribution: The Great Indian Desert called "Thar" covered provenance of Rajasthan, Gujrat, Punjab, and Haryana region.

Climate: The climate of this region is very harsh. The daytime temperature is very high while the night is cold. The summer season is extremely hot where the temperature reach beyond 50 °C is normal. Winter day is not too cold but the temperature drops down to –2 °C at night. The region receives little or no rainfall in summer. The annual precipitation ranges from 100 to 500 mm.

Vegetation: The highly drought resistant plants grow in this region. They adopt the mechanisms to survive without water for long. The variegation is mostly shrubby and herbaceous. In tree species *Acacia*, *Ziziphus*, *Calotropis*, *Aerva*, *Euphorbia*, *Cordia*, *Mimosa* etc are occur. In herbs and grasses genus *Ochthochloa*, *Dactyloctenium*, *Cenchrus*, *Lasiurus*, *Cynodon*, *Saccharum*, *Desmostachya*, *Eragrostis*, *Ergamopagan*, *Phragmites*, *Tribulus*, *Typha*, *Sorghum*, *Citrullus* are commonly grow.

Fauna: Very less populated grassland carry gazelles, blackbucks and some feathered migratory birds (sand grouse, ducks, and geese are common), quail, partridges etc are also common.

Fig. 4.6: Distribution of different type of vegetation in India (Source: www.mapsofindia.com)

C. Subtropical humid region

Distribution: A large area of North India and Northeast are subject to subtropical humid climate.

Climate: The summers are very hot and dry where the temperature reaches beyond 40°C. The winters are very cold, freezing and dry or with very less precipitation where the temperature droop down to 0°C. The annual precipitation in the west is recorded less than 1000 mm while in the northeast it is over 2500 mm.

Vegetation: The floral diversity of forest is generally high. The evergreen forest, dry mixed deciduous forests and semi evergreen deciduous forest dominated with *Dodonaea* sp, *Olea cuspidata*, *Shorea robusta* etc.

Fauna: Many threatened species including the royal Bengal tiger, elephant, otter, leopard, squirrel, flying squirrel etc are the common fauna. Golden langur, endemic to Assam region is also restricted to a small range of broadleaf forest. More than 340 species of birds reported in this region in which chestnut-breasted partridge is endemic to this region. The globally threatened white-winged wood duck and five hornbill species are found here.

D. Mountain region

Distribution: The northern region of India is mostly classified as a mountainous region. This region extends from Himalayan range (including Jammu & Kashmir, Mizoram, Meghalaya, Assam, Nagaland, Manipur, Sikkim etc) in north to Western ghats, Nilgiris and Vindhya range in South.

Climate: The climate in this region is very diverse. The climate in the foothills region is tropical while snowline also exists in higher altitudes. The temperature fluctuates within a short distance depending upon the slop, day light intensity and altitude variations. The rainfall is also inconsistence within a little distance. In northern side of western Himalaya has a cold desert.

Vegetation: Mountain forests in India are normally classified into two types, i.e. the northern mountain forests and the southern mountain forests. In Northern mountain, at the elevation of 4000-5300 m alpine forests are predominant in which junipers, pines, willows, *Rhododendron* are occur. At the altitude of 2700-4000 and 1300-2700 m coniferous and evergreen forests are dominant, respectively. In southern mountains of India, subtropical vegetation or moist and dry forests are dominant. Sal, Teak, Mahua, shisham, Bel, etc are the main tree species of low altitude while Laurel Magnolia, Wattle, and Cinchona are frequently occur in higher altitude regions.

Fauna: Mountain regions are the home of many herbivores and carnivorous species. Himalayan brown bear is native to this region. Clouded leopards, langoors, Himalayan goat antelopes, musk deer, Kashmir stag, yak etc are some other denizens animals.

E. Littoral and Swamp region

Distribution: Littoral or swamp are primarily found in reservoirs of Swamps in North East India, Deccan Plateau, saline coast of Gujarat, Gulf of Kutch, Rajasthan, Eastern Coast Deltas, lakes and rivers of Kashmir and Ladakh.

Climate: The climate is moderate having no clear seasonality. The rainfall range from 75 to 500 cm annually.

Vegetation: India is rich in Littoral and Swamp Forests. *Chilika* Lake (in Odisha) and *Keoladeo* National Park (in Bharatpur, Rajasthan) are protected as water-fowl habitats under the Convention of Wetlands of International Importance (i.e. *Ramsar* Convention). Mangrove grows along the coasts in the salt marshes, tidal creeks, mud flats, and estuaries; and, it has a number of salt-tolerant species of plants. In India, the mangrove forests spread over 6,740 sq. km, which is 7% of the world's mangrove forests. Mangroves are largely found in the Andaman and Nicobar Islands and the *Sunderbans* of West Bengal.

Fauna: It is home to a large variety of birds.

4.12 SUMMARY

Succession was among the first theories advanced in ecology. Ecological succession was first documented in the Indiana Dunes of Northwest Indiana and remains at the core of much ecological science. The basic idea of succession was firstly introduced by Anon Kerner in his book "Plant life of the Danube Basin" during the regeneration of a swamp forest. However the term "ecological succession" was first of all used by Hult. Ecological succession may be define as an orderly and progressively replacement of one community by another until a relatively stable community (i.e., climax community), occupies the area. In this process, the community begins with simplest form of life known as pioneering species which ultimately generate a complex system until it becomes stable climax community. The changes in the structure and composition of the community are rapid at first, slowing gradually until a point of dynamic equilibrium is reached, and the community is more or less stable.

The process of succession influenced by the various factors including the site conditions, events initiating succession, interactions between species, availability of colonists or seeds, weather conditions etc at the time of disturbance. Nowadays, two main important disturbances are listed as: anthropogenic activities and climatic change.

The succession can be categorized into two division: **Primary succession** (process of species colonization and replacement in which the environment is initially virtually free of life.) and

secoundry succession (changes occur after an ecosystem is disturbed but does not completely disintegrate). The primary and the secondary succession may be **Hydrach (**succession when starts in the aquatic environment)**, Mesarch (**succession when began in the area where adequate moisture is present**)** and **Xerach (**succession when starts in xeric or dry habit having minimum amount of moisture**)** depending upon the moisture contents.

The process of succession completed into following steps; **Nudation** (formation of the bare zone**), Invasion (**process of entering reproductive bodies i.e., seeds, propagules etc), **Competition** (competition can be intraspecific or interspecific), **Stabilization or climax** (terminal community becomes more or less stabilized for a longer period).

Coevolution is the process of evolutionary changes which happen between pairs of species or among different group of species in natural environment. The Coevolution relation is three types: **Parasite-host and Predator-prey (**relationship between two individuals wherein one individual called parasite/prey receives benefits at the expense of other individual called host/predator), **Competitive species, (**two individuals or species compete for limited resources), **Mutualistic species** (obligatory interaction that is beneficial to both species).

The world ecosystem can be broadly divided into six terrestrial ecosystems: tundra, taiga (boreal ecosystem), temperate deciduous forest, tropical rain forest, grassland and deserts. Here, we have discussed only tropical, temperate and boreal ecosystem. The tropical regions lie in between tropic of Cancer and tropic of Capricorn where the daylight, temperature and humidity are never experienced very low. This region contains the high biodiversity of flora and fauna. The temperate forest are characterized by a moderate climate broad leaved deciduous trees, which shed their leaves, are bare over winter and grow new foliage in the spring. These forests are the characteristics of North America, Europe Eastern Asia Chile, some parts of Japan and Australia. The boreal ecosystem distributed in Northern Hemisphere in between 50° to 70°N latitude across the world. The climate is subarctic having long winters. This is characterized by evergreen plant species.

If we talk about Indian terrestrial ecosystem according to their altitude variation, it can be divided into following zone: Tropical wet; Arid and semi-arid regions, Subtropical humid, Mountain, Littoral and Swamp area.

4.13 GLOSSARY

Aggregation: It is coming together of organisms into a group, as in locusts.
Biomass conversion: The changing of organic matter that has been produced by photosynthesis into useful liquid, gas or fuel.
Biomes: A community of living organisms of a single major ecological region.

Ecosystem: A community of living organisms and their interrelated physical and chemical environment.

Endangered species: A species that is in danger of extinction throughout all or a significant portion of its range.

Biodiversity: Diversity among and within plant and animal species in a given environment.

Biogeochemical cycle: A pathway through which a chemical element or molecule moves through the atmosphere, hydrosphere, lithosphere, and biosphere.

Biomass: The sum of all living organisms in a given area.

Biota: The total collection of organisms belonging to a particular geographic region or extant during a particular time period.

Boreal forest: Forest areas of the northern temperate zone, mostly consisting of conifers. Also called taiga in Siberia.

Climax community: A community of biological species that has reached a stable state, occurring when the different species are best adapted to average conditions in a given area.

Coniferous forest: One of the primary terrestrial biomes, culminating in the taiga.

Deciduous broadleaf forest: Any forest situated in a temperate zone whose trees shed their leaves during the cold season.

Decomposition: The process by which tissues of dead organisms break down into simpler forms of organic matter, thereby clearing the limited available space in a biome.

Desert: A landscape that receives less than 10 inches of rain per year.

Ecology: The scientific study of interactions between living organisms and their environment.

Ecosystem: The total of interacting organisms (biocoenosis) and non-living things (biotope) in a specific environment.

Endangered species: A species at imminent risk of becoming extinct.

Evaporation: The slow vaporization of water from either the soil or from surface water.

Habitat: A specific ecological area that is inhabited by specific plant and animal species.

Limiting factor: Any essential resource that is in short supply in a given environment and therefore limits the possibilities for change in other aspects of the same environment.

Parasite: An organism that depends for its survival on a symbiotic relationship with another organism its host which it does not usually kill directly but does negatively affect.

Prey: An organism upon which a predator feeds.

Primary production: The production of organic compounds out of carbon dioxide present in the Earth's atmosphere. All life on Earth directly or indirectly depends on it.

Producer: An organism that produces its own food from inorganic material present in the environment, through photosynthesis or, in the deep sea, through chemosynthesis. Also called a primary producer.

Soil: The naturally occurring, unconsolidated or loose covering of Earth's surface; part of the pedosphere.

Succession: The changes in vegetation and animal life by which one kind of population or community is replaced by others: it culminates into climax.

Trophic level: The position of an organism within a food chain: what it eats, and what eats it.
Tropical rain forest: A biome characterized by regular, heavy rainfall, a humidity of at least 80 percent, and great biodiversity.
Tundra: A permanently frozen, treeless expanse between the ice cap and tree line of arctic regions.
Wetland: A type of ecosystem consisting of land permanently or seasonally saturated with water; the habitat of aquatic plants.
Xerophyte: A plant adapted to dry conditions.

4.14 SELF ASSESSEMNET QUESTIONS

4.14.1 Multiple choice questions

1. After landslide which of the following type of succession occurs?
   (a). Primary (b). Secondary
   (c). Tertiary (d). Cyclic
2. Which of the following ecosystem consists of forest, grassland and deserts?
   (a). Artificial ecosystem (b). Natural ecosystem
   (c). Aquatic ecosystem (d). Terrestrial ecosystem
3. Which two biomes are the most similar with regard to rainfall?
   (a). Tundra and desert (b). Tundra and taiga
   (c). Rain forest and savanna (d). Temperate forest and prairie
4. Which biome is characterized by a layer of permafrost
   (a). Taiga (b). Savanna
   (c). Chaparral (d). Tundra
5. The eastern portion of the United States is dominated by what biome?
   (a). Temperate forest (b). Desert
   c. Taiga (d). Prairie
6. In which biome of Africa would you find lions, giraffes, and elephants?
   (a). Savanna (b). Chaparral
   (c). Desert (d). Tropical rain forest
7. Which of the following would represent an ecosystem?
   (a). A lake (b). A fish tank
   (c). A prairie (d). All of these
8. All the nonliving parts of an ecosystem are referred to as:
   (a). The community (b). Biotic factors
   (c). Abiotic factors (d). Biomes
9. Which of the following would be a biotic factor in an ecosystem?
   (a). Bacteria (b). Soil
   (c). Temperature (d). Rainfall

10. The types and numbers of species in a given area is most greatly determined by the area's:
    (a). Climate (b). Biotic factors
    (c). Precipitation (d). Biodiversity

4.14.2 Fill in the blanks

1. A _________ is called for the term used to express a community in its final stage of succession.
2. The term in which all the living organisms that occupy an area undergoing primary succession in the beginning stages is called _________
3. The _________ is called for the process when older communities of plants and animals are replaced by newer communities?
4. The succession driven by the biotic components of an ecosystem is called _________
5. The first process in ecological succession starts with _________

4.14.3 True and False

1. In the process of succession, the community begins with relatively few simplest plants or animals species.
2. In succession, progressively replacement of one community by another until a relatively stable community.
3. The basic idea of succession was first of all forwarded by Anon Kerner.
4. Climatic change is the only reason for affecting the process of succession.
5. Primary succession is the changes occur after an ecosystem is disturbed but does not completely disintegrate.
6. Lithosere is the succession initiated on saline water or soil.
7. The foliose and fruticose lichens do not completely cover the soil because they are attached to the substratum.
8. Mutualism is the relationship between host and parasite.
9. In Northern mountain, at the elevation of 4000-5300 m alpine forests are predominant.
10. Tropical distributed in Northern Hemisphere in between 50° to 70°N latitude across the world.

Answer Key:

4.14.1: 1(a); 2(d); 3(a); 4(d); 5(a); 6(a); 7(d); 8(c); 9(a); 10(a)
4.14.2: 1. Climax community; 2. Pioneer community; 3. Ecological succession; 4. Autogenic succession; 5. Nudation.

4.14.3: 1. True; 2. True; 3. True; 4. False; 5. False; 6. False; 7. True; 8. False; 9. True; 10. False

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4.17 TERMINAL QUESTIONS

4.17.1 Short answer type questions

1. Write a short note on primary and secoundry succession.
2. Briefly discuss the factors affecting the process of succession.
3. Write a short note on the vegetation of tropical ecosystem.
4. What do you understand by invasion?
5. Differentiate between interspecific and intraspecific competition.
6. Write a short note on reed swamp stage.
7. Discuss the relation of Parasite-host and Predator-prey in brief.
8. Describe the distribution and climatic conditions of boreal ecosystem.
9. Discuss the distribution, climate and vegetation of the great Indian Thar desert.
10. What do you understand by littoral and swamp region.

4.17.2 Long answer type questions

1. What do you understand by succession? Classified the succession in detail.
2. Write a detailed note on succession on Hydrosere.
3. Write a note on the tropical ecosystem.
4. Discuss the Indian ecosystem based on altitude in detail.
5. What do you understand by temperate and boreal ecosystem?

BLOCK-2- POPULATION ECOLOGY

UNIT-5- POPULATION, ECOLOGICAL ADAPTATIONS IN SPECIES AND SURVIVAL STRATEGIES

5.1 OBJECTIVES

After reading this unit students will be able to:

- Understand the population biology.
- Know the population resource relationship.
- Learn different types of ecotypes.
- Know the ecological adaptations of species.
- Understand different types of ecological adaptations and survival strategies in plants.

5.2 INTRODUCTION

A population is a group of organisms of the same species that live in the particular geographic area at the same time, with the capability of interbreeding. For interbreeding, the individuals must be able to produce offspring. However, populations contain genetic variation within themselves, and not all individuals are equally able to reproduce and survive.

The population that is very small in size and resides in a small area is called local population. Local population occupies a small area like a pond or a small patch of soil. A group of such a closely related local population is known as metapopulation where the populations are connected by the dispersion of individuals. Populations can also occur in large scales such as vast geographical regions, islands, continents and seas.

Population biology is the study of population characteristics and the factors that affect the size and distribution of it. The characteristics which are studied include the population density, the demographics (the birth and death rates, sex ratio and age distribution), the population genetics, migratory patterns, the life history traits and the group dynamics (the interactions within and between populations). Population ecology is the study of how these populations interact with the environment.

Most populations are not stable; they fluctuate in size over time. The fluctuations are usually in response to changes in the biotic and abiotic factors of the environment, which act as limiting factors against indefinite exponential growth of populations. For example, when food resources are sufficient and environmental conditions are favorable, populations may grow. Conversely, when predation is more, populations may deplete.

The characteristics of the population can influence how it is affected by certain factors. The effects of density-dependent factors on a population are determined by its size; for example, a larger, denser population will be destroyed more quickly by the spread of disease than a widely dispersed population. Life history traits, such as the maturation rate and life span, can affect the rate of growth of a population; if individuals mature later, the population will grow more slowly than if they mature relatively young.

Due to the genetic variation within populations, the larger populations are usually more resilient to the changes in their environment. This happens because there is a higher chance that a genetic mutation within the gene pool is better adapted to survive in the new condition. In an extreme condition, in which a large number of individuals within the population are unable to survive, the remaining individuals with the favored genes will reproduce, thereby increasing the frequency of these genes in the population by genetic drift. This is called a population bottleneck (Fig. 5.1).

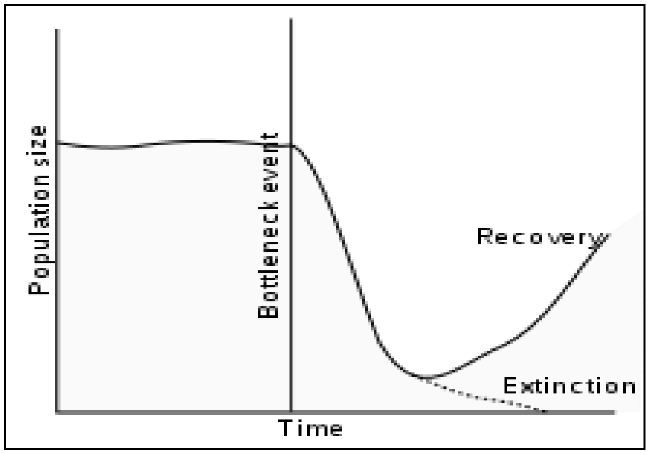


Fig 5.1 Bottleneck Effect
(Source: https://en.wikipedia.org/wiki/Population_bottleneck accessed on 21-02-2022, 02 57 pm)

Although the individuals who survived the bottleneck are adapted to the new conditions, there is not always a good rate of long-term success for the population. Genetic diversity within the new population is low, and only increases very slowly as mutations occur in each successive generation. This means that the new population is highly vulnerable to further changes to the environment or availability of resources, as well as suffering the consequences of inbreeding such as disease and deformity in offspring. If a bottleneck results in too few individuals there is a considerable risk of extinction after a few generations.

5.3 CHARACTERISTICS OF POPULATION

The populations have certain characteristics that can be measured as density, population size, natality and mortality, distribution and growth.

5.3.1 Population density

Population density refers to the size of the population. It is the average number of individuals per unit area or volume of a habitat. For example, 200 oak trees per hectare; 100 insects per 100 square meter, 4 million diatoms per cubic meter of water. Population density changes over time and space. A basic relative measure of how an organism responds to local environment is typically employed as population density. The density will be low if conditions are unfavorable for the species (organisms will be perished or emigrated out), but high if conditions are favorable (organisms will be reproduced and /or immigrated into the area). The changes in density can reveal information about the history of species preferences and tolerances of individuals of the species. The dynamics of most populations of organisms are influenced by a combined action of density dependent factors and density independent factors. The relative effects of the factors vary among populations. The density dependent factors in ecology are any force that affects the size of a population of a species in response to the density of the population. These factors are also known as regulating factors because of their potential for controlling the density. For example, competition for food, water and habitat rises among individuals of a population with the increase in population density. However, as density decreases (mortality or migration), the affect of density dependent factors also decreases as the competition for food, water and shelter become less for few individuals. The density independent factors of the environment are physical factors that do not depend upon density of a population. These factors differ depending on the population and affect it regardless to its size. Temperature, natural disasters, pollution, availability of oxygen in atmosphere etc. are density independent factors which affect the individuals of a population regardless of the density of that population.

5.3.2 Population size

Population size is the number of individuals in a population. For example, a population of deer might consist of 10 individual deer or many more. Population size depicts whether the species is going to survive or extinct. Generally, very small populations are at greatest risk of extinction. However, the density of a population may be more important than its size.

5.3.3 Population distribution

The individuals of a population are not spread out evenly in their habitat but they live in various patterns (Fig 5.2). These patterns show the characteristics of the species or its environment. Infact, the population distribution describes how the individuals of a population are distributed or spread in their habitat. The evenness in dispersion of individuals is highest in uniform, lowest in clumped or contagious and of intermediate level in random type of distribution. In uniform or regular distribution individuals of a population are spread out in a regular pattern. It occurs where members of a population compete for a limiting resource such as water in desert bushes. Clumped distribution is found where the resources are confined to particular areas. Animals in deserts have clumped distribution as the water resources are restricted to some areas only or we can say that animal populations are distributed contagiously because the water bodies occur in patches in arid regions. Random distribution occurs where the resources are distributed evenly but it can occur only where the environment is uniform and resources are available adequately throughout the year thus individuals have no competition among them.

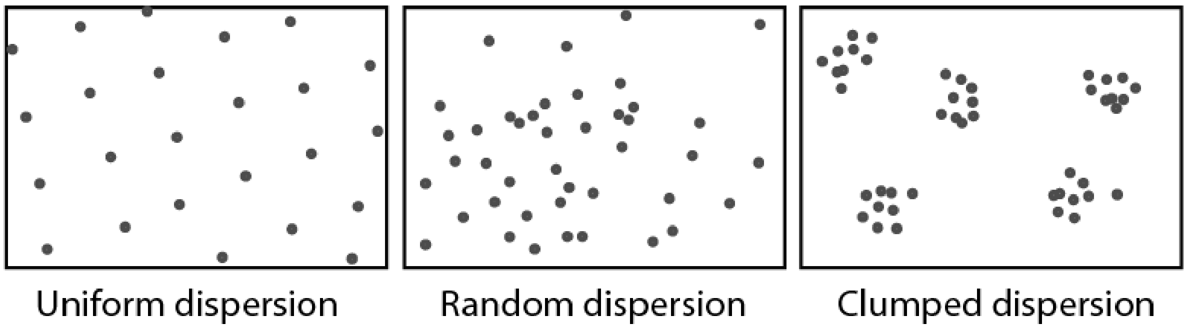


Fig 5.2: Types of population dispersion in a community (a) uniform or regular (b) random (apparently irregular) (c) clumped (contagious).
(Source: https://www.khanacademy.org/science/biology/ecology/population-ecology/a/population-size-density-and-dispersal accessed on 21-02-2022, 2:52 pm)

5.3.4 Birth rate (Natality)

Natality is the rate of production of new individuals by birth (humans and animals), hatching (birds), and germination (plants) or by fission (bacteria) etc. The birth rate may be expressed as the number of individuals born per female per unit time.

Birth rate or Natality (B) = Number of birth per unit time/average population

The maximum number of birth given by the individual (female) under standard conditions of environment is called potential natality. It is also known as reproductive potential, maximum natality or absolute natality. Natality varies from individual to individual. It depends upon the population density and environmental conditions. If the population density is low, the birth rate is also low because of few individuals and if it is too high the birth rate may also be low because of scarcity of resources, spread of diseases and other physiological reasons related to crowding.
There are two terms used to define natality.

(i) Physiological natality or Fecundity: It is the maximum production of new individuals under ideal conditions when there are no ecological limiting factors such as competition with other individuals, availability of resources (food, water, etc.). It is constant for a given population.

(ii) Ecological natality: It is also called realized natality or just ‘Natality’ which is the number of individuals produced under a specific environmental condition. It is also called fertility rate. The degree of physical constraints in an ecosystem varies with time and space thus the ecological natality is not constant for a population. The Natality is expressed as:

ΔN_n = Production of new individuals in a population
$\Delta N_n/\Delta t$ = Natality rate per unit time (B)
$\Delta N_n/N \Delta t$ = Specific natality rate (b) (i.e., natality rate per unit of population).
Where, N = initial number of organisms.
n = new individuals in the population.
t = time

5.3.5 Mortality (Death rate):

Mortality means the death of individuals in the population under certain environmental conditions. It refers to the number of death of individuals in a population per unit time. It has a great role in regulating population size.

Mortality rate = D/ t where D is the number of death of individuals in the time t.

Mortality may be of following types:

(a). Minimum mortality: It is also known as specific or potential mortality; it represents the theoretical minimum loss of individuals under favorable conditions. Though the environmental conditions are ideal but individuals would die because of their old age.

(b). Ecological or realized mortality: It represents the actual loss of individuals under a given environmental condition. Ecological mortality is not constant for a population but varies with population and environmental conditions. The maximum mortality is observed at initial stages of development like larval, egg, seedling stage in plants or old age. It is a constant for a given population.

Several environmental conditions such as population density, competition for food and water, predation, diseases, etc., affect mortality. Birth rates and Mortality rate are correlated with each other and when the natality rate is equal to the mortality rate the population is said to be stationary.

5.3.6 Life tables:

If we have the information of natality and mortality in different ages and sexes we can combine it to form life tables. From these tables the growth or decline of a population can be estimated. In each table there are columns for age of individuals, number of survivor of each age, the number dying in each age group; the proportion dying from the previous age category; fertility rate; the number of young born by each age group. The information obtained from these figures provides the net reproductive rate of the population i.e., offspring left by each individual. Similarly mortality is also estimated and these are then used to study the population growth.

5.3.7 Population growth:

The size of a population for any species is not a constant parameter, it keeps changing with time. The two simplest models of population growth use some equations to describe the rate of change in the size of population over a period of time. The first model is exponential growth which describes population that increases in numbers without any limit. The second model is logistic growth which introduces limits to reproductive growth that become more vigorous as the population size increases. Neither model perfectly describes the population found in nature, but they provide some points of comparison.

- **J-Shaped Curve:** This type of curve is formed when the population grows exponentially (Fig.5.3A). The population after attaining the peak may crash suddenly. The increase in population is continued till large amount of food is available in the habitat. After some time, due to the increase in population size the food supply becomes less available which ultimately results in the decrease is population size. For example many insect populations increase in numbers during the rainy season, but disappear at the end of the season. The equation showing the J shaped growth is:

  $dN / dt = rN$
  where, dN / dt represents rate of change in population size, r is biotic potential and N stands for population size.

- **S-Shaped curve or Sigmoid Curve:** When a few organisms are introduced in a new environment, the population increases slowly in the beginning (positive acceleration phase or lag phase) then increases rapidly (logarithmic phase) and finally in the last phase i. e., negative acceleration phase the increase in population is slowed down until an equilibrium is established (Fig. 5.3 B). The stage beyond which no remarkable increase can occur is termed as saturation level or carrying capacity (K) of the environment for that organism. K represents the point at which the upward curve starts to level, when the numbers of individuals of a population are plotted over time. In this stage the new individuals are almost equal to the number of dying individuals and thus population does not increase in size further. For example Yeast, a microscopic fungus is used to make bread and alcoholic beverages, exhibits the classical S-shaped curve when grown in test tube. Its growth ceases as the yeast population consumes all the nutrients that are necessary for its growth.

  The S- shaped sigmoid growth form is represented by the following equation:
  $dN / dt = rN (K-N/ K) = rN(1-N / K)$

  where, dN / dt is the rate of change in population size, r is biotic potential

  N is population size, $K-N / K$ or $1-(N / K)$ is for environmental resistance.

When N is very small, (K-N)/ K becomes close to K/K or. 1; we get r_{max} N which means the population is growing exponentially and is not affected by carrying capacity. Simultaneously when N is large, (K-N)/ K becomes close to zero, which means population will grow slowly or even stop. Thus population growth becomes greatly slows down in large populations by the carrying capacity K. This model also allows for negative population decline. It occurs when the number of organisms in the population exceeds the carrying capacity (value of (K-N)/ K is negative).

A graph of this equation yields an S-shaped curve; it is considered as a more-realistic model of population growth than exponential growth. There are three different sections to an S-shaped curve. At initial stage, growth is exponential because there are few individuals and adequate food supply. Then, as food supply becomes limited, the growth rate decreases. Finally, growth levels off at the carrying capacity of the environment, with a minor change in population size over time.

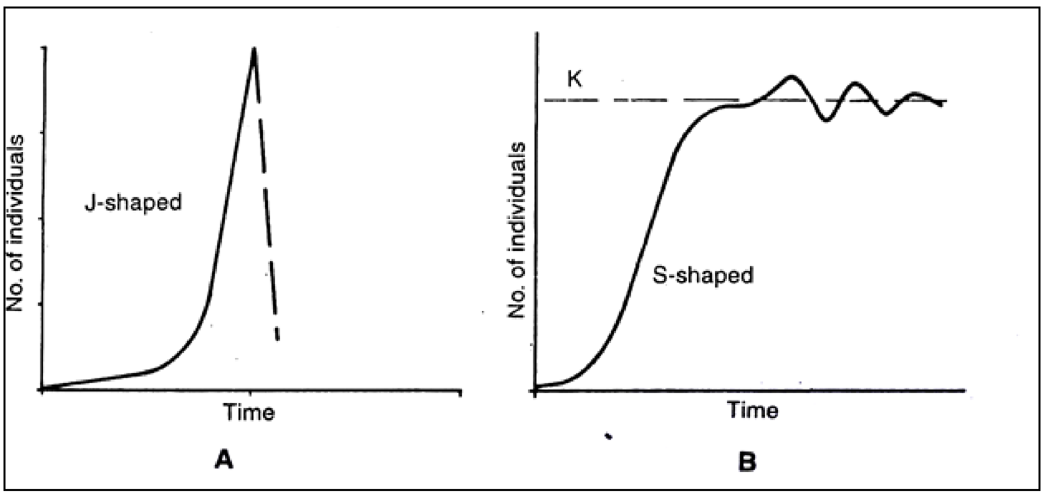


Fig 5.3 Population growth curves A. J-shaped; B. S- shaped (sigmoid) curve. K is carrying capacity.
(Source: https://www.biologydiscussion.com/population/population-growth/population-growth-curves-ecology/51854#google_vignette accessed on 24-02-2022,12:43 pm)

5.3.8 Age Structure (Pyramid):

Age structure is also a population characteristic. It refers to the proportion of individuals of different ages in a population. When the age distribution is represented by plotting percentage of individuals in the different age groups, it is called age pyramid (Fig 5.4). The age pyramids of human population generally show the age distribution of males and females in a combined diagram. The growth status of the population is represented by the shape of the pyramids.

(i). **Expanding:** It is represented by a pyramid with a broad base or triangular structure. It indicates a higher percentage of young individuals. In a population when the birth rate is high the population growth may be exponential and indicates higher proportion of young individuals with a decreasing proportion of older individuals.

(ii). Stable: It is represented by a bell shaped polygon which indicates a stationary or stable population comprising of more or less equal number of pre reproductive (young) and reproductive (middle aged) groups. The post reproductive group (old individuals) being the smallest in number.

(iii). Declining: It is represented by an urn shaped pyramid which shows low percentage of young individuals while increased number of middle aged and old population. This type of pyramid indicates dying off or declining population.

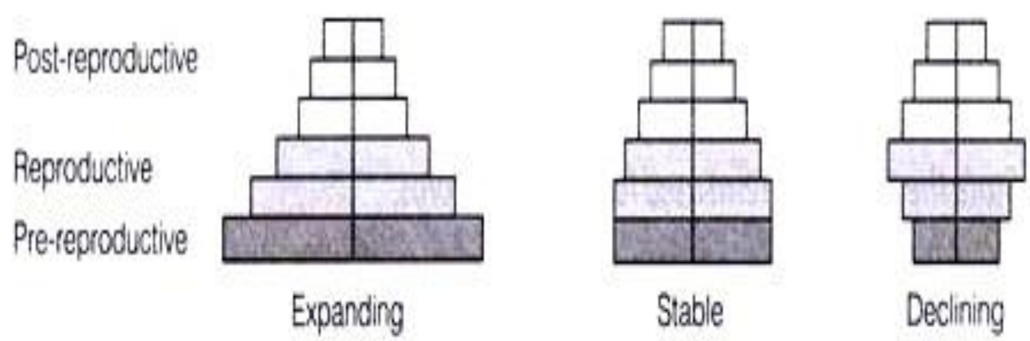


Fig 5.4. Representation of age pyramids for human population
(Source: https://www.biologydiscussion.com/population/population-definition-attributes-and-growth-biology/56309 accessed on 21-02-2022, 10:46 am)

5.4 POPULATION RESOURCE RELATIONSHIP

Population and resources have a strong relationship with one another. The availability of natural resources is affected by the growth or depletion of a population. On the other hand, the availability of natural resources affects the fate of a population. Availability of resources is described as the amount of natural resources that is present and can be utilized by the individuals of a population. If the availability or supply of natural resources becomes limited, it will negatively affect the size of a population.

In case of human if the population further increases, the possibility of resource consumption also increases. The human resource consumption patterns have severe effect on habitat and water availability, the increase in population size threatens biodiversity through the destruction of ecosystems. The higher population density lead to increase stress on natural resources like scarcity of water, decreased food security, slower development and consequently to deprivation.

It is obvious that more individuals relying on same natural resources put these resources under increasing pressure. As a result there will be fewer resources available per individual, which is likely to impact negatively both food security and social and economic development of the area.

It is a matter of debate that whether high population density or deficiency of resources can be held responsible for the population-resource imbalance. It is not always the high population growth or deficiency of resources that gives rise to population-resource imbalance. The pattern of social structure, the stage of technological development, the pattern of population dispersal and distribution, government policies etc. sometimes become responsible for the nature of balance between the individuals and resources of any particular area.

5.5 ECOTYPES

The ecotype refers to an ecospecies that describes a genetically similar variety, population or race with in a species which is adapted to specific or we can say local environmental conditions. The term ecotype was coined by G. Turreson (1922a, b). Ecotypes are also known as ecological races or physiological races. Individuals (ecotypes) of a species growing /residing in different habitats may exhibit phenotypic differences such as changes in morphology or physiology but they are capable of interbreeding with other ecotypes growing/ residing in other geographical area without losing fertility or vigor, they are kept in one taxonomic species. In plants the response of a species to a particular environmental condition may be shown in morphological changes like changes in the external appearance, variations in number and size of branches, leaves, flowers and seeds etc. The variations become genetically permanent and are transferred from one generation to the other generation. These variations are irreversible that is if they are grown in a neutral habitat they will retain their features. The grass *Euphorbia hirta* has two ecotypes. One has permanently adapted to survive in dry conditions and the other is adapted to survive in moist conditions.

Gote Turesson developed the term ecotype as a result of a series of observations and experiments on *Plantago maritima*. He collected live plants from different parts of Sweden and grew them together in the same garden. He described the study of ecotypes as a new research field, called genecology. The basic conclusions of Turesson’s study include the following aspects:

A species with wide ecological amplitude (the degree of adaptation of an organism to the changes in its environment) exhibit a variation in morphological and physiological characters; these characters vary from place to place within a habitat. (ii) This variation within species is largely correlated with habitat differences. (iii) This variation is not only phenotypic variation but also a result of the natural selection of specific genotypes from the pool of genetic variability present in the species. Mutations and natural recombinations in the individuals of a species produce small gene pool which becomes more adapted to the local environment.

In India Mishra and Shiva Rao (1948) found two closely related species of *Lindbergia* namely, *L. polyantha* and *L. urticaefolia* were not two distinct species but only ecotypes of the same species. They differ from each other in respect to the tolerance to high doses of lime. In another study Ramakrishnan (1965) showed two ecotypes of *Euphorbia thymifolia* one red ecotype and another green ecotype. The red ecotype of *E. thymifolia* grows in calcium rich soil (calcicol) as well as calcium deficient soils and the green ecotype grows only in calcium deficient soil (calcifuges) The red ecotype possesses a pair of dominant alleles whereas the green type possesses a pair of recessive alleles. Ecotypes have been reported in several plants like *Portulaca oleracea, Ageratum conizoides, Cenchrus ciliaris, Euphorbia hirta, Cassia tora* etc.

5.5.1Characteristics of ecotypes

1. Ecotypes of one species are capable of interbreeding. They are fertile as they are of the same taxonomic species.
2. They are genetically distinct and inheritable.
3. The variations are permanent and irreversible. They retain their variations and do not change even when cultivated in natural habitat.
4. They show wide ecological amplitude and can be distinguished on the basis of morphological and physiological characters.
5. The variations in ecotypes are not due to plastic response to change in environment but due to the natural selection of locally adapted population.

5.5.2 Origin of new ecotypes:

Ecotypes can be produced by the following methods:

1. **Hybridization:** The ecotypes can be produced by the natural cross between two species. For example, when *Spartia stricta* is naturally crossed with *S. alternifolia* the new hybrid *S. townsendii* is produced. Both the parents of this species are eliminated from the habitat as the hybrid species is more adaptive to its habitat.

2. **Mutation:** A tiny gene pool accumulates in a segregating population due to natural mutation and recombination, making it better adapted to the particular environment or habitat. Cultivation or protected growth can potentially develop novel ecotypes by removing competitive selection.

3. **Chromosomal changes:** Alterations in genotypes and phenotypes come from structural changes in the chromosomes, such as translocations, inversions and the loss or addition

of chromosome segments, resulting in the formation of new ecotypes. Because polyploids do not demonstrate the same level of ecological tolerance as their parents, polyploidy results in the development of new ecotypes.

5.5.3 Kinds of ecotypes

1. **Climatic ecotypes-**This type of ecotypes develop in response to varying climatic factors such as light, temperature, water etc. These are also called Climatic clines. Turreson (1930) found climatic ecotypes in *Leontodon autumnalis*.

2. **Edaphic ecotypes**–These ecotypes develop due to differences in soil factors like moisture, excess or deficiency in nutrients, soil pH etc. Gregor (1939) distinguished ecotypes of *Plantago maritima* that grows in waterlogged conditions. The above mentioned species *Lindenbergia polyantha* and *L. urticaefolia* are also an example of edaphic ecotypes of the same species. The red and green colour edaphic ecotypes in *Euphorbia thymifolia* are related to calcium content of the soil.

3. **Climato-Edaphic ecotypes-**These ecotypes are developed under the influence of both climatic and edaphic factors. e.g., *Cenchrus ciliaris*.

4. **Altitudinal and latitudinal ecotypes**-These ecotypes are developed in response to different altitudes and latitudes. Altitudinal ecotypes are found in *Pinus* and many other gymnosperms. In *Achillea* it is discovered by Clausen. Latitudinal ecotypes are found in *Cassia tora* (Senna) and *Anagallis arvensis.*

5. **Physiological ecotypes**-These ecotypes are developed due to physiological changes like photoperiod, water absorption, nutrient uptake etc. Photoperiodic ecotypes are found in *Boutelona curtipendula* (long day, short day), *Prosopis*, *Argemone* and *Rumex*.

5.5.4 Significance of ecotypes

1. Ecotypes help the species to extend its ecological range and dissemination into new places.
2. It has been possible to cultivate economically important plants in a variety of habitats.
3. New ecotypes of a species allow it to adapt to climatically and ecologically diverse environments.
4. Significant differences in the species that grow in different habitats can lead to the formation or evolution of new species.

5.6 ECOLOGICAL ADAPTATIONS IN SPECIES AND SURVIVAL STRATEGIES

In Ecology, adaptation refers to the process of adjusting in morphology, physiology or in behavior to withstand the adverse conditions of the environment. The living organisms react with their environment and they also have the effect of the environment in which they grow or live. Any morphological, anatomical, physiological and reproductive feature of an organism which enables it to survive in the environmental conditions of its habitat is called adaptation. Every organism develops some adaptive features. Plants must be able to find sources of water and nutrients. They must adapt to their environment and develop special survival strategies in order to thrive in the ecosystem. In this section you will study about the ecological adaptations and survival strategies by different groups of plants.

Ecological groups of plants

E. Warming in 1909 classified plant communities on the basis of their dependence on water. Water is the most essential ecological factors in the growth and dispersion of vegetation. The vegetative structure of a geographical region mostly depends on the availability of water. Warming divided the plants into three major groups on the basis of their water requirements. The comparative details of the morphological, physiological and physiological characteristics of the above plant group are given in Table 5.1.

- **Aquatic plants or hydrophytes:** Aquatic plants or hydrophytes grow in water or extremely wet soil where their roots, rhizomes and leaves submerge in water.
- **Land (terrestrial) plants:** These plants grow in moderate conditions of water and light. Land plants exhibit various modes of adaptation. In deserts or the areas where water is scarcely present xerophytes thrive better while mesophytes occur where the availability of water is adequate. Mesophytes hold the position between hydrophytes and xerophytes.
- **Helophytes or Marsh plants: T**hese plants grow in swamp or marshy places. The plant body remains rooted in soil or mud below the water level.

5.6.1 Hydrophytes:

Hydrophytes are further divided into the following five categories (Fig. 5.5):

(i). Free floating Hydrophytes: Plants like *Wolffia, Lemna, Azolla, Eichhornia, Salvinia Pistia* and *Spirodella* freely float on the water surface. They are not attached to the soil. Some plants have minute leaves while some have quite large leaves.

(ii). Rooted Hydrophytes with Floating Leaves: The roots of certain hydrophytes are fixed in mud but their leaves have long petioles which help them float on the water surface. The rest of the plant body remains submerged in water. *Nelumbo, Trapa, Marsilea, Nymphaea* and *Aponogeton* ae some example of it.

(iii). Submerged floating: These hydrophytes remain in contact with water but not rooted in the mud. Stems are long and leaves are generally small. Plants like *Ceratophyllum, Najas, Utricularia* etc. are completely submerged in water.

(iv). Rooted submerged: Some hydrophytes such as *Hydrilla, Vallisneria, Chara, Isoetes and Potamogeton* remain completely submerged in water and also rooted in the mud. In *Hydrilla, Potamogeton* and *Chara* stem is long and bears small leaves at nodes. In *Hydrilla* the plant body is slender and roots are fibrous. In *Isoetes* and *Vallisneria* the stem is corm like (tubrous). The leaves are long and ribbon shaped.

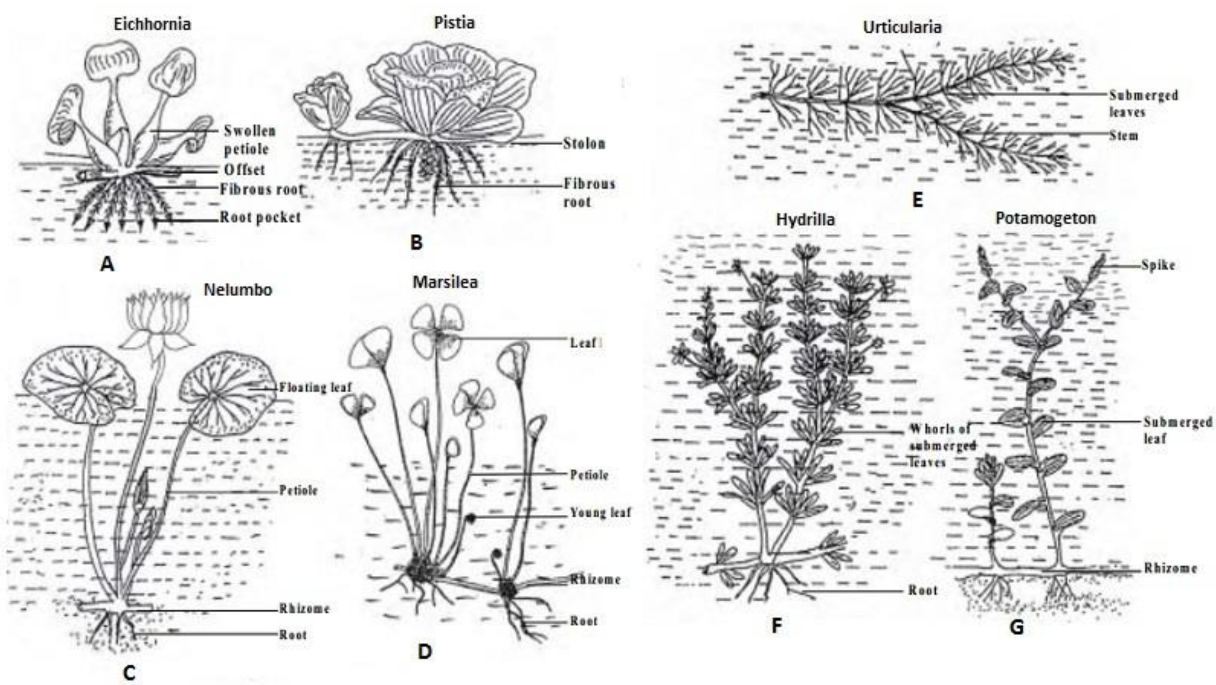


Fig. 5.5 Hydrophytes: A & B free floating hydrophytes; C & D rooted hydrophytes with floating leaves; E, F & G submerged hydrophytes.

(Source: https://www.brainkart.com/article/Hydrophytes-And-Classification-of-Hydrophytes_978/ accessed on 27-02-2022, 05.05 pm)

(v). Rooted emergent: Some hydrophytes grow in shallow waters but their shoots are partly or completely exposed to air. In *Ranunculus, Sagittaria, Limnophila* and *Monochoria* the stems are partly in water and partly in air (Fig. 5.6). In some other hydrophytes such as *Cyperus, Rumex, Typha* etc., the shoots are completely exposed to air like land plants. These plants are called marshy plants.

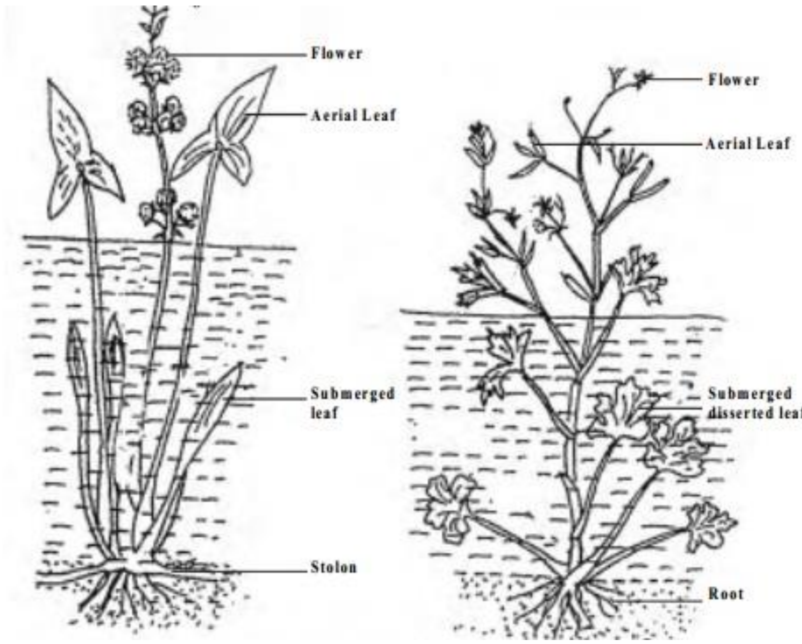


Fig. 5.6 Rooted emergents. Sagittaria; Ranunculus.
(Source: https://www.brainkart.com/article/Hydrophytes-And-Classification-of-Hydrophytes_978/ accessed on 21-02-2022, 12:35 pm)

Ecological adaptations in Hydrophytes

The hydrophytes are adapted to survive in water. There are some changes in the external and internal features of the plants in order to survive in its environment (water). Different parts of plants undergo some changes or acquire some specialized features which enable them to become adapted to their environment.

Morphological features:

1. **Roots:** In hydrophytes the roots may be entirely absent as in *Ceratophyllum, Salvinia*, and *Wolffia* or they are well developed and branched with distinct root caps as in *Ranunculus* and *Typha.* In *Hydrilla* the roots are poorly developed. In hydrophytes the root hair and root caps are usually absent. However in free floating plants as in *Eichhornia* root caps are replaced by root pockets. Roots are generally fibrous, adventitious, short, unbranched or poorly branched. In *Jussiaea repens* floating aerial roots are present where as in *Lemna* roots help in anchoring and balancing the plant.

2. **Stems:** In free floating forms, stem is thin and float horizontally on water surface e.g., *Azolla* or thick, short and spongy as in *Eichhornia*. The stem is long, slender, spongy and flexible in submerged forms as *Hydrilla* and *Potamogeton.* In hydrophytes which are

rooted with free floating leaves stem is a rhizome which is either well developed as in *Nelumbo* or small as in *Nymphaea*.

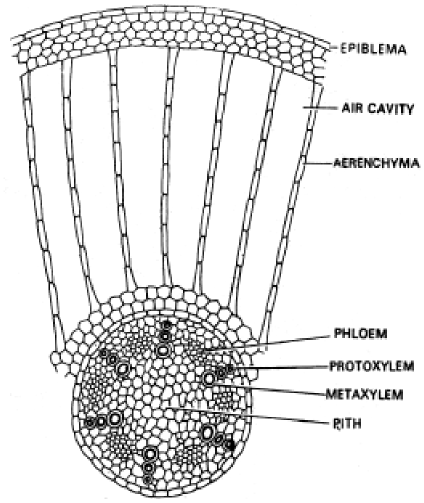


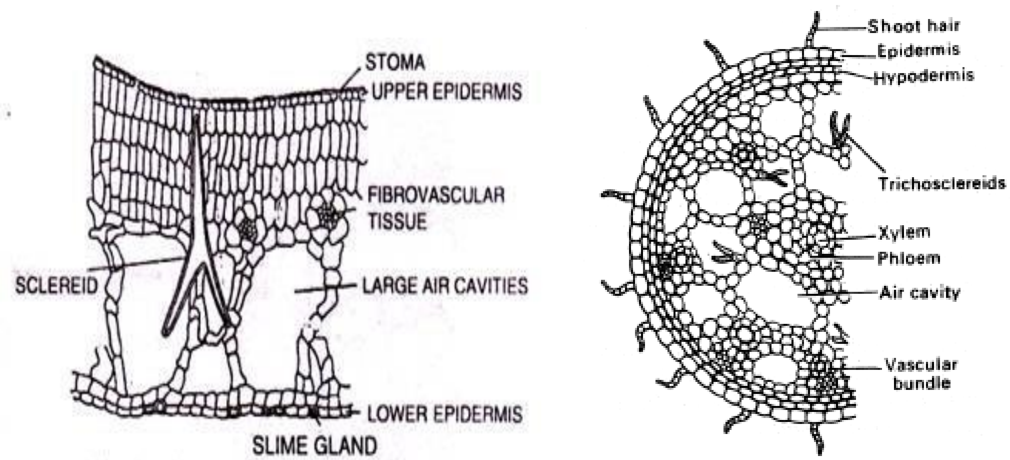
Fig. 5.7 T.S. root of Eichhornia floating leaved hydrophyte
(Source: https://www.entrancei.com/chapter-organisms-and-their-environment/hydrophtes accessed on 17-02-2022 4:10 pm)

3. **Leaves:** The leaves are generally thin and small. In submerged hydrophytes the leaves are translucent. The floating leaves of *Nelumbo* and *Nymphaea* are large, flat and their upper surfaces are coated with wax, their petioles are long, flexible and often covered with mucilage. In *Eichhornia* and *Trapa* the petioles are swollen and spongy. The leaves are long and ribbon shaped in *Vallisneria* where as in *Potamogeton* they are long and linear. *Ranunculus, Sagitaria* and *Limnophylla* show heterophylly (condition in which several kinds of leaves are present in one plant) with submerged, floating and aerial leaves.

4. **Flowers and reproduction:** The flowers are usually produced on the surface of water or above it. But in *Eichhornia, Pistia,* and *Vallisnaria* the fruits ripens under water. Pollination is carried out by the help of water, aquatic insects and birds. The vegetative reproduction takes place by runners, stolons, stem and root tubers, dormant apices etc.

Anatomical features: In hydrophytes the cuticle is absent or poorly developed. Epidermis is single layered made up of thin walled parenchymatous cells. In cortex the parenchyma and arenchyma (air spaces) are highly developed. The arenchyma gives resistance to the bending stress, offers buoyancy and permits gaseous exchange. The vascular and mechanical tissues are rather poorly developed. In emergent forms as *Ranunculus* and *Typha* vascular tissues are comparatively well developed. Stomata are completely absent in submerged species (*Anarachis* and *Potamogeton*). In floating species like *Nymphaea* stomata are confined only to the upper surface. The chlorophyll is present throughout the plant body (Fig. 5.7). In *Azolla* the roots also contain chlorophyll. Mucilage cells and mucilage canals are present for mucilage secretion which protects the plant body from decaying under water. In hydrophytes the reserve food material is in the form of starch grains found abundantly in pith and cortex. Cystoliths (sclerids) are common in leaves and other tissues which provide some mechanical support to the tissues.

Physiological features: Aquatic plants exhibit a low osmotic concentration of cell sap. In these plants the nutrients are absorbed through the plant surface. The exchange of gases takes place through epidermis. The gases produced during respiration and photosynthesis are partly retained in the arenchyma (air chambers). The emergent and free floating plants have high rate of transpiration while there is no transpiration from submerged plants.



A B

Fig. 5.8 Anatomical features of some hydrophytes A. Cross section of Nymphea leaf; B, Part of petiole of Nymphaea

(Source: https://quizlet.com/344282293/cross-sections-examplesplant-lab-flash-cards/ accessed on 21-02-2022 12:36 pm)

5.6.2 Mesophytes

Mesophytes represent the group of terrestrial plants which grow in moderate conditions of water and temperature. They are broad-leaved trees growing in wet habitats along lakes and rivers. They stand between hydrophytes and xerophytes and show features similar to both the groups. Mesophytes do not possess special morphological and physiological adaptations as hydrophytes and xerophytes.

Some of the significant morphological and anatomical features of mesophytes are: 1. The root system is well developed, they are branched containing root hairs and root caps for the uptake of water and minerals from the soil. 2. Stem is generally aerial, solid and branched. 3. Leaves are generally large, broad and exhibit shape variations, aligned horizontally, they are green and lack hairy or wax coating unlike hydrophytes. 4. In the aerial part cuticle is moderately developed but epidermis is well developed and contain chloroplasts. Stomata are generally present on both the surfaces of the leaves. Mesophylls are developed and differentiated into palisade and spongy parenchyma with many intercellular spaces to aid in exchange of gases between the plant and its environment. Vascular bundles are well developed. Mesophytes may exhibit temporary wilting during noon hours.

5.6.3 Xerophytes

Xerophytes are the plants which are able to survive in an environment with less availability of water. Daubenmire (1959) defined xerophytes as "plants which grow on substrate that usually become depleted of water to a depth of atleast two decimeters during normal growth season". Thus xerophytes are plants of relatively dry habitats and climate.

On the basis of morphology, physiology and life cycle patterns the xerophytes are classified into three categories.

1. **Ephimerals.** These are also called drought evaders or drought escapers. They are short lived annual plants which completes their life cycle when sufficient water is available. These plants avoid dry seasons and thus escape dryness in external and internal environments. The seed germination is followed by flowering and seed production with the onset of rainfall. Thus the entire life cycle of a xerophyte is completed before the dry season arrives. The main morphological adaptation of ephemerals is their small size and large shoot in relation to the root system. Most of the plants are small, dense shrubs e.g., *Argemone mexicana, Cassia tora Solanum xanthocarpum* etc.

2. **Succulents.** These are the drought enduring xerophytes. These plants suffer dryness in their external environment only. Their succulent, fleshy stems, leaves or roots serve as storage organs which store large amounts of water during the rainy seasons. In some xerophytes the roots become succulent (*Asparagus, Ceiba parvifolia*) while in some the stems (*Opuntia, Eurphobia*) and the leaves (*Aloe, Begonia, Agave, Bryophyllum, Yucca, Tradescantia* etc.) become succulent (Fig. 5.8). Except the succulent part the rest of the plant body is generally reduced. The roots are shallow and fibrous which help in the absorption of traces of water from the soil surface. In Cacti and Eurphobias the leaves are absent or modified into spines. The cuticle is thick and vascular system is usually ill-developed. The succulents have a physiological adaptation that they can utilize carbon dioxide during night through the CAM pathway (crassulacean acid metabolism). These plants adapt this type of mechanism because the stomata remain closed during the day to avoid water loss and gaseous exchange can occur only during night when stomata are open.

3. **Non Succulents Perennial.** These are drought resistant plants and are also known as true xerophytes. They have the ability to maintain growth under critical dry conditions and high temperature. These plants are woody trees, shrubs or herbs. The examples are *Acacia nelotica, Calotropis procera, Casuarina, Saccharum, Nerium, Zizyphus jujuba* etc

(Fig.5.9). They acquire some morpho-physiological features which help them to withstand dryness internally as well as from external environment.

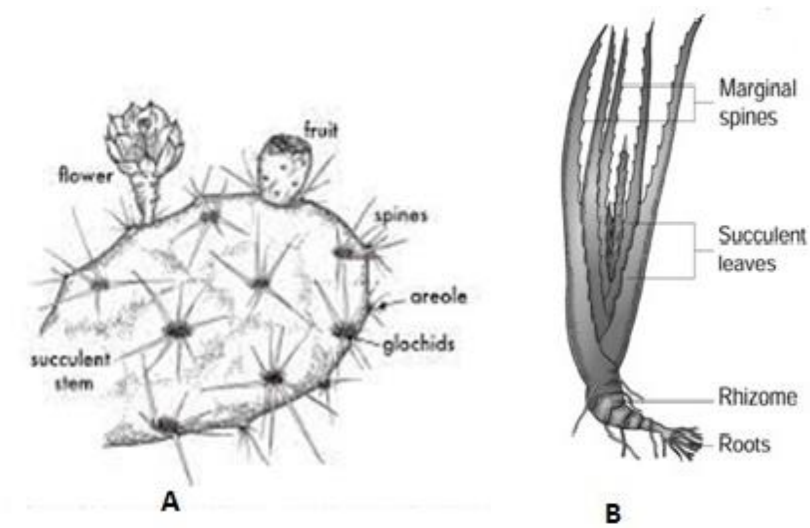


Fig. 5.9 Succulents A. Opuntia B. Aloe vera

(Source: Opuntia: https://nanopdf.com/download/phylogenetics-of-cacti-lab-exercise-copy_pdf accessed on 21-02-2022, 11.34 am; Aloe vera: https://studymateriall.com/ecological-adaptations-xerophytes-plants-plant-living-in-dry-places/ accessed on 21-02-2022, 12:07 pm)

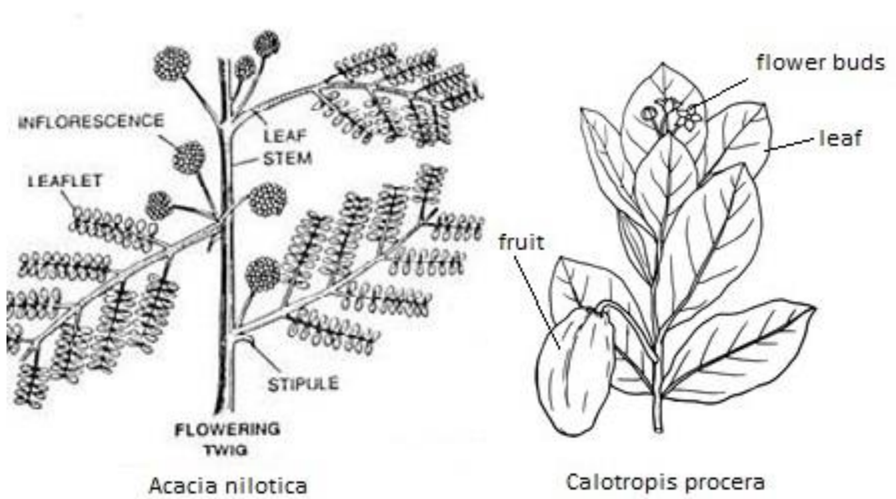


Fig. 5.10 Non succulent xerophytes.

(Source: Acacia nelotica http://botanystudies.com/family-fabaceae-acacia-nilotica/ accessed on 28-02-2022, 11.35 am; Calotropis https://www.shutterstock.com/image-vector/rubber-bush-sodom-apple-stabragh-kings-1545599573 accessed on 28-02-2022, 11.31am)

To prevent dessication they exhibit the several morphological and physiological adaptations. They have very extensive root system for example in *Alfaalfa, Calotropis* and *Prosopis* roots may be more than 125 feet long. To minimize the rate of transpiration the leaves are absent or they fall very early (caducous). In *Acacia nelotica* the leaves are small sized while in *Poa*, *Agropyron* and *Ammophila* the leaf blades roll and fold back. Some leaves have heavy cuticular and epidermal layers. The osmotic pressure of the cell sap is generally high. Plasmodesmata are absent. In some xerophytes such as *Banksia* the leaves are stiff and hard (sclerophyllous).

Ecological adaptations in xerophytes

In the above section we have studied about different types of xerophytes and their characteristics features. These features which enable them to survive in the harsh xeric conditions are discussed in details below:

Morphological features

1. **Roots** The xerophytes grow under water deficient conditions unlike hydrophytes. In order to obtain water present in deep layers of soil, the root system is well developed. The roots are long, tap roots with extensive branching have root hair and root caps which are well developed.
2. **Stems** Mostly xerophytes are woody, dry, hard, ridged undersized plants with thick bark. In some species the stem is underground (*Saccharum*) whereas in Cacti (*Opuntia*) it is fleshy, green, leaf like (phylloclade) with spines. On stems hairs and wax coating is generally present.
3. **Leaves** In xerophytes the leaves are much reduced, scale like and sometimes in form of spines. Leaf lamina may be divided into small leaflets (*Acacia*) or needle like as in *Pinus*. Foliage leaves may be thick, fleshy and succulent, sometimes tough and leathery. The leaf surfaces are generally shiny and glazed to reflect the light and heat. In some species like *Ammophila*, *Agropyron* and *Poa* leaves are folded and rolled to hide the sunken stomata thus minimizing the rate of transpiration. In *Acacia, Zizyphus, Eurphobia* etc., the stipules are modified into spines.

Anatomical features

1. **Roots** Root hairs and root caps are well developed in xerophytes. The root hairs are even present at the root tips (*Opuntia*). Roots become fleshy to accumulate water as in *Asparagus*. In *Calotropis* and *Pinus edulis* the roots have rigid and thick cell walls.
2. **Stems** The anatomy of succulents shows that the stems possess water storage region. In non succulent forms like *Casuarina* the cuticle is very thick and epidermis is well developed with thick cell walls. The hypodermis is multi layered and sclerenchymatous while stomata are sunken type. The vascular tissues are well differentiated and lignified comprising of several layered bundle sheaths. Bark is thick often contains oil and resins.
3. **Leaves** In *Peperomia* the epidermanl cells also serve as water storing organs. In *Aloe* and *Salsola* the mesophyll tissue store water. The cuticle is thick and outer walls of epidermal cells are deposited with cutin and cellulose in succulent species. In non succulent xerophytes such as *Pinus* and *Nerium* well developed cuticle, several layered thick

epidermis and sclerenchymatous hypodermis is present. The mesophyll is differentiated into palisade and spongy parenchyma. Stomata are sunken type and present only on the lower epidermis. In *Nerium* the stomata are found in pits. The vascular tissues are well developed comprising of xylem and phloem. In *Nerium* a large vascular bundle is situate near mid rib while small vascular bundles are found in the entire leaf.

Table 5.1 A comparative account of some morphological, anatomical and physiological features of three ecologically different groups of plant (Source: P.D. Sharma, 2016)

S.N.	Hydrophytes	Mesophytes	Xerophytes
Morphological features	Roots are generally reduced or absent. If present, roots are unbranched and lack root hair as in emergent forms.	Root sestem is well developed. Tap root system or fibrous roots are present with root hairs	Extensive root system is present. Roots are deep, larger than stems, hard and woody.
	Stem reduced, thin and fragile, sometimes modified into rhizomes.	Stem is rigid and strong.	Stems undersized, branched sometimes underground.
	Leaves thin, narrow with elongated petiole and large lamina. Wax layer or hairs are present.	Leaves large, thin without waxy covering.	Leaves small, reduced to scales or sometimes modified into spines. In some species leaves are thick and leathery with shining surface and glazed with wax and hairs.
Anatomical features	Arenchyma is extended in all vegetative parts.	Lack arenchyma.	Lack arenchyma.
	Cuticle usually absent.	Cuticle well developed.	Cuticle well developed, thick.
	Stomata generally absent, or confined to upper surface if present.	Stomata on one or both the surfaces.	Stomata sunken type, generally confined to lower surface.
	Mesophyll undifferentiated	Mesophyll well developed, differentiated.	Mesophyll generally on both sides.
	Epidermis thin walled	Epidermis thickened.	Epidermal cells distinctively thick.
	Mechanical tissues and Vascular bundles are less.	Mechanical and vascular tissues are well developed.	Mechanical and vascular tissues prominently well developed.
Physiological features	Special aerating organs are present, withstand low oxygen conditions.	Physiological process normal.	Minimum transpiration rates, some complete their life cycle in short period of time, high osmotic pressure, withstand dryness.

5.6.4 Halophytes

These are special type of xerophytes which grow on physiologically dry soils such as saline soils with high concentration of salts (sodium chloride, magnesium chloride, magnesium sulphate). Warming (1909) have classified halophytes on the basis of the substratum on which they grow. He divided halophytes into four categories:

1. Lithophilous (on rock and stones)
2. Psammophilous (on sand)
3. Pelophilous (on mud)
4. Helophilous types (in swamp): These are further divided into two types
    (i). Salt desert and salt swamp
    (ii). Littoral swamp forest (mangroves). The littoral swamp forests occur in all tropical seas, on muddy shores, lagoons, estuaries etc. The soil is flooded with water throughout the year or at high tide. These mangrove forests are found in tropical and subtropical regions.

In India mangroves are common on seashores of Kerala and Mumbai and in Andaman and Nicobar islands. The Sunderbans in the Bay of Bengal, is the largest mangrove forest in the world. They grow on water logged soil in areas where high precipitation, high atmospheric humidity and optimum temperature occur. *Rhizophora mucronata* and *Xylocarpus granatum, Sonneratia* are the common examples of mangrove plants.

The xeromorphic characters of halophytes are as follows:

- Most of them are succulents; their leaves are evergreen, thin, small and leathery with water storage tissues, thick cuticle and well developed palisade tissues.
- Most halophytes possess special type of negative geotropic roots that come out of the soil surface to increase the oxygen uptake. These roots are called Pneumatophores and they possess breathing pores for gaseous exchange.
- Some halophytes such as *Rhizophora* produce stilt roots which have well developed cork, lacunar primary cortex, with sclerids and secretory cells and well developed mechanical and vascular tissues.
- Their osmotic pressure values are very high.
- Some halophytes as *Rhizophora* show vivipary, i.e., the seeds germinate into seedling before being shed from the parent plant. The xerophytic characters of *Rhizophora mucronata* are discussed in detail below:

1. **Roots:** On the basis of anatomical characters the roots in *R. mucronata* are divided into two types; aerial and subterranean. The transverse section of subterranean root shows the following characters:

- The cork is several layered.
- Cortex is made up of star shaped or stellate cells which are connected with each other by lateral arms. The cortical cells have lignified, thickened ridges.
- Pith cells are thick walled with pitted thickenings of lignin.
- Oil and tannin are also found in some cortex and pith cells.

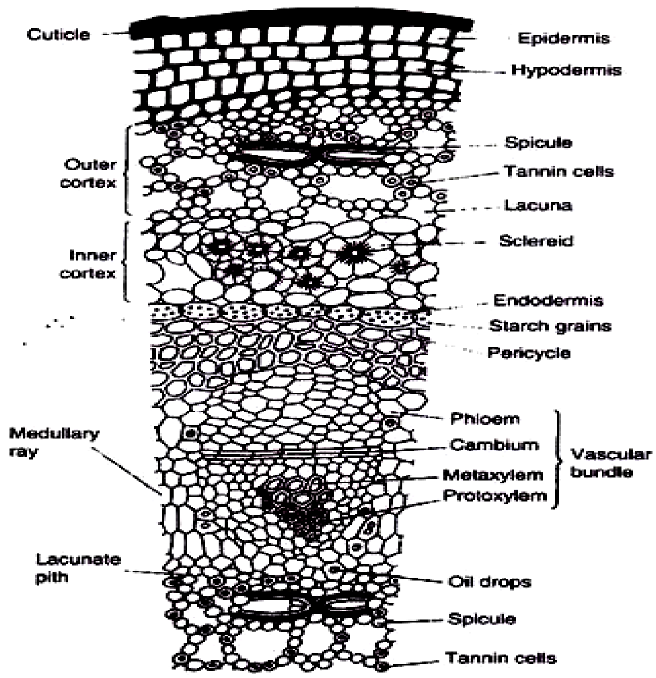


Fig.5.11 Rhizophora mucronata. Transverse section of young stem
(Source: https://www.pinterest.com/pin/851954454488217528/ accessed on 03-03-2022, 10:32 pm)

2. **Stem:** The transverse section of young stem shows:

- Thick cuticle.
- Thick epidermal cells with tannin and oil.
- Several layered hypodermis is present with thick cell walls.
- Primary cortex possesses lacunae filled with tannin and oil. The cells of the lacunae are also thick walled. Some of the cells possess calcium oxalate crystals. Spicules are present in these regions which are very thick and H-shaped. They provide mechanical strength to the cortex.
- The inner cortex possesses several branched, thick walled cells –sclerids that also provide mechanical strength to the plant.
- Several layered, sclerenchymatous pericycle is present.
- Pith also contains lacunae, H- shaped spicules and tannin.

3. **Leaf:** The leaves of halophytes possess:

- Well developed cuticle.
- Heavily thickened epidermal cells with calcium oxalate crystals.
- Stomata are sunken and confined to the lower surface.
- Beneath the upper epidermis several layers of thin walled cells are present filled with water, the outer layer of these cells is filled with oil and tannin. The lowermost layer possesses mucilaginous cells that are embedded into the palisade tissue. Mesophyll is well differentiated from other tissues.

Among the annual and perennial psammophilous halophytes the perennials show conspicuous xerophytic features. Some of the common examples of this group are *Suaeda fruticosa* and *Salsola foetida*.

5.7 SUMMARY

In this unit the learners have studied about the population and its characteristics, Ecological adaptation in species. The term population ecology comes under the major field ecology which refers to the study of dynamics of various species populations and their interaction with their environment. Earlier the ecology is divided into autecology and synecology. The former deals with the study of a single species in relation to the environment while the later is the study of many species in relation to the environment. The term autecology comes from Greek word auto means self, oikos means household and logos means knowledge. It encompasses the concepts such as life cycles and behaviour like ability of an individual to adapt to the environment. The synecology is divided into population ecology, community ecology and ecosystem ecology.

A population is defined as a group of individuals of same species who interact with each other. The total number of individuals in a population is referred to as population size and the average number of individuals in a population per unit area or volume is known as density. The population size can be influenced by births, deaths, emigration and immigration. In a population the maximum population size of the species that the environment can support is defined as the carrying capacity. It is determined by the available resources such as food, water, light, shelter or habitat etc. The size of a population is not a static parameter it keeps on changing. There are two types of population growth patterns which depend on specific environmental conditions. An exponential growth pattern occurs when the environmental conditions are ideal for a species. It is denoted by J shaped curve. A logistic growth pattern occurs when environmental conditions affect the rate of growth. It is denoted by S shaped curve. Likewise population growth patterns age structure is also a population characteristic. It is a graphical representation of distribution of the population by various ages in a population. It assumes the shape of a pyramid when the population is increasing. Thus the pyramid can be used to represent the age of a population. The age may be expressed as days, months or years and it can also be expressed in categories such as pre reproductive, reproductive and post reproductive. The age distribution is depicted by plotting the percentage of individuals in various age classes as a function of the relative width of successive horizontal bars, with the youngest at the bottom and the oldest at the top. A high percentage of organisms in reproductive phase indicate the rapid growth in population. The pyramid or age structure varies from population to population. A pyramid with a broad base indicates young population which is said to be fast growing. It depicts that the birth rate is higher than the mortality rate for a given population. The bell shaped polygon structure represents stable population as the number of births and deaths are almost equal. The urn shaped pyramid indicates declining population as the old individuals are in majority hence the population has a low birth rate.

The availability of resources is also influenced by population size. If a population grows rapidly, more resources are required to support it. The relationship between population and resource availability is complicated. The availability of natural resources is determined by population growth and decline. At the same time, natural resource availability influences population dynamics.

Meanwhile, genetics is to blame for some physical and/or physiological variances in small group populations, which are linked to habitat. They are, nevertheless, capable of mating with other ecotypes of the same species. Ecotypes are colonies or groups of species that have adapted to their local habitat.

Living creatures interact with their surroundings and develop certain morphological, anatomical, and physiological traits in order to survive in harsh environments and maximize their potential. Thus, Ecological adaptation refers to an organism's morphological, anatomical, and physiological characteristics that enable it to survive and reproduce in a given environment.

Today, there are around 8.7 million species on the earth, which live in a variety of natural environments such as acidic soil, saline soil, fresh water, saline water, marshy areas, desserts, and so on.

5.8 GLOSSARY

Altitude: The height of a place above sea level.
Bottle neck effect: It refers to the way in which a subsequent increase or decrease in a size of a population affects the distribution of genetic variation among its individuals.
Cystoliths: These are the outgrowths of the epidermal cell wall, usually made up of calcium carbonate generally present in the leaf of plants.
Density: It is the number of individuals of a given species that occurs within a given sample unit or study area.
Dispersion: It refers to how the individuals in a population are distributed in space at a given time.

Ecotype: A variety or race of a plant or animal species occupying a particular habitat in an ecosystem.

Emigration: Number of individuals of a population that leave the group to reside in other place.

Ephimeral: A plant that grows flowers and dies in a short period of time.

Evenness: Species evenness in an environment refers to how close in numbers each species is.

Evolution: It is the change in heritable characteristics of organisms over successive generations.

Fecundity: It is an individual's (usually female) physiological maximal potential reproductive output throughout its lifetime.

Genecology: It is a branch of ecology under which genetic variation of species and communities in comparison to their population distribution in a local environment is studied.

Habitat: place where and organism lives and grows.

Halophyte: It is a salt-tolerant plant that grows in soil or waters of high salinity, coming into contact with saline water through its roots or by salt spray, such as in saline semi-deserts, mangrove swamps, marshes and sloughs and seashores.

Hybridization: It is the process of crossbreeding between genetically dissimilar parents to produce a hybrid.

Hydrophytes: These are plants which grow only in or on water.

Immigration: Number of individuals that comes in a population over a period of time.

Latitudes: Latitude is an angle which ranges from 0° at the Equator to 90° (North or South) at the poles. It is used together with longitude to specify the precise location on the Earth.

Local population: A group of individuals within a same habitat.

Mesophytes: These are plants adapted to moderate condition of light and water.

Migration: Migration involves the movement of individuals from one place to another with intentions of finding food, water, settling permanently or temporarily at a new geographic region.

Mortality: It is the number of individuals that die in a given period (deaths per unit time).

Mutation: It is a change in DNA sequence. It results from DNA copying mistakes made during cell division, infection by viruses, exposure to chemicals (mutagens), exposure to ionizing radiation etc.

Natality: It is the ratio of the number of births to the size of the population i.e., birth rate.

Photoperiod: It is the day length that is the period of time each day during which a plant receives sunlight.

Pollination: It is the process of transferring pollen grains from the anther of a flower to the stigma of flower on the same or different plant.

Population: A population is the number of living organisms of a species that live together in the same place.

Species population: all individuals of a particular species.

Succulents: These plants are mostly inhabitants of dry areas. They are drought resistant plants in which the leaves, stem or roots have become fleshy to retain water.

Xerophytes: These are the plants adapted to a dry habitat such as desert, salt marsh, saline soil or acid bog.

5.9 SELF ASSESSMENT QUESTION

5.9.1 Multiple choice questions

1. Which is not the characteristic of a population?
   (a). Natality (b). Mortality
   (c). Stratification (d). Age structure
2. Plant species with a genetically similar variety adapted to specific environmental conditions is known as
   (a). Ecotype (b). Population
   (c). Ecosystem (d). Ecotone
3. The group of individuals that belongs to the same species and live in a geographical area is known as
   (a). Community (b). Keystone species
   (c). Guild (d). Population
4. What is the most important factor for the survival of a population?
   (a). Natality (b). Adaptability
   (c). Habitat (d). Inter species activity
5. Exponential growth occurs when there is
   (a). large environmental resistance (b). no environmental resistance
   c. static carrying capacity (d). no biotic potential
6. The average number of individuals living in per unit area or volume is called
   (a). Density (b). Natality
   ©. Mortality (d). Dispersion
7. The regular pattern of distribution of individuals of a population over an area is
   (a). Natality (b). Dispersion
   (c). Density (d). Pyramid
8. Hydrophytes exchange gases through
   (a). Lenticels (b). Stomata
   (c). Epidermis (d). All of these
9. Which plant is completely submerged in water and rooted in the mud?
   (a). *Wolffia* (b). *Polygonum*
   (c). *Hydrilla* (d). *Casuarina*
10. Plants growing on sand are known as
   (a). Psammophilous (b). chrysophytes
   (c). Pelophilous (d). Lithophilous

5.9.2 True and False

1. The size of the population is represented by the characteristics called density.

2. Urn shaped structure can be seen in the diminishing population.
3. *Pistia* is a rooted submerged plant.
4. *Lemna* is free floating hydrophytes.
5. The natural place of an organism of a species is known as habitat.
6. Vivipary occurs in *Rhizophora*.
7. Sclerophyllous leaves are found in *Banksia*.
8. In hydrophytes the parenchyma and arenchyma are ill developed.
9. In Nymphea the leaves are modified into spines.
10. Ephemerals are long lived perennial plants.

5.9.3 Fill in the blanks.

1. A population is a ______of individuals of a species.
2. The number of individuals of a species living in an area at the same time is called ______
3. The rate at which the individuals die in a unit time is called ______.
4. The number of individuals of a population increased in unit time is called ______.
5. The relative number of individuals of each age in population is called ______.
6. The maximum number of birth given by the individual (female) under standard conditions of environment is called ______.
7. ______ is an example of rooted hydrophytes with floating leaves.
8. *Rhizophora mucronata is* an example of ______ plant.
9. Plant that grows in saline soil is called ______.
10. *Typha* is an example of ______ plants.

Answer Key:

5.9.1: 1(c); 2(a); 3(d); 4(b); 5(b); 6(a); 7(b); 8(c); 9(c); 10(a)

5.9.2: 1.True; 2.True; 3.False; 4.True; 5.True; 6.True; 7.False; 8.False; 9.False; 10.False.

5.9.3: 1.Group; 2. Density; 3. Mortality; 4. Population growth; 5. Population structure; 6. Potential natality; 7. *Nelumbo;* 8.Mangrove; 9. Halophyte; 10. Marsh.

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5.12 TERMINAL QUESTIONS

5.12.1 Short Answer Type Questions

1. What is population density give example?
2. How do you define population size?
3. Write a short note on population growth.
4. Write a short note on natality and mortality.
5. Write a short note on drought resistance.
6. Write a short note on halophytes.

5.12.2 Long Answer Type

1. What is population? Give an account of various characteristics of population.
2. With suitable examples give a detailed account of different group of hydrophytes.
3. Write a detailed note on ecological adaptations in xerophytes.
4. What are ecotypes? Explain.
5. What are the features of ecological adaptations in halophytes?

UNIT-6- COMMUNITY STRUCTURE AND DEVELOPMENT

Contents:

6.1 OBJECTIVES

After reading this unit students will be able to:

- Understand the community structure.
- Understand the characteristics if community.
- Understand the community classification and concept of climax.
- Understand about ecotone and ecological niches.
- Understand community diversity and its development.

6.2 INTRODUCTION

Dear learners in the previous unit you have learnt about the population of a species which refers to a group of individuals of a species that lives in a specific geographical area. In the present unit we will study about the community and its attributes. In ecology, a community, also known as biocoenosis, biotic community, biological community or ecological community is a group or association of populations of two or more different species occupying the same geographical area at the same time. Thus, Populations of species interact with one another and form biological communities. The term community refers to groups of organisms in a certain area or time, such as the fish community of a lake.

Robert Whittaker in 1975 proposed one of the early formal definitions of community ecology. He defined it as an aggregation of living organisms that interact and form a community with a distinct structure and species composition. It is critical to understand how a community functions in order to promote and preserve biodiversity.
Community ecology or synecology is the study of interactions between many species in relation to the environment. These interactions occur between coexisting populations on many spatial and temporal scales like structure, distribution, abundance and demography. The interaction between populations as specified by distinct genotypic and phenotypic features is the core focus of community ecology.

Abiotic factors that influence species distributions or interactions are also considered in community ecology (e.g. annual temperature or soil pH). Because of differences in yearly precipitation, desert plant communities differ significantly from those found in tropical rainforests. Habitat disruption, such as the introduction of invasive species, can also have an impact on community structure.

The significance and value of the community notion in ecology is up for dispute on a deeper level. Local processes creating (or destructing) an assemblage of species, such as how climate change is anticipated to alter the make-up of grass ecosystems, have historically been understood on a fine scale. This local community focus has recently been criticised. Using evolutionary taxonomy and biogeography, Ricklefs and Schluter (1993) argues that it is more appropriate to think of communities on a regional scale, where certain species or clades evolve while others become extinct. Many traits of communities are not seen in populations. The community is the bigger unit of population. The sizes, habitats, and number of populations in communities vary.

Small communities rely on large communities and are heavily impacted by them, whereas large communities are self-sufficient and independent. Ecologists divide communities into groups based on a variety of factors. Depending on the development, size, and composition of the plants and organisms, the communities can be classified as forests, grasslands, logs, deserts, and so on. Communities that are increasing as a result of succession or changes are known as seral communities, while communities that remain stable are called climax communities.

The study of how communities of organisms are structured and operate is known as community ecology. Various populations of species interact with one another to create biological communities. Every population of a species that interacts and coexists in a given space or environment is considered as a community of organisms. Community ecology also examines the interaction between the members of a community to their environment. The community is usually categorized according to the habitat or biome. A forest, a pond and a desert are the examples of natural communities. A community has its own structure, development history and behaviours.

6.3 SIZE AND STRUCTURE OF BIOTIC COMMUNITY

The biotic community may be small or large. Some communities like ponds, tide flats, rocky plateaus, rivers, meadows and many others occupy small areas others like forests, swamps, deserts, grasslands, lakes and many more have an area of hundreds of kilometers. Biotic communities have certain structural characteristics that are frequently used to identify them from other types of communities. The study of plant communities is known as phytosociology.

The structural characteristics of a plant community can be categorized into two groups: analytical and synthetic. The analytical characters are those that can be directly observed in the field. These characters can be expressed and measured in quantitative terms depending on the fact that they can be either quantitative or qualitative. Based on the information gathered for the analytical characters, the synthetic characters were created.

6.3.1 Qualitative characters of community:

The following are the primary qualitative characteristics of plant community:

6.3.1.1. Physiognomy:

The exterior appearance of the plant community or physiognomy can be described in terms of the dominating plants as well as their density, height, colour, and other physical characteristics. It does not place focus on any particular individual or species.

In fact, physiognomy was defined by Cain and Castro (1959) as the shape and organisation of the vegetation or the appearance that comes from the life-form of the dominant plants. According to Daubenmire in 1947, the term ‘life form’ refers to the shape or appearance of an organism regardless of how it was created. The physiognomy of different communities is described by names like woods, grasslands, savannahs, scrub and bog among others.

6.3.1.2. Growth-forms and life-forms:

The growth forms and living forms define the physical structure of a community. The structure and growth forms depict the difference between various terrestrial communities. The vegetation of the community can be categorised based on its growth forms. Short bushes, shrubs or tall trees, woody or herbaceous plants, deciduous or evergreen plants may all be found in the same plant community. Needle-leafed evergreens, sclerophylls, thorn trees, broad-leafed evergreen or deciduous trees, shrubs, grasses, mosses, ferns and lichens are all sub-categories of herbs, shrubs, and trees.

Raunkiaer (1905) classified the plants on the basis of life forms. He defined life forms based on perennating tissue above ground or simply plant height. He proposed that all species in a given area are classified into six major life forms: epiphytes, phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes. The communities are dominated by phanerophytes where the climates are warm whereas cold climates are associated with communities dominated by hemicryptophytes and chamaephytes.

Numerous efforts have been made by plant ecologists to categorise plants based on their form (i.e., growth form and life form), habitat or other traits. Pound and Clements (1900) divided plants into three categories based on their growth forms: shrubs, trees, and herbs. These categories were then further divided into needle leaf evergreens, broad leaf evergreens, evergreen sclerophyll (small, tough, evergreen leaves, like those found in greasewood), broadleaf deciduous, thorn trees and shrubs, dwarf shrubs, ferns, grasses, forbs and liverworts.

The life form spectrum that shows the plant's adaptations to the environment, particularly climates can be created by categorising all the species within a community into one of the five classes and expressing the ratio between them as a percentage. For example, Warm temperatures would be characterised by communities with a high percentage of perennating tissue much above ground (phanerophytes). Deserts would have communities where therophytes and chamaephytes make up the majority of the plants, as well as communities where these two plant types predominate. Here is a short description of those five classes of plants.

1. Phanerophytes (Gr., phaeros, visible). Perennial buds are subjected to various climatic conditions while being flown high in the air. Trees and shrubs exceed 25 cm; they are common in humid, warm climates. Subtypes of phanerophytes include woody lianas, epiphytes and stem succulents (such as cacti and euphorbias).
2. Chamaephvtes (Gr., charrai, on the ground). Approximately 25 cm above the ground, perennial shoots or buds can be found. Snow cover and fallen leaves provide protection for buds. Examples are *Thymus, Silene, Trifolium, Rhanmus*, *Druba*, *Grewia* etc. that grow in cool, dry climates.
3. Hemicryptophytes (Gr., hemisus , half ., krypos, hidden). Many plants, such as grasses and herbs like *Thalictrum, Fragonia, Primula*, etc., have perennial buds at the surface of the earth where they are sheltered by soil. These plants are characterised by rosette leaves and are typical of cold, moist climates.
4. Cryptophytes (Gr., krypos, hidden). Perennial buds buried in the ground on a bulb and rhizome to be protected from freezing and drying. This category consists of plants with buds that remain submerged in water, such as hydrophytes, helophytes (marsh plants with rhizomes under the soil), and geophytes (terrestrial plants with underground rhizomes, tubers), etc.
5. Therophytes (Gr., thews, summer). Annuals that go through their entire life cycle from seed to seed in a single season. Deserts and grasslands are known for having plants that can withstand unfavourable conditions as seeds.

6.3.1.3. Phenology, periodicity or aspection:

The form of a plant changes with age, therefore the same species at various phases in its life cycle represents a community with a distinct structure. Periodicity describes the recurrent seasonal occurrence of different processes and their demonstrations (as formation of leaves, flowering, seed shedding).

Aspection is the term used to describe how the community looks overall during various seasons such as the rainy season, summer, spring, or winter. According to Lieth (1970, 1974), phenology is the skill of studying animal and plant life cycles or activities in relation to their temporal recurrence throughout the year. Phenophase refers to each stage of the life cycle. Diagrams and symbols have been used in a variety of ways to describe the phenophases.

6.3.1.4. Stratification:

The biotic community has an unequal distribution of organisms. Both the vertical and horizontal planes can be used to examine spatial distribution. Some additionally include the temporary stratification among these stratifications.

1 .Vertical stratification:

Stratification is the term for vertical shift in a pattern of community structure. In a biotic community, stratification is the vertical layering of organisms or environmental factors. The size, branching and leaves of plants, which in turn influence and are influenced by the vertical gradient of light are a major factor in how a community is stratified. Numerous animal life forms are physically adapted to live in the vertical structure of the plant community. Many communities have been found to have vertical stratification and the following are some clear examples of this phenomenon.

(i). Forest community: In a well established forest ecosystem there are multiple layers of vegetation. These are the over story stratum, also known as the canopy, the understory stratum, the transgressive stratum, or the shrub, the ground layer, the seedling stratum, also known as the herb and the forest floor, The forest floor is also known as the subterranean stratum which is the lowest subdivision. Subterranean materials include plant roots, trash and living things like soil bacteria, protozoa, fungi etc. The Herb or seedling substratum is located above the soil and contains the upper parts of growth forms. The subterranean (forest floor) strata made up the majority of the vertical stratification in the forest community Along with litters, fungi, bacteria, etc., herbaceous plants, shrubs and forest strata, the higher portions of growth form (canopy). An additional stratum is emergent trees which are found in tropical rain forests. These plants rise above the canopy of the forest (fig. 6.1).

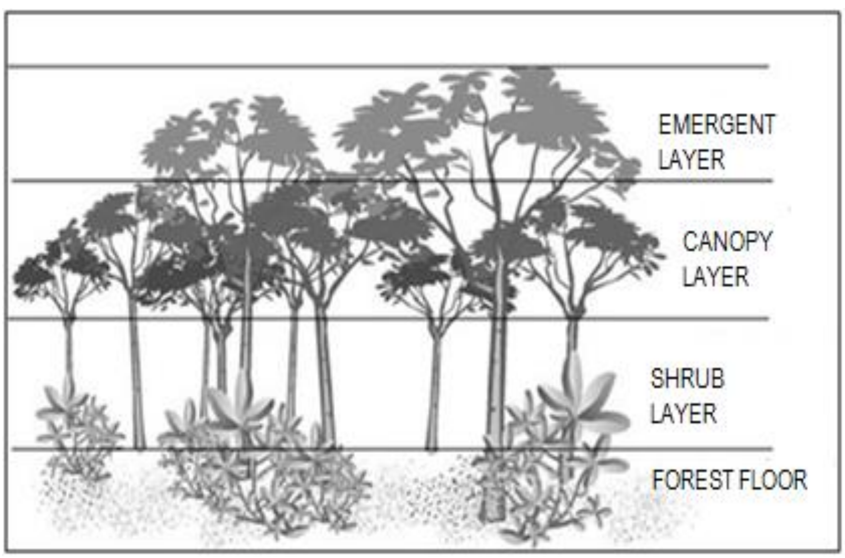

Figure 6.1: Structure of a rainforest

The roots of plants may be more widely dispersed or more deeply penetrating. Because the roots are spaced apart, the plants may extract the nutrients and water they need from various soil depths without interfering with one another. The canopy, which is the main location for energy fixation, has a significant impact on the rest of the forest. The understory tree strata and the shrub will be well developed if it is somewhat open (a forest in a dry environment) and receives a lot of sunlight. The shrub, understory trees and even the herbaceous layers will not develop well in a closed canopy (a rain forest). Additionally, the forest trees may benefit from reaching the canopy because the area receives plenty of sunlight, which supports photosynthesis. However, the tree must expend a significant amount of photosynthesis energy to grow woody tissue in its stem and branches in order to support the foliage of the canopy.

The low light levels that the forest herbs must endure may seem to be a disadvantage, yet the herbs do not need to invest their little photosynthetic profit in woody supporting tissue. In order to adapt to the gradient of light intensity, forests contain a gradient of growth-forms, including higher and lower trees, upper and lower shrubs, upper and lower herbs, and soil-surface mosses.

Along the gradient, growth-form designs shift from one extreme that is the upper tree with foliage in full sunlight, massive supporting stem and branch structure and a root system with a mass smaller than the above ground structure to herbs with adaptations at the other extreme (photosynthesis at low levels of light intensity, little investment in above ground supporting structure and accumulation of reserve food in a root system that is more massive than the above-ground structure.

Tall shrubs, understory trees and young trees constitute the understory strata; some of these are the same species as those in the crown, while others are of different species. Others eventually reach the canopy after some of the elder trees die or are cut down; species that cannot endure shade and competition will perish.

Different forests have different shrub layers. The type of the herb layer depends on the soil moisture levels, density, over story, slope positioning and slope characteristics, all of which change from location to location throughout the forest. Small liverworts, prostate plants and mosses on the ground may form another layer of vegetation below the herbs. On the tree trunk and branches, lichens and epiphytes can be found growing in various strata. The decomposition of the forest litter and the release of nutrients into the nutrient cycle occur at the site of the topmost layer, the forest floor.

Additionally, the number and development of the forest's layers have a direct impact on the type of life that exists there. For instance, stratification is more prevalent in rain forests with greater species diversity. In contrast, all the plants in an agricultural field that has been cleared of weeds from the same stratum. However, if particular layers are lacking, the animals that they typically protect and support are also absent. Consequently, a well-maintained forest supports a wide variety of living beings.

(ii). Grassland Community: In grassland community, only three strata: the herbaceous layer, the ground or mulch layer and the root layer can be easily distinguished. In comparison to other ecosystems, grasslands have the most prominent root layer, which is home to a variety of invertebrates including earthworms, spiders, insects and other invertebrates as well as soil bacteria, fungus, protozoans and nematodes.

(iii). Aquatic Communities: Strata in aquatic ecosystems including ponds, lakes, and oceans are determined by light penetration, temperature profiles and oxygen profiles. In summers, well stratified lakes have a layer of freely flowing surface water, the Epilimnion; the second layer is Metalimnion, represented by a thermocline (i.e., a very steep and rapid decline in temperature); the third layer is hypolimnion, which is a deep, cold layer of dense water about 4°C, with less oxygen; and a layer of bottom mud (fig. 6.2).

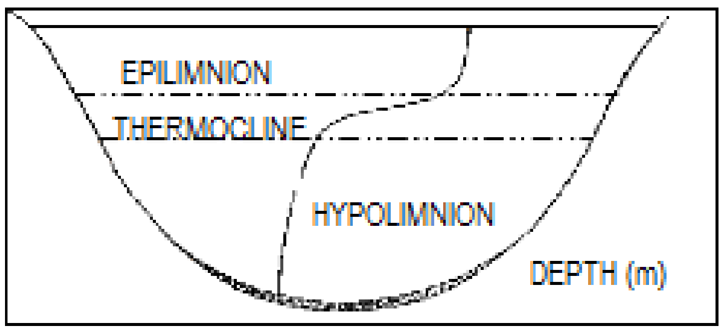

Figure 6.2: Thermal Stratification of a lake

On the basis of light penetration, two additional structural layers are identified: a lower layer, where decomposition is most active and an upper layer roughly comparable to the Epilimnion, where phytoplankton predominates and where photosynthesis occurs. Hypolimnion and bottom mud are basically equivalent to the lowest layer.

Biological or tropical structures are common to all communities, whether they are terrestrial or aquatic. They have an autotrophic layer that is concentrated in the areas with the highest light and that stores solar energy while producing food from non-organic materials. This layer is concentrated in the canopy of forests, the herbaceous layer of grasslands and the upper layer of water in lakes and seas (i.e., in phytoplanktons). A heterotrophic layer exists inside the biotic communities as well, which uses the food that autotrophs have stored, transmits energy, and circulates matter through herbivores, predation in the broadest sense and decomposition.

2. Horizontal stratification:

Horizontal stratification or dispersion relates to the distribution of organisms, principally plants, in the horizontal space (i.e., on the ground) or across the canopy. Like vertical stratification, it can influence the presence and absence of certain forms of animal life. The following three distribution patterns are observed for the organisms:

(i) Random distribution, in which no organism appears to be put with regard to another organism's location and there is no interaction between individuals on the positive or negative side, (ii) Clumped or contagions dispersion occurs when a number of people congregate in various locations throughout the area. In contrast to a helter-skelter arrangement, ants are organised into colonies, fish into schools, and people into cities. (iii) Regular or uniform distribution is caused by the adverse effects of one organism on another; each organism is spaced at specific intervals from others in the same species.

The creosote bush (*Larrea* spp.), which is fairly uniformly spaced, and some breeding birds that build and defend territories from other individuals, which parcel out the space in a predictable manner, are examples of desert plants with this distribution pattern. Most of the plants are clumped to varied degrees. The following factors affect the horizontal spread of plants and some animals:

(i). **Seed distribution and vegetative reproduction:** Plants with airborne seeds may be extensively dispersed, but plants with heavy seeds or with noticeable runners or rhizomes for vegetative reproduction will cluster close to the parent plant. The clustering of some sessile animals, which release larvae that settle close to the reproducing adult, is also explained by a similar dispersal process.

(ii). **Environmental variations:** Herbaceous plants in the forest may cluster in areas where pools of light penetrate the canopy and reach the forest floor. Other variations in the environment might also exist. Since the area is not uniform, certain places are better suited than others for growth, reproduction and survival.

The mosaic design of the environment causes organisms to be distributed unevenly within it. Clusters of organisms can form when they are individually influenced by the same environment rather than because there is an attraction between them. Zonation is a prominent type of horizontal stratification that is primarily brought on by variations in climatic or edaphic circumstances that slow down or prevent rooted vegetation. Around ponds and bogs, this form of stratification is particularly noticeable.

(iii). **Species interrelations:** Interactions between species can be either harmful or beneficial. Positive interactions cause individuals to cluster, whereas negative interactions cause them to be evenly spaced apart.

3. Temporal stratification:

In addition to the spatial stratification of communities, there is also a temporal stratification of communities. Environmental elements like light, temperature and other environmental parameters typically follow daily and yearly cycles in biotic communities surroundings. There are also intricate rhythms created by the rise and fall of tides in some towns, especially those that are near coastal areas. Biotic communities generally experience functional rhythms as a response to environmental cycles.

In many water bodies, the plankton population varies quickly, with different species replacing one another over the course of days and weeks. Throughout the year, a variety of significant species may be found to be the dominant plankton species. Thus, the winter plankton in freshwater lakes may be dominated by species of diatoms and other yellow green algae. These are replaced by desmids and other green algae when the water warms in the later spring and early summer.

When temperatures are at their highest during the summer, blue green algae may dominate or codominate with green algae; as the weather cools, the green and yellow green algae regain supremacy. Every species has a dormant stage during which it can endure the seasons that are unfavourable to its activity. Every species has a specific location in the yearly pattern, determined by how it reacts to temperature changes and other environmental conditions. The plankton community exhibits a difference in timing, with several groups of species occurring at various points throughout the seasonal cycle. The total number of plankton species throughout the year is substantially higher than the amount that is present at any given time.

In forests, seasonal and daily differentiation (stratification) also takes place. A certain type of bug is active during the day, another type is active at night, and a third type may be active during the twilight hours between dawn and night. Flycatchers, warblers and other insectivorous birds are active throughout the day in terrestrial communities, followed by bats at night and nighthawks after dusk. The emergence of various plant species in blossom as well as various insect species visiting these flowers serve as indicators of the progress of the seasons. Spring beauties, dogtooth violets and other herbs grow their foliage and bloom before the trees are in leaf in deciduous forests.

6.3.1.5. Species abundance and species diversity:

The community is made up of a variety of species; most of which are rare and only few are abundant. Species abundance or species richness in the community shows how widely the species is distributed there. Despite being a qualitative estimate, it is related to density.

While a large number of individuals in an area will not be considered abundant, the same number of individuals dispersed around the community may appear to be abundant. An arbitrary scale is used to express the species richness or abundance, which is expressed in five degrees as follows: On an arbitrary scale, the species richness or abundance is stated in five degrees as follows: There are five different types of rarity: (i) rare (r), (ii) occasional (o) or sparse, (iii) frequent (f) or not numerous, (iv) abundant (a) or numerous, and (v) very abundant (va) or very numerous.

Species richness and species evenness are two factors that are helpful in determining the species diversity of a community. A community with a small number of individuals of various species will have a higher level of diversity than one with a similar number of individuals from a smaller number of species.

For the purposes of comparison, the Shannon Wiener index is employed to measure species diversity. This index calculates diversity using the following equation:

$$H' = -\sum_{\infty}^{s} (p_i)\,[\ln(p_i)]$$

Where, H = the diversity of species
s = the number of species
p_i = proportion of individuals of the total sample belonging to the species.

This index considers both the total number of species and their relative abundance.

Species diversity is useful in evaluating global ecosystems because it allows for comparison of similar communities within a particular area. A latitudinal gradient would show a decline in plant and animal populations as one left the tropics and moved north through the temperate zone to the arctic zone.

Fisher (1960), discovered that nesting bird species approach 1395 in Colombia, decline to 1100 in Panama, 143 in Florida, 118 in Newfoundland, and 56 in Greenland. The same pattern can be observed in fish, lizards, trees and mammals (Simpson, 1964; Pinaka, 1967; Monk, 1967). (Lowe Mc Connell, 1969). The diversity of species increases from cold to warm climates. However, the diversity of species in the oceans rises from the continental shelf, where there is plenty of food but a more unstable environment, to the deep, cold water, where there is less food but a more stable environment.

Additionally, peninsulas have fewer species than adjacent continental areas and mountains generally support more species than flatlands. Compared to large islands and those closer to continents, small or remote islands have fewer species (Smith, 1977).

The following theories have been put forward to explain why one island should have more species than another or why the tropics should harbour more species than the temperate zone:

1. **Time theory:** Species diversity and evolutionary time have been linked by Fischer (1960) and Simpson (1964). It has been discovered that older societies have more diversity than younger ones. Tropical communities develop and diversify more quickly than temperate or arctic groups, in part because the climate is more stable and natural disasters are less common. This view is supported by certain paleontological evidences.

2. **Spatial heterogenity theory:** According to Simpson (1964), the more complex and heterogeneous the physical environment, the more complex and varied its flora and fauna would be. There will be more variety of species present in a community if there is a greater variance in topographic relief, a more complex vertical structure of the vegetation, and a greater variety of microhabitats. A community will have more bird species present if its vertical stratification is more complicated (MacArthur, 1972).
3. **Climatic stability theory:** According to Fischer (1960) theory, there would be more species present in a more stable environment. The tropics have probably been the most stable and largely free from harsh climatic circumstances that could have an impact on a population throughout evolutionary time. Under tropical environments, competition between individuals and members of different species has a significant impact on natural selection.
4. **Productivity theory:** According to Connell and Orias (1964), the quantity of energy moving through the food web affects how diverse a group is. The capacity of ecosystem and the level of environmental stability both have an impact on the rate of energy flow.
5. **Competition theory:** Dobzhansky (1951) and Williams (1964) claimed that biological competition has a more significant role in the evolution of species and the specialisation of niches in tropical regions with milder climates than high physical stress environments like the Arctic.
6. **Predation theory:** Paine (1966) suggested that predator populations are higher in more diversified communities like the tropics, where they control the abundance of prey species considerably reducing competition among prey species.
7. **Stability-time hypotheses:** According to Sanders (1968), there are two distinct types of communities: those that are physically regulated and those that are biologically governed. A stress gradient results in a steady decline in species numbers. The communities that are predominately biologically adapted have the greatest diversity.

6.3.1.6 Sociability:

The term "sociability" shows how organisms relate to one another and denotes how closely organisms are knit together within a community. Braun Blanquet (1932) identified the five arbitrary forms of sociability as follows: S_1, plants that grow singly, S_2 plants growing in small groups, S_3 plants found in small patches, S_4 plants growing in big patches, and S_5 plants growing as large populations. Whitford (1949) used the following equation to explain the sociability of plants in quantitative terms:

$$\text{Sociability} = \text{Density} \times 100/\text{Frequency}$$

6.3.1.7 Vitality:

The ability of a plant species to grow normally and reproduce, which aids in sustaining its place in the community is referred to as vitality.

The following five kinds of vitality have frequently been recognised by plant ecologists: Plants classified as V1 are those that germinate but do not live long enough to reproduce; V2 are those that persist after germination but are unable to do so; V3 are those that reproduce only vegetatively; V4 are those that reproduce sexually but do so rather poorly; and V5 are those that reproduce very well sexually.

6.3.1.8 Disseminule type:

In recent years, the type of dispersion organ or disseminule of a plant species has also been employed as a community feature. The following plant disseminule kinds have been recognised by Dansereau and Lems (1957) (Table 6.1):

Table 6.1. Disseminule types of plants:

Disseminule type according to agent	**Disseminule type according to morphology**	**Examples**
Autochore (Self dispersed)	Expulsive Stoloniferous	*Vinca, Ruellia* *Fragaria*
Anemochore (wind dispersed)	Pulmose Minute Winged Tumbleweed Catapult	*Tridax, Taraxacum* *Orchids, ferns* *Tilia, Pinus* *Physalis* *Papaver*
Zoochore (animal dispersed)	Fleshy Nutlike Adhesive	*Rubus* *Ficus, Psidium* *Xanthium, Cenchrus*
Hydrochore (water dispersed)	Buoyant Splash cup	*Eichhornia, Hydrilla* *Marchantia*

6.3.2 Quantitative Characters of Community

6.3.2.1. Density:

The strength of the species in the community is measured by density. Plants grow at various distances from one another. The density of a unit area can be estimated by the number of plants growing there.

A community's structure is influenced by changes in the species density within it through time and space. Density reveals how competitive an area is. There is more competition amongst the individuals of the species if the density is higher.

Density is calculated as the number of organism per square meter and is stated as follows:
Density = Total number of individuals of the species in all the sampling units / Total number of sampling units studied

6.3.2.2. Frequency

Frequency is expressed as the percentage occurrence of individuals of a species in a number of samples. It denotes the homogeneity of the dispersion of the individuals of a species within the community. It is measured as follows:

$$\text{Frequency (\%)} = \frac{\text{Number of sampling units in which the species occurred}}{\text{Total number of sampling units analyzed}} \times 100$$

As a result, the size of the sampling unit affects the frequency estimate. Widely spread individual frequency is underestimated by extremely tiny sampling units, whereas frequency is overestimated by big sampling units.

The percentage frequency of the different species that were observed is then calculated, and these are then divided into Raunkiaer's (1934) five frequency classes-A, B, C, D, and E according to their percentage frequency:

A =	0 -20	per cent
B =	21 -40	percent
C =	41 -60	per cent
D =	61 -80	per cent
E =	81-100	per cent

According to Raunkiaer’s “law of frequency,” the percentage of species falling under each of the five classes of frequency will be in the following order: A>B>C>D>E. He also suggested a normal frequency diagram with the percent values A=53, B=14, C=9, D=8 and E=16 for the various frequency classes. The diversity of the species has a significant impact on the frequency distribution.

6.3.2.3. Species dominance

Physical or abiotic factors like substrate, lack of moisture and wave action, as well as some biological mechanisms, regulate the nature of biotic communities. Communities that are biologically managed are frequently influenced by a single species or by a number of species that alter the environment. These species are known as dominants; for instance, huge trees are dominant in forest communities, whereas shrubs and plants are typically subdominant.

Determining a dominant species or describing one is difficult. A community's dominants may be the most numerous, have the highest biomass, occupy the most space, contribute the most to the flow of energy or the cycling of nutrients, or in some other way exert power or influence over the other members of the community.

Consequently, trees predominate in a forest ecosystem. They reduce light intensity, raise relative humidity, block precipitation, utilize the majority of soil moisture and nutrients, lower wind speeds, and provide animals with food and shelter.
Grasses in grassland communities, sedges, rushes, and cattails in marsh communities, sagebrush in the Great Basin's arid habitat, mussels and barnacles on a rocky shoreline, and so on all play comparable but less obvious roles.

Even though some ecologists have stated that numerical superiority alone is insufficient, dominant organism roles are not always allocated to those that are numerically abundant. For instance, a plant species may be extensively dispersed in the region but have little impact on the community as a whole.

Although there may be a numerical advantage for little or understory trees in the forest, the larger trees tend to dominate the community. The dominating species in such a setting are those with the highest biomass or those that occupy the majority of the canopy space and so control the dispersion of light. Ecologists use biomass or basal area to quantify such dominants (i.e., cover).

(i). **Community mass:** Biomass, the weight of live or dead organic stuff, is referred to as the community mass. The biomass of terrestrial ecosystems is inversely proportional to the mass and complexity of the strata. Dense tropical forests growing on river flood plains are where biomass is found to be at its highest.

These forests could have a dry weight per hectare of up to 1000 metric tons (Vyas and Golley, 1975). The biomass of a 60-year-old Indian forest close to Varanasi was calculated by Misra (1972) to be 239 metric tons per hectare. Grassland at Varanasi had a biomass density of up to 33 metric tons per hectare. A drop in temperature, moisture or both as well as an increase in biotic disturbance causes biomass to fall below the level that is ideal for the community.

Animal biomass in terrestrial communities typically makes up less than 10% of plant biomass. However, in aquatic ecosystems where the production takes the form of algae or when the animals eat imported organic materials, the biomass of the plants may be substantially smaller than that of the animals.

(ii). **The canopy or basal cover**: Cover, also known as basal cover or canopy cover, refers to the space a plant occupies. The land area that the cross section of a stem occupies is known as the basal cover. The total area of land covered by a plant's canopy is known as the canopy cover. In actuality, the basal area can only make up a small portion of the entire land area in a community, but due to overlapping canopies, the canopy cover of the dominant species can reach several times the total area.

Furthermore, even if the dominating organism is relatively rare, it still can influence the community's makeup through its activity. For instance, the predatory starfish Piaster feeds on several species that are related to it and lessens competition between them, allowing a variety of prey species to coexist (Payne, 1966).

Several prey species vanish and one takes over if the predator is eliminated. Therefore, the predator must be viewed as the dominant because it effectively controls the community's structure.

In terms of energy flow and nutrient cycling, the dominant species may not even be the most crucial species in the community. In order to maintain their dominance, dominant species take up niches that could otherwise be inhabited by other species in the community.

For instance, when the American chestnut was eradicated by blight from an oak-chestnut forest, other oaks and hickories came in to take its place. Even though dominant species frequently influence populations at lower trophic levels in the community, dominance generally belongs to species that are found at that level of the trophic pyramid.

To become dominant, a species or small group of species must relate to the entire population of species, all of which have the same ecological needs. Because they can take advantage of the variety of environmental requirements better than other species in the same tropic level, one or more species become dominants.

The subdominant species can exist because they can occupy a niche or specific areas of it that the dominant species cannot. Thus, dominant organisms are capable of using a variety of physiological tolerances whereas subdominant species are more specialised in their environmental requirements and have fewer physiological tolerances.

Finally the degree of dominance displayed by any one species seems to be partially influenced by the community's location along a physical or chemical gradient. For instance, species A and B might predominate at a specific location along a moisture gradient. Species B may become subdominant as the gradient grows drier, with species C replacing it as the dominant species in the community. The structure of the community may also change as a result of nutrient enrichment.

When excessive sewage is discharged into lakes, a variety of nutrient-sparing diatoms are replaced by a small number of blue green algae that may take advantage of a nutrient rich environment (Smith, 1977).

Keystone species: These are dominant species (plants or animals) that, in proportion to their abundance, have a major impact on the composition and operation of a community. Strong interrelations between these keystone species and other species control the variety and abundance of other species in the community. Therefore, if we remove keystone species, the community will significantly shift from its original composition and function.

A classic example of a keystone species is the starfish (*Pisaster ochraceus)*. For mussels, sea urchins, and a variety of other shellfish, it is the only naturally occurring predator. Therefore, if we remove starfish, the mussel or urchin population will increase uncontrollably and alter the community.

The prey-predator system, which includes microscopic predators like the weevil (*Euhrychiopsis lecontei*), which consumes herbaceous plants, is another example. The predatory *E. lecontei* (weevil) prevents the invasive Eurasian water milfoil (*Myriophyllum spicatum*) from eradicating the dominant plant species in an inhabited region by eating on it. There must be fewer predators given that there are fewer prey species (Eurasian water milfoil). The dominant species of the community will be eliminated if the predator is removed because the prey will vastly outnumber them. The community's characteristics will consequently shift without its real dominant species. This example indicates that dominant species directly control community character, whereas keystone species influence community character indirectly.

Several methods are employed to establish ecological dominance. Relative species abundance refers to the distribution of a species within an ecosystem when a considerable number of individuals of that species are discovered in a sample taken from a vast area.

a) **Relative abundance:** Species abundance is the number of individuals per species, while relative abundance is the consistency of the distribution of individuals among species within a community. The number of species in two communities may be same, but their relative abundances may be different. For example, each community may comprise five species and 300 individuals. In one community, all species are equally abundant (e.g., 60 individuals of each species), whereas in the second community, one species considerably outnumbers the other five species.
b) **Relative dominance:** Measurements of dominance among species of the same size include occupying the entire community's area as a species.
c) **Relative frequency:** is the frequency of one species or life form as a percentage of total plant frequency. The sum of these three measurements gives each species a significant value. These factors help the species to attain top position. The index species is a species with a high level of significance value.
d) **Sporadically/Locally abundant:** The frequency of species occurrence in all the samples examined is known as incidence which is related to the abundance. If the frequency or

incidence is low but the abundance of species is high in the sample, the species is said to be sporadically abundant.

There are various methods for calculating relative abundance of the community such as Track count, spotlight count, monitoring point pressure, road kill counts and plant cover for plant species etc.

$$\text{Relative abundance of species} = \frac{\text{No.of species from one sampling unit}}{\text{Total no.of species of all sampling units}}$$

6.4 CLASSIFICATION OF COMMUNITY

The current, well-developed perspective sees a community as a continuum, yet the flora and fauna of any vast area is so complicated that it needs to be divided into subdivisions. To be researched, documented, or compared to similar community stands in other habitats, the aggregation of organisms in any given site or habitat must really be seen as a unit. Despite the fact that the communities in a region frequently cannot be divided into distinct units, some sort of classification system is required to bring order to the study of communities. The most prevalent classification schemes are those that take into account physiognomy, habitat, floristic traits including species composition and dominance, as well as community dynamics.

6.4.1 Physigonmic classification

When surveying large areas and using general appearance to further divide major types into their component communities, physiognomy is a very useful way for naming and designating communities. Because animal distribution largely depends on vegetation structure rather than species composition, classifying organisms according to their physical characteristics will relate both the animals and the vegetation of a region.

Communities that fall under this classification are typically named after the dominating form of life, which is typically a plant. Examples of such communities include coniferous or deciduous forests, sagebrush, short-grass prairies, and tundra.

These early attempts at physiognomyic classification by various plant ecologists might be summed up as follows:

Warming (1909) distinguished between autotrophs and heterotrophs. The aerial autotrophs were divided into atmophytes, ombrophytes (plants that grow in areas with abundant rainfall), psychrophytes (plants that grow in cold soils), halophytes (plants that grow in soils with high salt contents), psammophytes (plants that grow in sandy soils), agrophytes (plants that naturally occur in crop fields), oxylophytes (plant of acidicasoils) etc.

Raunkiaer (1934) categorised plants based on how different living forms adapted to their local climates. He assigned around 1000 different plant species from around the world to their respective life forms. Raunkiaer's system of classification has been used by certain plant ecologists to categorise Indian populations. The classification of Iversen (1936) was based on the water requirements of plants. The classes of terriphytes (land plants), telmatophytes (aerial plants with arenchyma), amphiphytes (marsh plants), and limnophytes (water plants) were among those he recognised. The physiogmonic categorization system also incorporates symbolic classification, in which several species traits—such as life form, plant size, leaf shape and function, texture of the leaves, etc. are symbolically represented. Kuchler (1967) used a variety of alphabets, while Dansereau (1957) used visual symbols.

6.4.2 Habitat Classification

Communities are categorised and given names using physiography in places where the habitat is clearly defined. Sand dunes, cliffs, tidal mud flats, lakes, ponds, and streams are a few examples.

6.4.3 Floristic Classification

The floristic classification comprises numerous concepts, including frequency, dominance, stability, presence, and fidelity, as well as a thorough examination of individual community.
Communities were divided up into sociations by the Scandinavian ecologist Du Rietz (1921), who characterised them as perennial plant communities with essentially uniform species compositions and at least a few dominant species in each stratum. If a multilayered community is only dominated by one species in the upper stratum, another floristic unit consociation was suggested for the community. Therefore, the consociation can be described as a class made up of distinct concrete sociations whose higher strata are dominated by the same species.

European ecologists group communities into classes, orders, alliances and associations. **Association** is defined as a community of definite floristic composition, uniform physiognomy and occurring in uniform habitat conditions. The associations are recognized on the basis of common dominant species in several stands and they are used in naming the association for example *Anogeissus Boswellia* association, *Shorea- Terminalia* association or *Balanus- Mylitus* association. The floristic system of community classification works much better with plants alone than animals or with both.

The stands are viewed as a continuum, which changes the floristic classification system. The community complex of a major physiognomy is separated into five parts, wet, wet mesic, mesic, dry mesic, and dry, according to species composition and connected with an environmental gradient (Curtis 1959). For instance, Wisconsin's deciduous forest has been split into northern forest, southern and northern hardwoods, and Wisconsin's deciduous forest. Using a moisture gradient, these are further segregated. The dry southern hardwoods include brown, black, or white oak as their dominating species, while the dry mesic has red oak or basswood, sugar maple, and beech. The wet mesic has silver maple, elm, and ash, and the wet woods have willow or cottonwood. Such a system acknowledges the effects of habitat on community structure.

6.4.4 Dynamic System

By placing a strong emphasis on community dynamics, Clements (1928) transformed the floristic system. He referred to the emergence of climax vegetation in a location with a macroclimate (whenever the vegetation reaches highest development becoming more or less stable for more or less definite period, under the existing climate, it is called formation). Each formation was separated into a few associations, which were thought of as discrete climax communities with a few dominant species. The two or three main species each have their own relationship. The association was further classified into the following categories in a hierarchical order:

1. **Consociation.** Unit containing a single dominating species. Consocies are the developing or seral communities inside a climax consociation.
2. **Faciation.** Within the same general climate, an association emerged under several microclimatic circumstances. It has two or more dominating species and is distinguished by a particular temperature, precipitation, and evaporation pattern. As a result, the seral communities are referred to as facies.
3. **Lociation.** This is a limited variation of an association that differs from it in the makeup of some major subdominant and chief secondary species; seral communities are thus referred to as locies.
4. **Society.** A group that includes one or more subdominants. The socies are the seral communities.

6.5 CONCEPT OF CLIMAX

The climax community is final, terminal and self-perpetuating community in succession, as it is in more or less equilibrium with itself and its environment. It represents a steady state of species composition, community structure and energy flow. According to traditional ecological theory, succession comes to an end when a species reaches equilibrium or a stable state with its biotic and abiotic surroundings. The community is self-replicating and stable at this stage. It will last forever unless there are significant disruptions. The climax is the point at which a series ends.

6.5.1 Characteristic of climax

The vegetation is resistant to environmental conditions. It has a large variety of species, well-drained spatial habitats, and intricate food webs. Equilibrium exists in the climax ecosystem. There is a balance between total respiration and gross primary production, between the energy from sunlight and the energy produced during decomposition and between the intake of nutrients from the soil and the return of nutrients through litter fall. The individuals in the climax stage are replaced by the individuals of the same species. As a result, the species composition remains stable. It is an indicator of the local climatic conditions. The growth or life forms reveal the climatic type. Theories relating to three schools of thought that describe the climax ideas are as follows:

1. **Monoclimax or Climatic Climax Theory:** This theory, was introduced by Clements in 1916, he acknowledged only one climax whose attributes are completely regulated by climate, or climatic climax. The effects of variations in topography, soil parent material and other aspects are overridden by the processes of succession and environment alteration. A uniform plant community would be present throughout the entire area. Communities that are related to and distinct from the climax are known as subclimax, postclimax, and disclimax.
2. **Polyclimax Theory:** Tansely put forth this hypothesis in 1935. It suggests that the vegetation climax of an area is made up of several vegetation climaxes that are influenced by topography, slope exposure, soil moisture, soil nutrients, fire and animal activity.
3. **Climax pattern theory:** Whittaker (1953) put forth this notion in 1953. The pattern theory governed climax pattern of climaxes addresses a range of reactions by species populations to biotic and abiotic environments. This hypothesis states that the composition, species organization and balance of a climax community are all determined by the ecosystem as a whole. The environment comprises biotic connections between species as well as how they react to moisture, temperature, and nutrients. The potential for flora and wildlife to inhabit the area, the likelihood that seeds and animals will be dispersed, the soils, the climate and any disturbances like fire and wind. As the environment changes, climax vegetation will change in nature. The climax community symbolises a population pattern that changes in accordance with the pattern of the environment. The climatic climax is the most important and widely dispersed community.
4. **Information theory:**Leith (1970), Odum, and Golley have put forth this view. For ecosystem development, succession and climax was taken into account. The diversity of organisms tends to rise together with an increase in the amount of organic matter and biomass sustained by the available energy during autotrophic succession (ecosystem development). As a result, in a climax community, the biomass and energy available also known as the information content increase. In contrast, a heterotrophic succession gradually depletes energy since respiration rates are always higher than production rates. The heterotrophic and autotrophic successions, however, work simultaneously within an ecosystem. The autotrophic organisms take minerals from the soil and atmosphere, while the heterotrophic organisms continue on the return of the nutrients to the soil and atmosphere through the decomposition of complex dead organic matter. Consequently, succession reaches a point, known as the climax stage, at which the energy and nutrients that the plants took in from their environment are again returned to it in a quantity that is more or less comparable through the process of decomposition by heterotrophs.

6.5.2 Types of Climax

Climatic climax: Climatic climax refers to a situation where there is only one climax and the growth of the climax community is governed by the local climate. Take the growth of the maple-beech climax community over the moist soil as an example. Theoretically, a climate climax occurs when the physical characteristics of substrates are not so extreme as to significantly alter the impacts of the local climate.

Edaphic climate: The term edaphic climax refers to an area with many climax communities that have been influenced by regional substrate conditions such as soil moisture, soil nutrients, terrain, slope exposure, fire, and animal activity. When terrain, soil, water, fire and other disturbances prevent the development of a climatic climax, succession ends in edaphic climates.

Catastrophic climax: Climax vegetation is susceptible to a catastrophic occurrence, such as wildfire. For example, Chaparral vegetation is the final type of vegetation in California. The mature vegetation is destroyed by the wildfire and decays. Before the shrub dominance is regained, herbaceous vegetation develops quickly. It is referred to as a catastrophic climax.

Disclimax: Anthropogenic subclimax, also known as a disclimax or disturbance climax, refers to a stable community that is sustained by humans or domesticated animals but is not the climatic or edaphic climax for the particular place. For example, excessive grazing by livestock may result in a desert ecosystem of bushes and cacti, even though the local climate would normally allow grassland to persist.

Preclimax and post climax: In some places, various climax communities grow under similar climatic circumstances. Pre climax is used to describe a community that has lesser life forms than the anticipated climatic climax. A post climax community is one that possesses higher life forms than the anticipated climactic climax. Pre climax strips grow in hotter, less humid environments. Post climax strips, however, grow in places that are cooler and more humid than the general environment.

6.6 ECOTONE

Ecotones are areas along an environmental gradient where there is a sharp transition between two ecological communities, ecosystems or ecological zones (fig. 6.3). Ecotones are found at many spatial sizes and can be either natural or created by humans. They include transitions between broad biomes and ecoregions as well as mountain treelines (e.g., Mediterranean and arid).

Ecological gradients frequently have ecotones along them. These gradients are a result of changes in elevation, climate, soil and many other environmental factors over time and space. Ecotones frequently occur in regions of abrupt climatic change along environmental gradients.

They can be found at a variety of geographical sizes, from small scale ecotones where local vegetation communities and microhabitats overlap to continental scale transitions between major biomes.

They display a variety of boundary types, such as manmade ecotones and natural barriers (such as altitudinal and latitudinal transitions) e.g., forest clear cut edges or urban ecotones. Numerous studies have demonstrated that species richness and abundances tend to increase in ecotonal zones.

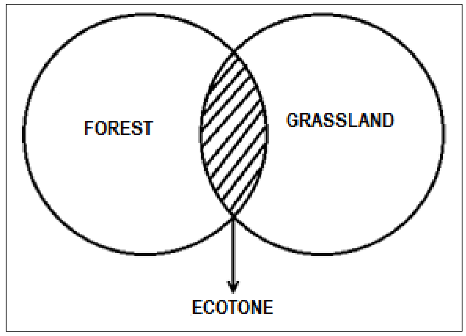

Figure 6.3: Diagrammatic representation of ecotone between forest and grassland community.

Ecotones serve as natural laboratories for the investigation of a variety of evolutionary processes including speciation; the process through which new species arise. According to some studies, ecotones should receive significant investment in conservation because they could act as hubs for biodiversity and speciation.

Formation of Ecotones

An apparent and distinct interface between two populations is established when the physical environment shifts, for example from a forest to undisturbed plain. Furthermore, when distinct local species and species common to both interacting communities are present together, like in mountain ranges, a progressive blended interface occurs. Most wetlands are ecotones, such as the Western European forests.

Type of ecotone

a) Halocline (salinity gradient)
b) Thermocline (temperature gradient)
c) Pycnocline (water density gradient)
d) Chemocline (chemical gradient)

Characteristics of Ecotones

1. An ecotone is indicated by a sudden change in vegetation, such as the colour of the grass.
2. Physiognomy is a crucial ecotone marker for physical differences across plant species.

3. Changes in species are characteristics of an ecotone, where we see some particular organisms on one side of the ecotone boundary and others on the other.
4. Spatial mass effect: The introduction or migration of new plants hides an ecotone because they are unable to establish self-sustaining populations in other ecotones. The ecotone however, exhibits species richness if it persists between two groups.
5. Through careful observation of the abundance of foreign species, an ecotone can indicate the effectiveness with which two communities share their territory as well as the kind of biomes.
6. The best model for studying a diverse ecosystem.
7. Ecotone represents change in dominance.
8. For the species that colonise at the junction known as the edge effect, the ecotone serves as an ecological niche.
9. **Ecoclines:** An ecoline is a zone of physical transition between two biological systems that is related to an ecotone. It shows how physiochemical environmental changes, such as microclimatic shifts or chemical signs like pH, salinity or hydrothermal gradients, signal an ecotone.

Edge effects

In ecology, ecotone exhibit changes in population constituting community structure allowing for greater biodiversity at the boundaries of the merged habitats and this is called as edge effects. When two habitats are separated by wise edge effects called ecotone than they develop their own type of vegetation and environmental conditions.

Types of edge effects

1. **Narrow Edge Effect:** A narrow edge effect is when one habitat abruptly ends where another habitat starts.
2. **Wide Edge effect:** Also known as an ecotone, It occurs when two habitats are significantly separated from one another.
3. **Induced Edge effect:** It refers to structural alterations that are brought about over time, either by human intervention or by natural disruptions (such as fire).
4. **Inherent Edge effect:** The margin between two habitats that is maintained and divided by natural features is known as the inherent edge effect.
5. **The perforated edge effect:** Gaps in the distance between two habitats that support nearby habitats.
6. **Convoluted Edge effect:** This phenomenon results from the nonlinear partitioning of two habitats.

Edge effects on Succession

Edge effects have an influence on succession as vegetation expands. Distinct species colonize the centre or the periphery, resulting in a different distribution of species. The edge also shifts with the change in orientation, taking part in various vegetation patterns. Seasonal and diurnal fluctuations are possible additional structural variables. The population of the communities varies throughout time and space. The basis for community organisation is pattern diversity. The patterns can be vertical stratification or horizontal segregation etc., among others.

6.7 ECOLOGICAL NICHE

The word niche (plural: niches) is derived from the French word nichier, which means ‘to construct a nest’ and the Latin word nidus, which means ‘nest’. The interaction between a species and all the biotic and abiotic elements that have an impact on it is referred to as an ecological niche. The term ‘niche’ was first introduced by Joseph Grinnell in 1917; he saw it as largely being equal to a species habitat. Elton (1927) believed that a niche was equivalent to a species' place in a trophic web. Hutchinson (1957) used the term ‘niche’ to refer to the multidimensional space of resources that a species can access and utilize.

Despite the fact that niches have been defined differently, it is now generally accepted that it has to do with how an organism or a population adapts to competition and the distribution of resources. It specifically describes the position of a population or an organism in an ecosystem. A niche may be influenced by biotic and abiotic factors of an ecosystem. However, the niche of a species in a particular ecosystem will help set the features of its environment as these features will be crucial to its survival.

A habitat in ecology is a location where an organism or a biological community typically lives or occurs. It could be a desert, forest, river or mountain. While a habitat is a physical location, a niche refers to the species interaction with ecosystem elements. The niche of an organism reveals how it functions and survives in its surroundings. As a result, a habitat may have numerous niches and be home to a variety of species at any given moment. The concept of a niche focuses on a single species existing in a habitat and engaging in all biological activities that are influenced by both biotic and abiotic influences. Therefore, living factors could be used to define the niche of organisms. In a broad sense, a niche is described as a cavity, hollow, or recess particularly in a wall. An ecological or biological niche, on the other hand, can relate to any of the following:

- The particular location that an organism resides in.
- The function of an organism or species within an environment.
- The interactions between a species and all of the biotic and abiotic elements that have an impact on it.

Formation of Niche: Abiotic and biotic elements work together to create an ecosystem's niche. Natural selection works to determine which niches will be favoured and which ones will not by determining the abiotic elements of an ecosystem, such as temperature, climate, and soil type. The species gradually acquires unique characteristics that aid in environment adaptation as a result of time. They could adapt and survive in environments that complemented their traits if they blended in. Nevertheless, biological limitations including parasitism, competition and predation may limit the size of their population.

- Competition for available nutrients, available space, available light and other essential resources among co-habitats may limit the population of a species in a habitat.
- Depending on the number of predators and the level of predation, predation may also limit the population of a species.
- In parasitism, the presence of parasites that use the species as their host and susceptibility to infections that cause diseases are additional elements that might limit the population of the species. As these elements alter, ecosystem niches develop and take different forms.

Niche Segregation: As a result of natural selection and the fact that each niche is occupied by a particular species, niche segregation is the process by which competing species are forced into distinct niches. A niche cannot be shared by two species. Nevertheless, coexistence might enable competitor species to carve out distinct ecological niches. In order to avoid competing for scarce resources, they must be able to discover ways to cohabit, such as by resource differentiation (or niche partitioning). Without it, natural selection will prefer one of the two competing species while driving the other one into extinction.

Types of Niches

- **Fundamental niche**: The niche that a species occupies when there is no competition is referred to as a fundamental niche. In contrast, a realized niche is one that a species fills as a result of pressures, such as the introduction of a rival species to its habitat (fig. 6.4).

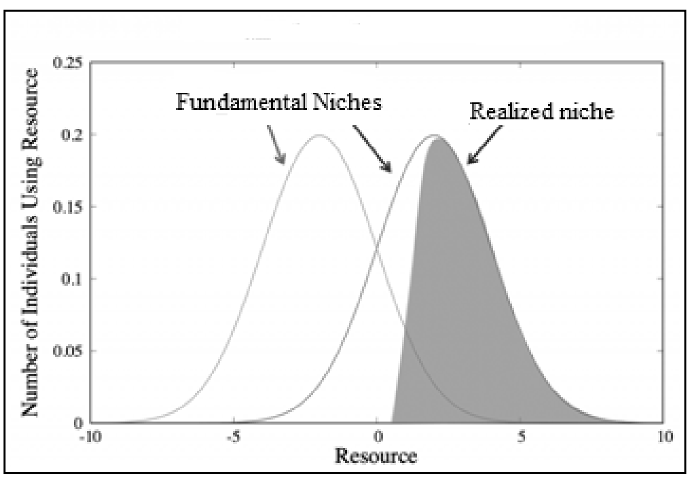

Figure 6.4: Representation of fundamental and realized niches

- **Niche overlap** is the usage of the same resources or other environmental factors by two different species. In many cases, niches only partially overlap because there are common resources.

- In an environment, a **vacant niche** is one that has not yet been filled. The idea of a vacant niche, however, is still up for debate. However, ecological disruptions (such forest fires and droughts) and evolutionary events are thought to be the root causes of unfilled niches (i.e. when species failed to evolve).

The beaver niche and the dung beetle niche are both examples of ecological niches.

1. Niche of beavers: Beavers are nocturnal, semi-aquatic rodents of the genus Castor. They are renowned for building hotels, canals, and dams. Because of this activity, the river where they dwell may see changes in water flow, which could have an impact on both biotic and abiotic aspects of their ecosystem. The ecological niche that beavers fill in determining the characteristics of their surroundings may have an impact on other species that reside close to the water bodies.
2. The niche of flightless dung beetle: *Circellium bacchus*, a species of flightless dung beetle, fills a special ecological niche. They consume animal waste and deposit it as dung balls in their burrows. Eggs are deposited inside the dung ball so that the larvae would have access to food sources when they emerge. The feeding habit of dung beetle aerates the soil and replenishes nutrients in the soil.

6.8 COMMUNITY DIVERSITY AND CONTINUUM

Community or Ecosystem diversity refers to the changes in ecosystems within a given geographic area and how they affect both the environment and human life comprehensively.
Ecosystem diversity focuses on the characteristics of both biotic (biodiversity) and abiotic properties (geodiversity). It is either a variety in the ecosystems present in a particular area or a variation in ecosystems over the entire world. Both terrestrial and aquatic habitats can vary, which is referred to as ecological diversity. Ecological diversity can also take into consideration the variance in a complexity of biological community including the quantity of various niches and other ecological processes. The ecosystems diversity such as deserts, forests, grasslands, wetlands and oceans, would serve as an illustration of ecological diversity on a global scale. The biggest scale of biodiversity is community diversity, and each community contains a vast quantity of species and genetic variation.

Based on environmental variations, there are many different ecosystems on earth, each with their own complement of unique interconnected species. India has a remarkable wealth in terms of ecosystem diversity. Aquatic ecosystems like those found in the ocean, lakes, and rivers as well as those found in mountain ranges, forests, deserts, and grasslands are examples of distinctive natural ecosystems. In an ecosystem, there may be a variety of landforms, each of which supports a particular type of flora. When natural ecosystems are exploited or overused, they degenerate and become less productive.

The boundaries of communities that are not well defined form and divide several sub-ecosystems, making ecosystem diversity more difficult to quantify than species and genetic variety. To characterize the ecosystem's diversity, communities in diverse ecological niches are examined within the given ecosystem. Each community has distinct complexity related to the structure and biodiversity of that community. The decline in environmental diversity is ultimately what leads to the extinction of species and genetic diversity. Diversity of the community is another name for ecosystem diversity. Community diversity refers to the variety of ecological units or community types found within various and major ecological niches.

Community diversity is unique from habitat variety, which describes the various animal species that live in various ecosystems. The number of species has a considerable impact on ecological processes through functional variations between species rather than directly affecting ecosystem processes. Ecosystems having a diversity of functional features (functional diversity) are more efficient and offer high productivity as well as resistance to invasion.

In order to understand the functional diversity, Hooper proposed in 1998 that the scope of functional differences within the species pool be investigated. Functional diversity is a term used to describe the variety of tasks carried out by various organisms in ecological systems. The species can be separated into functionally related taxonomic units, such as deposit feeders, suspension feeders, etc., or into unique functional kinds, such as plant growth forms, feeding guilds, within the community or habitat. The functionally related species in the habitat may come from several taxonomic groups. There are three levels of community or ecological diversity:

a. **Alpha Diversity (within habitat diversity):** Alpha diversity (α -diversity) is measured by the number of species in an ecosystem or by the species richness. It describes the biological diversity found in a given area, community, or ecosystem. The number of various groups of organisms in the environment, such as different species, genera and families, or the number of taxonomic entities (number of taxa), can be used to calculate the alpha diversity.
b. **Beta Diversity:** Beta diversity (β-diversity) is the quantitative measurement of community diversity along environmental gradients. To calculate beta diversity, the species diversity that is subjected to diverse environmental conditions across ecosystems is compared. It is expressed as the rate at which species composition varies between communities or between various ecological habitats.
c. **Gamma Diversity:** The species richness or overall number of species over a wide area is referred to as gamma diversity (γ-diversity) (ecological, units). The quantitative evaluation of total diversity for various ecosystems reveals gamma diversity, also known as large-scale landscape diversity, within an area. The species diversity of the component communities is a usual method of expressing it.

Community unit concept

This viewpoint is also referred to as the discrete view of community. This point of view contends that if a habitat occurs more than once in a particular geographic area, the related species group also repeats itself. The uniformity in the species composition must be recognized as being relative. This point of view places an emphasis on how each community functions as an integrated whole with a defined border.

Each distinct community is made up of species that have coevolved (with similar distributions along an environmental gradient). The distribution pattern of species along an environmental gradient as anticipated by this theory is shown in fig. A distinct community or specific association is formed by the species that share a range on an environmental gradient (horizontal axis) and a pattern of increase and fall in importance value (vertical axis). Little overlap exists across the boundaries of neighbouring associations, resulting in acute or dispersed ecotones.

The pioneer worker of this viewpoint, F. F. Clements (1916, 1920), compared communities to organisms. According to the organismic idea, the community is a kind of super organism or an organic entity that develops, grows, reaches maturity and then perishes or dies. The community has particular traits and functions for different populations that make up its composition. According to Clements, the Climax community is the fundamental, cohesive unit of vegetation because it has the ability to reproduce itself, repeating the stages of its growth with a high degree of consistency.

Continuum concept

Ramenski (1924) and Gleason (1926) put up an alternative explanation to the community unit theory known as the individualistic hypothesis. In the 1950s, the continuum view was developed out of this hypothesis. According to Gleason each species is dispersed differently, according to its own genetic, physiological, and life cycle traits as well as how it interacts with its environment and other species. As a result, no two species are distributed similarly.

The species do not cluster into distinct communities that define them. In other words, the abundance and distribution of a species population are independent of with those of other species populations. The vegetation of a region is thought to result from a combination of two factors: the random and spontaneous movement of plants into the area, as well as the equally random and varied environment, with a gradual and ongoing change in species composition along an environmental gradient.

In other words, contrary to the discrete view, groups of species with similar distributions do not result from the evolution of species in relation to one another.

6.9 COMMUNITY DEVELOPMENT AND CO EVOLUTION

As species interact with one another, they evolve in response to one another. One of the main mechanisms by which biological communities are organised is through co evolutionary processes, which refer to these reciprocal evolutionary changes in interacting species. Local populations of interacting species adapt to one another through co evolution, occasionally even creating new species in the process.

Scientists must distinguish between features that have coevolved and those that were previously present in ancestors before the interspecific interaction started in order to comprehend how co evolution influences interactions within communities. Hummingbirds, for example, use their wings and beak to access the nectar found inside flowers. A hummingbird with a long bill may have coevolved with a particular species of flower, but co evolution did not give rise to the hummingbird's wings. Birds already had wings before hummingbirds evolved. Therefore, it is important to investigate both the evolutionary ecology and the phylogeny (history) of the interacting species. The phylogeny chart shows when each species within a lineage first appeared as well as when each novel characteristic first appeared. The ecological studies can then demonstrate how each of those characteristics has been used and shaped by various ecological contexts.

The interaction between phylogeny and ecology is illustrated by research on the coevolution of Prodoxidae moths and the plants that serve as their hosts. Some species of prodoxid moths have evolved into important plant pollinators. Yucca moths (of the genus *Tegeticula* and *Parategeticula*) and Greya moths are two of the pollinators for these plants. Greya moths accidentally or passively pollinate the flowers they visit, whereas their closely related yucca moths actively or purposefully do this. Female yucca moths have specialised appendages attached to their mouthparts that they use to capture and transport pollen. Their progeny eat the growing seeds and then they visit yucca flowers to lay their eggs in the floral ovary.

A female moth visits each flower and deposits some of the pollen she is carrying just on the stigma of the flower. Her young ones will consequently always have developing seeds to eat. These moths are the only pollinators the yuccas rely on due to evolution. They do not waste energy trying to attract pollinators since, unlike many other plant species; they do not generate nectar or any other kind of reward for the pollinators. They suffer some seed loss to yucca moth larvae, but that is the price they pay for coevolving with such an effective pollinator.

Due to the fact that the relatives of yuccas produce nectar while the relatives of yucca moths, the Greya moths, do not actively pollinate their host plants, phylogenetic studies have shown that the loss of nectar production in yuccas and the evolution of active pollination in yucca moths are novel traits that have arisen through co evolution. Other components of the connection make advantage of the traits that did not develop simultaneously in yuccas and yucca moths. Instead, the ancestors had the traits. Regardless of the plants they feed on, all of the near relatives of yucca moths share two characteristics, namely the ability to lay eggs in flowers and local specialisation to one plant species.

Therefore, by combining ecological and phylogenetic data, scientists may reconstruct the co evolutionary history of these species. As a result of their interactions, their ancestors unintentionally improved their chances of survival and reproduction, which led to the beginning of the coevolved mutualism between yuccas and yucca moths. Yuccas that did not waste energy on nectar production to draw in other pollinators outcompeted plants that did; yucca moth populations that aggressively pollinated the flowers in which they lay their eggs outcompeted populations by ensuring the availability of developing seeds for their young ones. Despite the fact that the process certainly had many more detours along the way, the integration of evolutionary ecology and phylogenetic research enables at least a partial reconstruction of the co evolutionary process.

Natural selection works on qualities that are already present within species, moulding them in new ways by favouring new mutations that fine tune the relationship. All coevolved relationships are similar to those between yuccas and yucca moths in this regard. The biologist Francois Jacob compared the evolutionary process to playing rather than engineering and his comparison to coevolution is undoubtedly valid. Coevolved interactions are not created from the ground up to be as effective as possible. Instead, evolution interacts with already existing structures and behaviours, adapting them to serve new purposes; essentially judge them. Consequently, this improvised character of adaptation and co evolution is reflected in the structure of biological groups.

Ecological adaptation: A detailed note is given in the chapter: Population, ecological adaptations in species and survival strategies.

6.10 SUMMARY

In the previous chapter learners have studied the population ecology now in this chapter they have understood the structure and development of community. Learners as you know that a group of individuals of a species is known as population but when such various populations reside in a geographical area, share the resources and interact with each other they form a community or more appropriately a biotic community. A forest, grassland, a desert or a lake are examples of communities. A community possess only biotic (living) components unlike ecosystem which include biotic as well as abiotic (non living) components. The concept of community dates back to the time of Theophrastus (370-250 BC) who identified plant communities relation of species with their environment.

There are essentially two different types of communities: Major and minor communities.

a) Major Community: It is a sizable, autonomous unit that is self-governing, self-sustaining, and composed of a number of subordinate communities. A pond, a lake, a forest, a desert, a meadow, and grassland are examples of major communities. These major communities each contain a number of smaller communities.
b) Minor Community: It is a more compact community that cannot support itself. Its survival is reliant on other communities. The plant community (plant population), the animal community (animal population), and the microbiological community (bacteria and fungi) are three of the numerous minor communities that make up the main community of a forest.

Animal and plant communities are typically researched individually, which ultimately obscures the community's unity and constricts our knowledge of its significance. The distribution of animals can be connected to the life forms of plants and varieties of flora, which can help us really overcome this problem. This leads to a more extensive classification that covers various plant communities but also includes animal life related to them; this classification is known as a biome. A wide ecological unit known as a biome is distinguished by homogeneity and distinctive life forms of the climax species, whether they are plants or animals. The species composition of the climax and its successional stages are homogeneous and distinct, dividing it into smaller groups. Thus, rather than taxonomic composition, the emphasis is placed on the life forms of plants.

6.11 GLOSSARY

Abiotic: abiotic components or **abiotic factors** are non-living chemical and physical parts of the environment that affect living organisms and the functioning of ecosystems.
Alpha diversity: It is the mean species diversity in a site at a local scale.
Beta diversity: It is the number of species unique to each environment that is used to measure species diversity between two ecosystems.
Biogeography: It is the study of the distribution of species and ecosystems in geographic space and through geological time.
Biomass: The quantity of organic material present in unit area at a particular time mostly expressed as tons of dry matter per unit area; organic matter that can be used as fuel.
Biome: A biome is a biogeographical unit consisting of a biological community that has formed in response to the physical environment in which they are found and a shared regional climate.
Biotic: related to, produced by, or caused by living organisms.
Coevolution: The reciprocal evolutionary change that occurs throughout time as a result of interactions between a group of interacting populations is known as coevolution.
Community: a group of populations living in the same place or having a particular characteristic in common.

Continuum: theories or models that explain progressive changes without sudden shifts from one state to another

Dominants: one or more species that occupy their ecological community due to their size, number, productivity, or other associated qualities or because they contribute a larger share of the biomass.

Ecological diversity: focuses on how ecological differences within a certain geographic area affect the ecosystem, plant, and animal life in general.

Ecotone: An ecotone is a region of transition when two biological communities come together and interact.

Ecological niche: It is defined as the compatibility of a species with a certain environmental circumstance. The response of an organism or population to the distribution of resources and competition, as well as how it changes those same factors, are described.

Environment: The surroundings or conditions in which a person, animal, or plant resides or functions.

Gamma diversity: it (γ-diversity) is the total species diversity in a landscape. The alpha diversity and beta diversity constitute independent components of gamma diversity.

Greasewood: Also known as **black greasewood**, (species *Sarcobatus vermiculatus*), North American weedy shrub of the Sarcobataceae family. It is a characteristic plant of strongly alkaline and saline soils in the desert plains of western North America.

Homogenous: similar in structure because of common origin.

Interspecific: Existing, occurring or arising between species.

Keystone species: It is a species which has a disproportionately large effect on its natural environment relative to its abundance.

Nocturnal: relating to or occurring at night.

Phenotypic: relating to the observable characteristics of an individual resulting from the interaction of its genotype with the environment.

Physiognomy: the general form or appearance of something.

Physiological: relating to the way in which a living organism or bodily part functions.

Qualitative: relating to, measuring, or measured by the quality of something rather than its quantity.

Quantitative: relating to, measuring, or measured by the quantity of something rather than its quality.

Sampling unit: A Sampling unit is one of the units selected for the purpose of sampling. Each unit being regarded as individual and indivisible when the selection is made.

Segregation: the process of separating of something from other.

Self perpetuating: capable of continuing or renewing oneself indefinitely.

Seral community: It is an intermediate stage found in ecological succession in an ecosystem advancing towards its climax community.

Sessile animal: an animal that remains fixed in one place.

Stratification: the arrangement or classification of something into different groups.
Ecological Succession: the steady and gradual change in a species of a given area with respect to the changing environment.
Susceptibility: It is a tendency to be affected by something.
Taxonomy: A taxonomy (or taxonomical classification) is a scheme of classification, especially or plants and animals.
Topography: the arrangement of the natural and artificial physical features of an area.
Transitional: involving, providing, or consisting of a passage, movement, or change from one state, condition, subject, place, etc., to another.

6.12 SELF ASSESSMENT QUESTIONS

6.12.1 Multiple choice questions:

1. Study of inter-relationships between an entire community and its environment is :
   a) Autecology b) Resource Ecology
   c) Species Ecology d) Synecology
2. The plants occurring together with a similar ecology in definite strata are called
   a) Periodicity b) Stratification
   c) Floristic d) Vitality
3. The number of species in a unit area is known as
   a) Abundance b) Density
   c) Frequency d) Cover
4. The estimation of individuals of species is called
   a) Abundance b) Frequency
   Frequency d) Cover
5. The rhythmic phenomena related to seasonal changes is called
   a) Periodicity b) Stratification
   c) Floristic d) Vitality
6. The capacity of plants to complete its life cycle is called:
   a) Stratification b) Periodicity
   c) Floristic d) Vitality
7. The relative occurrence of specie in an association or a group of related association is:
   a) Fidelity b) Dominance
   c) Constancy d) Presence
8. The species which have high number and large volume are
   a) Constancy b) Fidelity
   c) Dominants d) Presence
9. A geographical place where a species resides or occupies
   a) Niche b) Ecosystem
   c) Habitat d) Physiognomy

10. Niche of a species in the absence of competition.
   a) Realized niche b) Fundamental niche
   c) Vacant niche d) None of the them

6.12.2 Fill in the blanks:

1. The relationship of a species with the abotic and biotic factors is termed as ___niche______.
2. The niche of a species due to pressure is known as_______.
3. Niche that is theorized to exist due to habitat disturbances or evolutionary eventualities is _____.
4. Transition zone between two ecosystems is called ______.
5. Set of ecosystems is called_____.
6. The female yucca moth have specialized appendages that they use to ______and ______pollen.
7. The female yucca moth deposits some of the _____ down to the ovary to fertilize the plant & seeds will be available for offspring.
8. _______ results from the nonlinear partitioning of two habitats.
9. Two species _____occupy the same niche in the same place.
10. Species richness and species evenness are two factors that are helpful in determining the __________ of a community.

6.12.3 True and False:

1. The biotic community interacts with its abiotic environment to form an ecosystem. The whole earth can be considered as one large ecosystem.
2. Organisms that make their own food are called autotrophs.
3. Abiotic factors that influence species distributions or interactions are not considered in community ecology.
4. The climax community is final, terminal and self-perpetuating community in succession.
5. The forest floor is also known as the subterranean stratum.
6. The biotic community has an equal distribution of organisms.
7. The exterior appearance of the plant community is known as phytosociology.
8. Well stratified lakes have a layer of freely flowing surface water, the Metalimnion.
9. Fundamental niche is the same as realized niche.
10. When disturbances in the ecosystem are frequent species who take a long time to grow and become established will dominate.

Answer Key:

6.12.1: 1. (d), 2. (b), 3. (d), 4.(a), 5. (a), 6. (d), 7. (a), 8. (c), 9. (a), 10. (b).

6.12.2: 1. niche, 2. fundamental niche, 3. vacant niche, 4. ecotone, 5. biome, 6. capture and transport, 7. Pollen, 8. convoluted edge effect, 9. cannot, 10. species diversity

6.12.3: 1. True, 2. True, 3. False, 4. True, 5. True, 6. False, 7. False, 8. False, 9. False, 10. True.

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6.15 TERMINAL QUESTIONS

6.15.1 Short answer type questions

1. Write a short note on phenology.
2. Write short note on Ecotone.
3. Write a short note on keystone species.
4. Write a short note on cover and basal area.
5. Write a short note on edge effects.
6. Write a short note on niche segregation and types of niches.

6.15.2 Long answer type questions

1. Define biotic community. Describe the various features that characterize a community.
2. Give a detailed account of analytical and synthetic characters of a plant community.
3. Write a detailed note on stratification.
4. Write a detailed note on ecological niche and the factors that influence a species ecological niche.
5. Write an essay on community diversity and continuum concept.

BLOCK-3- CONTEMPORARY ENVIRONMENTAL PROBLEMS AND CONSERVATION

UNIT-7- LAND DEGRADATION

Content

7.1 OBJECTIVES

After reading this unit student will be able:

- To know about land degradation
- To Understand about its concept
- To learn its causes and consequences
- To know about types of degraded land
- To understand about prevention and control measures of land degradation

7.2 INTRODUCTION

Any change which decreases productivity of the land is land degradation. It is a process in which the value of the biophysical environment is affected by a combination of human-induced process acting upon the land. Land degradation means:

- Loss of natural fertility of soil because of loss of nutrients.
- Less vegetation cover.
- Changes in climatic conditions because of unbalanced created in the environment.
- Pollutions of water resources from the contamination of soil through which water sweeps into ground or runoff to the water bodies.
- Any change or disturbance to the land perceived to be unfavorable or undesirable.

According to UN/FAO, Land degradation generally signifies the temporary or permanent decline in the productive capacity of the land. It is a natural or human-induced process that negatively affects the land. Some environments are naturally more vulnerable to land degradation than others. Steep slopes, heavy rainfall, and soil organic matter all influence the likelihood of degradation. Generally, it refers to process that negatively affects the land's natural functions of water, energy, and nutrient acceptance, recycling and storage leading to a decline in land productivity. Many scientists gave different definitions of land degradation. These definitions provide a broad view on the nature of land resources (they include soil, vegetation and water) and the range of products, goods and services people obtain from the land.

According to Barrow (1991) it is impossible to give a precise definition of land degradation. It may be defined "as the loss of utility or the reduction, loss or change of features or organisms which cannot be replaced".

Blaikie and Brookfield (1987) describe that land is degraded when "it suffers a loss of intrinsic qualities or a decline in its capabilities".

Winfried (1986) defined as "weathering down of the land surface".

According to Young (1997), land degradation is the lowering of the productivity, capacity of the land through processes such as soil erosion, loss of soil fertility and soil salinity.

The degradation of the earth's surface (i.e., land degradation) is one of the most severe problems. The process of land degradation not only reduces the capability but also accelerates the process of converting productive land into wasteland and wasteland cannot support the life, so it must be conserved in order to continue the support. India is basically an agricultural country. Out of India's total land mass of 305 million hectares nearly half is waste land, hence nearly 143 million hectares are used for agricultural purposes. From remaining, nearly 18 million hectares are under urban productive use, 21 million hectares are rocky or snowcapped, 17 million hectares are culturable waste lands, 23 million hectares are fallows, 83 million hectares are forest and pasture lands.

7.3 CONCEPT

The word "land degradation" is broad and can be used in a variety of ways in the subject area. The idea of land degradation was taken into account in four different ways, including the impact on the environment and soil productivity, decline in the usability of the land, loss of biodiversity, shifting ecological risk, and a reduction in the land's potential for production.

The concept of land degradation originates from soil degradation and it's often used as a synonym for soil degradation. It is evident that if soil is degraded it has huge impacts on both the land and landscape, because soil degradation prevents or disrupts plant growth. The characteristics and quality of soil adversely affects its fertility. Eventually, land degradation stresses the world's agricultural land and grazing land, which provide food, water, and clean air to all people on the planet. Land degradation means much more than the degradation of the land/soil. It is a global issue that impacts everyone due to food poverty, climate change, environmental threats, the loss of biodiversity, and ecosystem services is the deterioration or loss of the productive potential of soils for the present and the future.

Land degradation processes can have both natural and human (anthropogenic) origins. The loss of a sustained economic, cultural, or ecological function as a result of human activity in conjunction with natural processes is a pure anthropogenic definition of land degradation. It is obvious that since the appearance of human beings on the earth the importance of anthropogenic processes is enormous and has grown exponentially with time. Global processes like global climate change, land use and land cover change, together with population increase, accelerate and increase land degradation. Especially, third world countries suffer from degradation processes. In these countries overexploitation of natural resources in environmentally sensitive areas also contribute to the acceleration of degradation processes. The effect of global warming on already degraded land also increases the intensity of degradation.

Land degradation is a threat to natural resources with consequences for food security, poverty and ecological and political stability. The increasing frequency of climatic extremes e.g., heat waves, droughts, heavy rainfall affects land degradation processes including floods, mass movements, soil erosion by water and wind and salinization in all regions of the world.

7.4 TYPES OF LAND DEGRADATION

The impact of a land degradation process varies depending on the land's inherent characteristics, specifically soil type, slope, vegetation, and climate. Thus, an activity that is not degrading in one location may be degrading in another due to differences in soil characteristics, topography, climatic conditions, or other circumstances. As a result, equally erosive rainstorms that occur above different soil types will result in varying rates of soil loss. As a result, determining the cause of land degradation must take into account the interactions between different elements in the landscape that affect degradation, as well as the site-specificity of degradation. There can be many types of land degradation. Some of the major types are:

1. **Soil erosion-** A partial or complete loss of the top fertile layer of soil. It is the most widely recognized and most common form of land degradation. It comprises various processes that are described separately below; however, any one of these processes may occur in the same locality, either in combination or at different times of year. Soil erosion by water is often widespread and can occur in all parts of drylands where rainfall is sufficiently intense for surface runoff to occur. This category includes processes such as splash, sheet, rill and gully erosion. Soil erosion by wind is also widespread throughout drylands that are exposed to strong winds. It includes both the removal and re-depostion of soil particles by wind action and abrasive effects of moving particles as they are transported.

2. **Soil contamination**-Soil contamination is the occurrence of contaminants in soil above a certain level causing deterioration or loss of one or more soil functions. When xenobiotic (human-made) chemicals are present or other changes are made to the natural soil environment, it contributes to the degradation of the land. It is typically caused by industrial activities, agricultural chemicals or improper disposal of waste. It alters soil biodiversity, reduces soil organic matter and soils capacity to act as a filter. It also contaminates the water stored in the soil and ground water, and cause an imbalance of soil nutrients. Mining, dumping of oil and non-degradable waste, radioactive wastes on soil leading to pollution or degradation of the soil quality and ecosystem.

3. **Desertification**: It is defined as "a type of land degradation in which a relatively dry land region gradually becomes arid, typically losing bodies of water as well as vegetation and wildlife." Agriculture is threatened by increasing desertification of the soil. When soil loses all its water and green matter, land becomes desert due to factors such as climate change, loss of vegetation and agricultural mismanagement. In this case, it’s very hard to restore the land.

4. **Soil Acidification**: Soil acidification can be defined as a reduction in the pH of the soil. When the soil becomes too acidic, it loses its productivity. It can be caused by soil amendments, acid rain, nitrogen emissions in the air, and other factors. Soil acidification and the formation of acid sulphate soil resulting in barren soil.

5. **Soil Salinity**-Soil salinity is defined as increase in the salt content of the soil. Salinisation greatly reduces soil quality and vegetation cover. Due to the destruction of the soil structure, saline and sodic soils are more easily eroded by water and wind. Salination induces desertification effects such as soil crusting, loss of soil fertility, soil structure destruction and compaction etc. Salinization is used in its broad sense to refer to all types of soil degradation brought about by the increase of salts in the soil. When the soil becomes to saline, it loses its productivity. It can be used by ocean environments, over irrigation, water sources with salinity issues, and other factors.

6. **Loss of vegetation cover:** Vegetation cover is defined as the percentage of soil covered by green vegetation. Vegetation has a blanketing effect on loss of atmospheric humidity and temperature changes during day or night, or summer and winter. The summers are less hot and winters are warmer when the soil is covered with vegetation. The erosion of soil brings about the loss of vegetation cover and hence its moderating effect on climate. Vegetation is important in many ways. It protects the soil from erosion by wind and water and it provides organic material to maintain levels of nutrients essential for healthy plant growth. Plant roots help to maintain soil structure and facilitate water infiltration. Vegetation cover is a critical factor in land degradation. Reduced perennial cover is regarded as an important indicator of the onset of desertification. Vegetation cover is very important in protecting the soil surface from raindrop splashing, increasing soil organic matter, soil aggregate stability, water holding capacity, hydraulic conductivity, retarding and reducing surface water runoff, and so on.

7.5 CAUSES OF LAND DEGRADATION

Land degradation may be generally caused by natural processes associated to the characteristics of the given land resources and ecosystems. Human activities, on the other hand, frequently accelerate these degradation processes. Mining, dumping of oil and non-biodegradable waste, and radioactive wastes on soil all contribute to pollution or degradation of soil quality and ecosystem, resulting in a rapid decline in the quality and quantity of land resources as well as the ecosystem services that flow from them. Arid regions are particularly fragile and vulnerable to land degradation. A variety of complex interconnected degradation processes contribute to land degradation. One of the primary causes of increased land degradation is overexploitation of natural resources. The main causes of land degradation are:

1. **Soil Erosion:** The loss of soil or disturbance of the soil structure is called soil erosion. Soil erosion may be defined as the loss of the superficial fertile layer (top soil) of the soil. The chief agents responsible for it are water, ocean waves, glaciers, rains, over-grazing, over-cropping and improper tilling. Soil erosion due to water and wind, and degradation of vegetation cover were the main processes that has led to land degradation.

2. **Overgrazing:** Overgrazing is the grazing of natural pastures at stocking intensifies above the livestock carrying capacity. Degradation occurs when the recovery of vegetation and soil properties during periods of normal rainfall does not reach its previous statue. It can reduce ground cover, enabling erosion and compaction of the land by wind and rain. This reduces the ability for plants to grow and water to penetrate, which harms soil microbes and results in serious erosion of land. Over-grazing have a major impact on the productivity of our crop lands and are responsible for soil erosion. In India pasture land area is decreasing day by day due to expansion of agricultural land. Recent satellite data show that the area under pasture land is severely degraded. This poor condition of pasture lands is due to excessive grazing.

3. **Desertification:** Desertification is the process leading to desert formation. Desertification is a widespread process of land degradation on arid, semi-arid, and dry sub-humid areas resulting from various factors, including climatic variations and human activities. The UNO conference on Desertification (1977) has defined desertification as the “diminution or destruction of the biological potential of land can lead ultimately to desert like conditions”. Desertification happens over land which loses its vegetation, where rainfall is conspicuously absent or due to human errors.

4. **Shifting cultivation:** It is also one of the causes of land degradation. Many tribal communities, particularly in the north-eastern India, follows the practice of jhum (shifting) cultivation In jhum cultivation, a path of ground is cleared by cutting down trees and setting them on fire and then crops are raised on the resulting ash. The cultivations keep on shifting from one part to another where new patches of land are cleared. Excessive jhuming cycles degrade forest and disturb soil fertility.

5. **Fertilizer misuse:** Fertilizers are the widely used medium to increase the food productivity. The farmers maintain productivity of soil by applying chemical fertilizers but make less use of organic manures. However, overuse of chemical fertilizers has lead to several problems such as serious soil degradation, soil compaction, nitrogen leaching, reduction in soil organic matter, and loss of soil carbon. Fertilizers may affect the accumulation of heavy metals in soil and plant system.

6. **Mining:** It is the most important factor for land degradation. Mining disturbs the physical, chemical and biological features of the soil. Mineral processing, grinding of

lime stone, ceramic industry releases a heavy amount of dust, which later settles down in the surrounding areas.

7. **Water logging:** Over irrigation of land is also responsible for land degradation, water logging, increases salinity and alkalinity in soil making it unfit for cultivation. Soil alkalinisation owing to irrigation with water containing sodium bicarbonate leading to poor soil structure and reduced crop yields. Excessive irrigation and improper drainage facility in the fields cause rise in the ground water level. Thus ground water mixes with surface water used for irrigation and creates a situation called water-logging. Soil water logging in irrigated land which calls for some form of sub surface land drainage to remediate the negative effects.

8. **Industrilization:** Development of industries for the economic growth leads to excessive deforestation and utilization of land in such a way that it has lost its natural up gradation quality. Large areas of fertile and productive lands are lost due to encroachment of urban, industrial and agricultural developments, construction of dams, canals, roads, railways, airports, mining etc. The development of industries such as paper and pulp mills, oil refineries, chemical fertilizer industry, coal mining, and so on has an impact on the chemical and biological properties of soil. Waste disposal from these industries may result in the entry of hazardous chemicals into the food chain via soil, resulting in adverse effects. Radioactive pollutants (uranium, Th, Ra, carbon isotopes, and potassium) from nuclear testing laboratories or industries may enter soil and water. All these have, thus aggravated the problem of land degradation.

9. **Urbanization:** Increasing growth of population and demand for more residential areas and commercial sector is one of the reasons for land degradation. Global population growth and uncontrolled urbanization places additional pressure on land resources for food production. This leads to soil erosion and loss of arable lands for housing.

10. **Deforestation:** Deforestation refers to the decrease in forest areas across the world that are lost for other uses such as urban development, mining, agricultural croplands or other land uses. Deforestation is when forests are destroyed by cutting trees and not replanting them. The loss of trees, which anchor the soil with their roots, causes widespread erosion. As it looses soil slowly the land starts losing its fertility and all the nutrients present in them. Deforestation has resulted in many ecological problems like habitat, loss, mass extinction, increases CO_2 emissions etc.

11. **Salination:** Increase in the concentration of soluble salts in the soil is called as salination. This could be either salinization, an increase in salt in the soil water solution, or sodication, an increase of sodium cation ($Na+$) on the soil particles. Salinization often occurs in conjuction with poor irrigation management. In most cases salination is caused by dissolved salts in the water supply. This supply of water

can be caused by flooding of the land by sea water, seepage of seawater or brackish groundwater through the soil from below. Mostly, sodication tends to occur naturally; areas where the water table fluctuates may be prone to sodication.

12. **Siltation:** The accumulation of slit (fine particles of sand, mud, and other materials) in the reservoir is known as siltation. Some slit in water is normal, but many tonnes of slit pollute the water. Every river carries slit which doesn't necessarily mean that it is polluted, it is just soil erosion and water is mearly carrying these particles. It can become a serious problem, especially in water reservoirs where siltation occurs as a result of ground erosion and since the water is not moving it has nowhere to go.

7.6 EFFECTS OF LAND DEGRADATION

Land degradation is any change in the condition of the land which reduces its productive potential. This includes the loss of top soil, the loss of vegetative and increasing soil salinity. It not only affects soil productivity but also have more significant impacts on receiving water resources. It is the process through which land becomes unfit for cultivation. Several land degradation affected a significant portion of the arable lands, decreasing the wealth and economic development of nations. The major outcomes of land degradation are as follows:

1. **Loss of Soil fertility:** Land degradation affected soil productivity by affecting physical, chemical and biological properties of soil. The impact of land degradation on physical properties of soil such as- decline in soil structure, decrease in root zone depth, low porosity, decrease in moisture and nutrient retention capacity, decrease in aeration etc, biological properties such as -reduction in microbial population, reduction in soil respiration rate, reduction in organic matter content due to loss of vegetation from top soil, decline in land biodiversity etc, and chemical properties such as- reduction in soil pH which cause acidity in soil, decrease in cation exchange capacity, accumulation of weathered salt causes alkalinity and salinity etc. The loss of fertile soil makes land less productive for agriculture, creates new deserts, vegetation cover of the soil is reduced, pollutes waterways and potentially making flooding more common.

2. **Siltation:** Soil particles carried by river water are deposited in the plains. Siltation over the flood plains on the river banks destroys crop land. Siltation is caused by human activities that cause fine soil to leach into nearby rivers. This result in an abnormally large accumulation of slit that remains in that specific area of the river. Rainstorms may also carry these soils into other bodies of water. In their native waters, sensitive marine life and freshwater fish may be harmed by suspended slit. Because they are filter feeders, benthic organisms such as coral, oysters, shrimp, and mussels are particularly vulnerable to slit. Slit accumulations may also impair the function of waterways and irrigation canals. Other negative effects of siltation include human health concerns, the loss of wetlands, changes in coastlines, and changes in

fish migration patterns. Silt is a major issue because it causes the river bed to become shallower, causing river channels to hold less water. Floods are also common in these areas.

3. **Forest degradation:** Biotic resources are being depleted and the productive capacity of forests is being lowered as a result of human activity. Erosion on the hill slopes destroys the forest vegetation of the mountains and foot hills. Overexploitation of the natural resources is one of the main factors for the increase in land degradation.

4. **Climate change:** Land degradation also contributes to climate change, releasing massive quantities of carbon (stored in soil) into the atmosphere. Soil is the biggest terrestrial carbon sink. The world's soils store more carbon than the planets biomass and atmosphere combine. Soil carbon is the solid carbon stored in global soils. This includes both soil organic matter and inorganic carbon as carbonate minerals. Loss of soil organic carbon is one of the principal signs of land degradation, and land degradation is one of the leading challenges for sustainable development, biodiversity conservation, and mitigating and adapting to climate change.

5. **Famine:** Soil erosion results on the reduction of productivity of the land, reduces water availability for irrigational purposes and reduced hydroelectric power during dry periods of the year. When the seasonal rain fails, there is little water and the other inputs available for supporting crops. Hence famine overtakes the area.

6. **Spread of desert:** The sand particles picked up by wind from a desert area are deposited over the adjacent crop lands, ponds, lakes and irrigation channels. Vegetation gets killed through abrasion and suffocation while the soil becomes sterile. The filling up of water reservoirs and channel further increases aridity and gives rise to desert condition.

7.7 PREVENTION AND CONTROL OF LAND DEGRADATION

Land resources are non-renewable and it is necessary to ensure sustainable management of these finite resources. Human life can sustain only if lands are productive. Continuous use of land over a, long period of time without taking appropriate measures to conserve and manage, it has resulted in land degradation. This has serious repercussions on society and the environment. Land degradation has become a major global problem, limiting the sustainability of ecosystem services and agricultural production. Land is a limited resource, and its importance in our lives is usually ignored. Regarding the world's increasing population and limited natural resources, sustainable land management is defined as a basic requirement for long-term agricultural management and agricultural sustainability success. Natural processes affected by human activity, such as climate change and biodiversity loss, worsen land degradation. The damaged caused by erosion is due to loss of surface soil, plant nutrients, sub-soil water, silting up of water channels, reduction of land productivity and ultimately lowering the standard of living. Soil conservation is the only way to protect the productive lands. It increases crop yield and also prevents deterioration of the land. Modern approach to soil conservation is based on sound land use and treatment of land with those adaptable practical measures that keep the soil permanently productive while in use.

Land degradation can be controlled by afforestation and agrostological methods. To check the spread of sand dunes or desert conditions or blowing away of fertile top soil, trees are planted which reduce the velocity of the wind. Strips of grasses, laid in between growing fields crops are highly beneficial in conserving soil, soil water and productive capacity of the soil. Shifting cultivation can be replaced by crop rotation, mixed cropping or developing plantation crops which would improve fertility and support a larger population.
Following are some practices for controlling land degradation:

1. **Reforestation:** The forests, which are supposed to be the national wealth, which provide timber, fuel, wood, pulp, gums, resins, turpentine etc, are also important in checking floods and soil erosion. By restoring forest and grass over, soil erosion and flood can be checked. The forests build up a thick layer or humus, they protect soil from erosion. The rocks of plants also serve as natural dams in holding water and soil. Thus for the control of land degradation, the cutting of timbers, forest fires should be prevented.

2. **Crop rotation:** It is one of the agricultural practice in which different crops are grown in same area following a rotation system. Crop rotation is the method of alternating saving of leguminous and cereal crops. The crop rotation prevents soil, depletion and especially when used with fern manures and commercial fertilizers in valuable in the control of erosion, weeds and many plant diseases. Shifting cultivation can be replaced by crop rotation practices. Mixed cropping or developing plantation crops would improve soil fertility and support a larger population.

3. **Contours plantation:** This method is practiced on hill slopes. In this method the land is ploughed against the slope instead of up and down the slope. This result in the formation of cross wise ridges and check the flow of water. The log slopes are broken up into a number of strips laid out across the slopes so that crop rows are on the level. Sometimes the slope is divided into a series of small flat fields called terraces (this method is known as terracing), these consists of a broad bottomed channel and an outlet. Sometimes low ridges are also build us across the terraces which serve as small dams, for holding water and thus in checking soil erosion.

4. **Mulching:** Mulching is a process in which any material such as-grasses, straw, leaves, crop residues and other forms of plant litter placed on a soil surface. In this method soil is allowed to remain untilled. Mulching retains soil moisture, decreases run-off, increases soil infiltration, provides thermal insulation, reduces the incidence of weeds, stimulate, growth of soil and increases humification. The covered soil does not come in direct contact of the agencies of erosion.

5. **Control of grazing:** Grazing eliminates not only the seedlings, herbs and undershrub but the soil is also trampled, made compact and hard and becomes unfit for plant growth Different animals like buffaloes, horses, sheep, goats etc has definite references as to the type of vegetation grazed and each animal affect the pasture in a markedly different manner. Overgrazing by these animals causes soil erosion and partly spreads the desert conditions. By continuous grazing for a period of years, soil becomes lose and it is easily eroded by wind or water. To control grazing, a certain area should not be allowed to be grazed for a long time. Control grazing is the management of forage with grazing animals. It limits excess to grazing by subdividing pastures with permanent and temporary fences.

6. **Organic farming:** Organic farming is an agricultural technique where the land is supplemented with organic fertilizers instead of chemical ones. Legume root nodules are the best source for nitrogen and natural fertilizers such as cow dung, agricultural wastes also improve nutrients value of the soils.

7. **Strip farming:** It is the practice in which two different kinds of crops are planted in alternate rows. One set of rows consists of crops in which individual plants can be relatively widely spaced, such as cotton, soyabeans, corn etc. The second set of rows contains plants that grow very close together, such as wheat, legumes etc. As a result of this type of farming, water is channeled along the contour of the land, not down its slope. In addition, the closely planted crops in one row protect the exposed soil in the more widely spaced crops in the second row. The strip farming is determined by a number of factors, such as length and steepness of the slope. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion. Strip farming helps to stop soil erosion by creating natural dams for water, helping to preserve the strength of the soil. It helps the soil to retain its nutrients.

8. **Ridge and furrows formation:** It is a conservation farming method in which seeds are planted in ridges, which creates warmer soil temperatures and traps rainwater in the furrows between the ridges. Ridge and furrows formed act as continuous barrier to the free movement of water downwards thus provides more infiltration time. Hence, the removal of soil along with nutrients is checked to a great extent leading to increment in soil fertility and crop yield. Ridges and furrows is one of the various in situ soil and water conservation methods for black and red soils. Microclimates under mulched ridges and furrows favour soil microbial activity, increase soil biodiversity, and improve environmental benefits.

9. **Construction of dams:** A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. A check dam may be built from stone, sandbags filled with pea gravel, or loss. Check dams can be used where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible and velocity checks are required. Check dams are commonly used to reduce

flow in small temporary channels that are presently undergoing degradation, stabilize sedimentation, limit catchment erosion, and increase the reservoir storage capacity of dam. They block active gullies and divert the water flows to a stable area.

There are some other measures to control land degradation are as follows:

a) Adequate drainage should be made to prevent salinity of soil.
b) Salt affected lands can be recovered by bleaching them with more water.
c) Sufficient plantation of appropriate plant species can prevent shifting sand, mulching or covering the area with artificial protective covering also prevents shifting sand.
d) Using the farm machineries of lesser weight.
e) Reducing the number of passes of implements during tillage operations.
f) Keeping off the soil when it is in wet condition.
g) Reducing the soil compaction by deep ploughing, occasionally.
h) Reducing soil crusting by light cultivation, adding Gypsum ($CaSO4$) and mulching.

7.8 SUMMARY

Land degradation is defined as the temporary or permanent decline in the productive capacity of the land. The concept of land degradation originates from soil degradation and it’s often used as a synonym for soil degradation. It is a natural or human-induced process that negatively affects the land. Land degradation usually result from different human activities, such as waste dumping, agricultural practices, deforestation, mining operations and urbanization. The top layer of the soil is most important since all nutrients required by plants are present in this layer. Besides pollution, soil faces several problems associated with degradation. These include salination of soil, deforestation, erosion, flooding and water-logging, and ill planned urban encroachment.

The change in the characteristics and quality of soil which adversely affects its fertility is called degradation. It is a natural or human-induced process that negatively affects the land. The concept of land degradation originates from soil degradation and its often used as a synonym for soil degradation. This includes the loss of top soil, the loss of vegetative and increasing soil salinity. Main causes of Land degradation are- Soil erosion, over grazing, Desertification, shifting cultivation, Fertilizer misuse, mining, water logging. Industrialization, Urbanization, Deforestation, Salination. Several land degradation affected a significant portion of the arable lands, decreasing the wealth and economic development of nations. The major outcomes of land degradation are Loss of soil fertility, siltation, Loss of forest vegetation, climate change, Famine, or spread of desert. There can be many types of land degradation such as- soil erosion, soil contamination, desertification, soil acidification, soil salinity, Loss of vegetation cover etc. Soil conservation is the only way to protect the productive lands. Human life can sustain only if lands are productive. Reforestation, crop

rotation, contours plantation, Mulching, control of grazing, organic farming, strip farming, ridge and furrows formation, construction of dams are some practices for controlling land degradation.

7.9 GLOSSARY

Land Degradation: The disturbances in the natural structure and properties of soil due to direct or indirect anthropogenic (human) influences.
Organic farming: Farming without artificial fertilizers or pesticides**.**
Mulching: It is the process of covering the soil to make more favourable conditions for plant growth, development and efficient crop production.
Siltation: is a process by which water becomes dirty as a result of fine mineral particles in the water.
Shifting cultivation: It is a system of cultivation in which a plot of land is cleared and cultivated for a short period of time, then abandoned and allowed to revert to producing its normal vegetation while the cultivator moves on to another plot.
Jhum: It is the process of growing crops by first clearing the land of trees and vegetation and burning them thereafter.
Soil acidification: It is process where the soil pH decreases over time.
Arable: It is defined as land that is able to produce crops.
Agrostological methods: In this method grasses are grown to check the soil erosion.
Humification: It is a process in which humus is produced by the decomposition of plant twigs, wood, etc.
Wetland: An area of land that is either covered by water or saturated with water.

7.10 SELF-ASSESSMENT QUESTIONS

7.10.1. Multiple choice Questions:

1. The problem with the shifting cultivation is that it requires:
   (a) Lot of fossil fuel (b) lot of inorganic fertilizers
   (c) Continued application of pesticides (d) long time for the soil to recover
2. Land capable of being ploughed and used to grow crops is called as:
   (a) Dry land (b) Domestic land
   (c) Arable land (d) Unarable land
3. Wearing away of a field's topsoil by the natural physical forces of water and wind is known as:
   (a) Soil erosion (b) Wind erosion
   (c) Sand erosion (d) None
4. Process of conversion of productive land to arid or semiarid lands is known as-
   (a) Deformation (b) Desertification
   (c) Land form (d) Deforestation

5. What is salinisation?
   (a) It is a process of accumulation of soluble acid in upper soil horizons.
   (b) It is a process of accumulation of soluble minerals in upper soil horizons.
   (c) It is a process of accumulation of soluble salts in upper soil horizons.
   (d) It is a process of accumulation of soluble base in upper soil horizons.
6. What is deforestation?
   (a) Heavy construction working (b) Excessive paper production
   (c) The removal of trees from forested lands (d) None
7. Decline in the productive capacity of land for some time or permanently:
   (a) Land profile (b) Land degradation
   (c) Land reclamation (d) None
8. It is the uppermost layer, rich in humus and minerals and consists of sand, slit and clay:
   (a) Top soil (b) Black soil
   (c) Sub soil (d) b or c
9. Land capable of being ploughed and used to grow crops is known as-
   (a) Dry land (b) Arable land
   (c) Domestic land (d) None
10. Process of conversion of productive land to arid or semi arid lands is called as-
   (a) Desertification (b) Land form
   (c) Deforestation (d) Deformation

7.10.1 Answer key: 1-(d), 2-(c), 3-(a), 4-(b), 5-(c), 6-(c), 7-(b), 8-(a), 9-(b), 10-(a)

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7.13 TERMINAL QUESTION

7.13.1: Short Answer Type Questions:

1. Define land degradation. How can we conserve land resources?
2. Write a short note on strip farming.
3. What are the effects of land degradation?
4. How can we prevent land degradation?
5. What are the important measures of land degradation?

7.13.2: Long Answer Type Questions:

1. Define land degradation. What factors lead to land degradation?
2. Explain about the causes of land degradation?
3. What is land degradation? Discuss about its concept.
4. Describe the major types of land degradation.
5. Discuss about the prevention and control of land degradation.
6. Write short notes on:
    a) Salination
    b) Shifting cultivation
    c) Desertification
    d) Mulching

UNIT-8- ENVIRONMENTAL POLLUTION AND HUMAN HEALTH

Content

8.1 OBJECTIVES

After reading this unit student will be able:

- To know about the pollution and pollutants
- To learn about different types of pollutions- air, water, soil, noise, radioactive, solid waste.
- To understand about the causes, effects and control of pollutions.

8.2 INTRODUCTION

The presence or introduction of harmful or poisonous substances into the environment is called as pollution. The biosphere and ecosystem are self-sustaining and nature maintains a balance between the land, water, air and living organism. Any kind of imbalance in the biosphere is causes environmental pollution.

The term pollution is derived from the latin word polluere, which means 'to contaminate any feature of the environment'. The idea about pollution first given in 1949 by the delegates at the first world science conference on the conservation and utilization resources convened by the United Nations and held at lake Sussess in 1949. According to Pollution Committee of National Academy of Sciences 1966, the unnecessary changes in physical, chemical or biological properties of soil, air and water is pollution.

Odum (1971) has defined pollution as "an undesirable change in the physical, chemical or biological characteristics of our air, land, and water that may or will harmfully affects human life or that of desirable species, our industrial processes, living conditions, and cultural assets". Southwick (1976) has defined pollution as the unfavourable alteration of our environment, largely as a result of human activities. According to certain ecologists such as Smith (1977), Odum (1971), Southwick (1976), many factors such as human population explosion unplanned urbanization and deforestation, profit oriented capitalism and technological advancement, which may have originated pollution crisis on earth.

The introduction of contaminants into natural environment makes it less favourable for organisms. Pollution is linked to human activities such as- transportation, waste disposal, consumption, energy generation. Humans are responsible for impacting biophysical environment, biodiversity and other resources and the working mechanism of the environment. Pollution is result of the ignorance of humans towards their environment. Humans pollute the air, land, water by burning fossil fuels over reusing chemicals and pesticides, and creating sewage run-off. Pollution adversely affects biological species, including humans. In the modern era, humans adapt natural resources to make them more useful and live with the trash they create after using them. These waste materials harm the environment. Negative effects on nature result from the introduction of undesired and dangerous substances into the environment.

8.3 POLLUTANTS

A substance that makes the air, soil, water or another natural resource toxic is called as pollutant. The term "pollutant" refers to a group of compounds that are present in dangerous concentrations and act as pollution-causing agents that have a negative impact on the environment and living things.

A pollutant is the byproduct of man’s action. It can be any chemical, geochemical substance, biological organism or product, or physical property (heat) that is released intentionally or in advertently by man into the environment with actual or potential adverse, harmful or unpleasant and inconvenient effects. Some of the important pollutants are:

1. Deposited matter-smoke, tar, dust
2. Gases-sulphur dioxide, carbon monoxide, nitrogen oxide, hydrogen sulphide, ammonia, fluorine, chlorine etc.
3. Metals- Lead, iron, mercury, zinc, tin, cadmium etc.
4. Agriculture pollutions- pesticides, herbicides, fungicides, insecticides, fertilizers etc.
5. Organic pollutants- benzene, acetic acid, ether, benzopyrenes etc.
6. Photochemical- Oxidation pollutants from automobiles such as photochemical smog, ozone, peroxyacetyl nitrates, oxides of nitrogen, aldehydes, ketones.
7. Noise and Heat etc.
8. Solid wastes.

Pollutants are divided into two categories

1. **Biodegradable pollutants:** They consist of domestic sewage, cloth, paper, wood etc, which can be rapidly decomposed by natural processes like the action of microorganisms etc. They may create problems when their input into the environment exceeds their decomposition.
2. **Non-biodegradable pollutants:** The materials and poisonous substances like aluminium, cans, mercuric salts, plastics, waste glasses, phenolics, DDT etc, that do not degrade or degrade very slowly in the natural environmental conditions are called non-degradable pollutants. They are not recycled in an ecosystem naturally. These pollutants are ‘biologically magnified’, i.e. they pass from one biological system to another.

Pollutants are also classified into the following two categories on the basis of their forms they exist in the environment after their release.

a) **Primary pollutants:** These are the pollutants which exist as such after being added or released into the environment, e.g., oxides of Sulphur, nitrogen etc.
b) **Secondary pollutants:** These are the pollutants formed by the reactions of primary pollutants, particularly in the environment in presence of sunlight, e.g., hydrocarbons and nitrogen oxides react in atmosphere in presence of sunlight to form a group of nitrous compounds like peroxyacetyl nitrate (PAN).

Pollutants can be introduced into the environment both naturally such as volcanic ash and by humans such as industrial pollution.

8.4 TYPES OF POLLUTION

Environmental pollution is the inappropriate discharge of mass or energy into the planet's natural resources, such as the land, the air, and the water, which has an adverse long- or short-term effect on the environment and the health of its ecosystem, as well as a negative qualitative and quantitative impact on the living things and their existence. Various types of pollution are classified on the basis of the type of environment being polluted, or the pollutant involved.

1. Air pollution
2. Water pollution
3. Soil pollution
4. Noise pollution
5. Radioactive pollution
6. Solid waste pollution

8.4.1 Air Pollution

The addition of undesirable substances in air causes the air pollution. The air pollution may be defined as the presence of material in air in such concentration which are harmful to man and environment. The World Health Organization (WHO) defines Air pollution as “limited to situation in which the outer ambient atmosphere contains materials in concentrations which are harmful to man and his environment”.

The importance of air pollution can be estimated by a calculated fact that air constitutes nearly 80 percent of man’s daily intake by weight. A man breathes about 22,000 times a day inhaling about 16 kg of air. Approximately 91% of people worldwide currently reside in areas where the air quality does not match the safe levels set by the World Health Organization. Air pollution has direct or indirect consequences on human health, physiology and growth of plants and animals, and structure and processes of ecosystems (see winner, 1994).

Sources of Air Pollution: The main sources of air pollution are combustion such as- Transportation, fuel burning and refuse burning. All these three kinds of combustion release several types of gases. Air pollution sources are divisible into two categories:

1. **Mobile sources:** Mobile source air pollution includes any air pollution emitted by automobiles, airplanes, locomotive and other engines and equipment that can be moved from one location to another. Transportation as a whole account for 70% of CO, 44% of oxides of nitrogen, 33% volatile organic compounds, and 21% particulate matter annually generated into air.

2. **Stationary Sources:** Stationary source in air quality terminology is any fixed emitter (non-mobile) of air pollutants. The stationary sources of air pollution include thermal power stations, refineries, factories, power plants and boilers. Petroleum refineries are responsible for hydrocarbons and particulate pollution. In India, industries such as steel and iron, fertilizers, pulp and paper mills, thermal power plants, copper/aluminium/zinc smelters, oil and cement refineries are major stationary sources of pollution (CPCB, 2000a).

Other sources: Packing and disposal of packages generate pollution, dust from fertilizers, livestock feedlots; mining operation, insecticide, radioactive fallout etc are other sources of air pollution.

Air pollution results from gaseous emissions, mainly from industries, thermal power stations, automobiles, domestic combustion, etc. Besides, volcanic eruptions, forest fires, natural organic and inorganic decays let out large quantities of harmful dust and sulphurous gases. Industries and automobiles give out huge amount of gases like carbon monoxide, nitrogen oxide, fluorides and large amounts of carbon particles, called smoke. Petroleum refineries are the other major source of gaseous pollutants, especially SO_2 and NOx. Cement factories emit large amount of dust. Food and fertilizer industries also emit many gaseous pollutants. Thermal power stations produce a considerable amount of fly ash, SO_2 and other gases and hydrocarbons. Solid wastes are a major source of air pollution in urban areas. Backyard burning and open burning of the heaps of the solid wastes results in the emission of smoke and gaseous pollutants such as carbon monoxide, oxides of nitrogen etc.

Common air pollutants: Air is easily polluted by gases, smoke, dust, etc. which are lighter objects and get mixed up in atmosphere. Some of the significant air pollutants are:

1. **Nitrogen Oxide:** Oxides of nitrogen are a mixture of gases that are composed of nitrogen and oxygen. Oxides of nitrogen include nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), dinitrogen trioxide (N_2O_3) and dinitrogen pentaoxide (N_2O_5) which are generally represented by the symbol NOx. Out of these two more toxicologically significant pollutants among them are nitric oxide (NO) and nitrogen dioxide (NO_2). The main source of the nitrogen oxides is the combustion of fossil fuels (Coal, gas, and oil). Natural source of nitrogen oxides include volcano. Nitrogen oxides are important gaseous air pollutants which arise due to burning of fossil fuels in power plants and automobiles.
2. **Oxides of Carbon:** The important pollutants of carbon are Carbon dioxide (CO_2) and carbon monoxide (CO) which are produced by cigarette smoking, automobiles, burning of fuels in houses, industrial plants, power houses and carbon dioxide is also produced by respiratory activity of animals and plants. CO is colorless, odorless and tasteless gas which is very toxic air pollutant. Carbon monoxide combines with atmospheric oxygen to increase carbon dioxide concentration in the atmosphere. This will adversely affect the environment by leading to ozone depletion and global warming.

3. **Sulphur compounds:** Sulphur dioxide is a colorless, acidic gas with a pungent and suffocating smell. These include Sulphur dioxide (SO_2), Hydrogen sulphide (H_2S) and Sulphuric acid (H_2SO_4). Sulphur dioxide is originated primarily from the combustion of coal and petroleum. It is estimated that Sulphur dioxide remains in the air for an average of two to four days. In the atmosphere, Sulphur dioxide reacts with moisture to form Sulphuric acid (H_2SO_4) which causes many respiratory diseases. H_2SO_4 and acid rainfall reduces forest growth.
4. **Photochemical oxidants**: It is formed by photochemical reactions between primary pollutants like oxides of nitrogen and hydro-carbons. The oxides of nitrogen react with unburnt hydrocarbons derived from incomplete combustion of automobile fuel in presence of sunlight, e.g., peroxyacetyl nitrate (PAN), ozone, aldehydes and other organic compounds in the air. These are called secondary pollutants.
5. **Hydrocarbons:** Compounds of hydrogen and carbon are called hydrocarbon such as- ethane, methane etc. The chief sources of hydrocarbons are motor vehicles; they are emitted by evaporation of gasoline through carburetors, crank case, etc. Methane is produced during decay of garbage and aquatic vegetation and also released by burning of natural gas and also from factories. From amongst many, the chief air pollutants are methane, benzene, and benzopyrene. Benzene a liquid pollutant is emitted from gasoline. It causes lung cancer. Benzopyrene is most potent cancer-inducing hydrocarbon pollutant. Hydrocarbons are the principle constituents of natural gas and petroleum products.
6. **Fluoride:** Fluoride is a wide spread, non biodegradable and relatively persistent pollutant. Fluoride in atmosphere come from industrial process of phosphate fertilizers, aluminum, ceramics, fluorinated hydrocarbons (refrigerants, aerosol, propellants etc), fluorinated plastic, uranium and other matters. Anthropogenic fluorine emitted into the atmosphere is highly reactive and readily hydrolyzes to form hydrogen fluoride (highly corrosive and irritant gas).
7. **Particulate pollutants:** These are fly ash, dust, grit and other suspended particulate matter (SPM) released from power plants and industries (stone crushers) etc. There are also bacterial cells, fungal spores and pollens in air as biological particulate pollutant.
8. **Aerosols:** An aerosol is defined as a suspension or dispersion of fine solid particles or liquid droplets in air or another gas such as- Smoke, mist, fog etc. Aerosols are such as fluorocarbons (carbon compounds having fluorine) released by jet aeroplane emissions causing thinning of ozone layer which forms a protective shield against harmful ultraviolet radiations reaching the earth.
9. **Radioactive substances**: A large number of radioactive elements are released in the atmosphere from atomic power reactors. It happens due to the release of radioactive substances into the environment during nuclear explosions and nuclear weapons testing, production and decommissioning of nuclear weapons, the mining of radioactive minerals, the handling and disposal of radioactive waste, and accidents at nuclear power plants.

10. **Metals**: These include chiefly lead, nickel, arsenic, beryllium, tin, vanadium, titanium, cadmium etc; present in air as solid particles or liquid droplets or gases. They are produced mostly by metallurgical processes, automobiles, seaspray etc.

Effects of air pollution: Air pollution has a performed influence on the biological system and environment. Some major effects of air pollution are as follows:

1. **On human health:** Many gaseous and particulate pollutants have a serious effect on human health. Air borne small, solid particles and liquid droplets are commonly known as particulates. They are present in air in excess and pose a serious threat to air pollution problems. The particulate, matter when entered in the human body system increase blood viscosity, blood flow resulting in blood clot and heart problems. The effects of particulate pollutants are largely dependent on the particle size. Air borne particles such as dust, soot, fumes, and mists are potentially dangerous for human health. The size of particles is directly linked to their potential for causing health problems. Fine particles ($PM_{2.5}$) pose the greatest health risk. These fine particles can get deep into lungs and some may even get into the blood stream. Exposure to these particles can affect a person's lungs and heart. Coarse particles ($PM_{10-2.5}$) are of less concern, although they can irritate a person's eyes, nose and throat. Lung cancer bronchitis, emphysema and asthma are some chronic diseases caused mainly due to exposure to polluted air. Sulphur dioxide cause intense irritation to eyes and respiratory tract. H_2S causes headache, nausea, conjunctivitis and irritation by mucous membranes, collapse, coma and finally death due to respiratory failure. SO_2 forms sulphur particles which, if inhaled regularly can cause bronchitis and asthma. Carbon monoxide when inhaled, it combines with the blood haemoglobin and causes oxygen deficiency. This results in hard breathing, headache and irritation of mucous membranes. Nitrogen oxides and PAN (Peroxyacetyl nitrate, produced photochemically in the atmosphere containing olefins and nitrogen oxides) damage lungs and heart and causes eye irritation. Food and drinks are the most important sources of human fluoride intake. There is a disease of fluorosis, which is due to chronic fluoride intoxication. Several other inorganic gases like ammonia, chlorine and phosgene, cause lung and respiratory tract diseases. The fine dust particles of metals present in the air causes number of diseases. Lead can damage the brain of young children and even cause death; in adults it effects the functioning of nervous system. Cadmium is a respiratory poison and leads to high blood pressure and heart diseases. Mercury can damage the nervous system, liver and eyes, besides headache, fatigue, anxiety, lethargy and loss of appetite. Atmospheric pollution arising from smoke and grit causes lung irritation, asthma, bronchitis, etc. Cotton dust causes occupational disease byssinosis, very common in India. Various kinds of biological particulate matter like bacterial cells, spores and pollens cause bronchial disorders, allergy and many other diseases. In humans, strontium-90 is concentrated in tissue, and causes damage to bone and marrow cells and may also result in production of tumour.

2. **Effects on animals:** The effects of air pollution on domestic animals are similar to those observed in humans. Chronic poisoning results from the ingestion of forage contaminated with atmospheric pollutants. The major metallic contaminants are arsenic, lead and molybdenum. In addition, various fluorine compounds which fall on foliage of plants are eaten by livestock causing abnormal calcification of bones and teeth in them, called fluoride toxicity, i.e., fluorosis. It may cause lameness, loss of weight and frequent diarrhea in animals.

3. **Effects on plants:** Air pollution has adversely effects on plants. Some of them are:

a) High concentration of SO_2 leads to chronic injury in plants. Cotton, wheat, barley and apple are some crops which are fairly sensitive to SO_2. Sulphur dioxide causes chlorosis, i.e., loss of chlorophyll.
b) At higher concentration Carbon monoxide causes leaf drop, leaf curling, reduction in leaf size, premature ageing etc and also inhibits cellular respiration in plants.
c) Fluorides destroy the leaf tissues causing chlorosis and necrosis of leaf apex and margins.
d) The increase in atmospheric NO_2 causes leaf injury and growth retardation in plants.
e) Ozone causes tip burn in pine seedlings. Ozone also damages cereals. Fruits, cotton, crops etc. It also causes immature yellowing and shedding of leaves.
f) Hydrocarbons, such as ethylene, causes epinasty and inhibition of mutation in tomato and sweet pea.

4. **Effect on materials:** Acid rains and photochemical smog affect metals and buildings. The pollutants most destructive to materials are smoke, grit and dust and oxides of Sulphur. Acid rain has a corrosion action on metal surfaces and causes fading of textiles and deterioration of fabrics, corrodes building, monuments, bridges, railing etc. Aluminum and copper and their alloys, iron and steel are corroded when exposed to contaminated air. H_2S decolorizes silver and lead paints.

5. **Effect on environment:** Air pollution impacts the environment by reducing visibility and blocking sunlight, causing acid rain, and harming forests, wildlife and agriculture. Acid rain forms when sulfur dioxide and nitrogen dioxide mix with water droplets in the atmosphere to make sulfuric acid and nitric acid. Winds can carry these pollutants for thousands of miles, until they fall to the earth’s surface as acid rain. A high level of particulate pollution reduces the amount of sunlight that reaches the surface and even changes the appearance of the sky.

   The hole in the ozone layer is caused by air pollutants. Chemicals used as refrigerants, such as chlorofluorocarbons (CFCs), contain chlorine atoms. Releasing chlorine atoms into the atmosphere destroys ozone. The ozone layer blocks harmful ultraviolet-B (UVB) radiation from the Sun. Air pollution includes greenhouse gases such as carbon dioxide and methane. Greenhouse gas pollution is causing climate change. It actually prevents earth from freezing cold temperatures. They trap some amount of heat from Sun and prevent it from escaping earth, thereby maintaining a moderately warm environment which is good enough for living things to survive.

Increased level of greenhouse gases will result in more heat getting trapped on the earth and when there is more heat trapped the result will be an increased in an adverse temperature of earth and this phenomenon is called global warming with the increase of the amount of these gases the heat is also increasing leading to global warming. Melting icesheets, warming oceans, and extreme weather conditions are examples of how climate changes caused by greenhouse gas pollution. When the earth is becoming warmer the polarice cap will start melting and this will lead to the rise in water levels of oceans and seas all across the earth which will cause disaster like floods bring about severe and dramatic climatic changes and also submerge islands and coastal areas.

Prevention and control of air pollution: Problems of environment are so much that all phases of human activity is intimately associated with the environment, release of toxic chemicals, automobiles emissions, nuclear testing, depletion of natural sources have all contributed to the rapid deterioration of the biosphere. Environmental aims at not only controlling pollution problems but also improvement and development of the atmosphere. Some steps to control air pollution are as follows:

(i). Factories and industries should be situated as far as possible from the city limits with in a limited industrial zone.
(ii). The chimneys of factories should be fitted with special fitters such as scrubbers, cyclone separators or electric precipitators to filter out the larger particles of carbon pollutants.
(iii). To check automobile pollution by the use of unleaded petrol, better engines with low emissions and proper maintenance of vehicles.
(iv). Tree plantation should be increased which will reduce carbon dioxide contents of the environment and make it pure by releasing oxygen.
(v). Indiscriminate use of pesticides and biocide should be checked.
(vi). Appropriate acts are required to control air pollution by motor vehicles, industries, etc. We have air pollution boards at central and state level. They can issue and cancel licenses to polluting industries enforce emission standards and frame rules and regulation for the control of air pollution.
(vii). The automobile industry should manufacture battery operated and solar energy operated cars rather petrol or diesel run vehicles.
(viii). Excessive and undesirable burning of vegetation should be stopped.
(ix). Nuclear explosion should be avoided.

The most important and fundamental programme for dealing with environment problems is to impart environmental education. Every citizen should be made aware of the problems of environmental pollution.

8.4.2 Water pollution

The term water pollution is referred to any type of aquatic contamination between following to extremes: (i) a highly enriched, over productive biotic community, such as river or lake with nutrients from sewage or fertilizers (cultural eutrophication), or (ii) a body of water poisoned by toxic chemicals which eliminate living organisms or even exclude all forms of life (See Southwick, 1976).

The contamination of water bodies such as ocean, lake, river, ponds, ground water etc, is known as water pollution. Water is typically referred to as polluted when it is impaired by anthropogenic contaminants. The water is one of the greatest natural resources which are helpful in transportation, hydroelectric power, food and ration. Water pollution may be defined as 'the adverse change in composition or condition of the water such that it becomes less suitable for the purposes for which it would be suitable in its natural state'.

The waste products such as vegetable wastes from houses and industries, papers, tins, plastics etc. are creating greater problems for this disposal. A general survey has revealed that nearly 70 percent streams and rivers in our country contain polluted water. Water pollution is one of the most serious environmental problems for the world as a whole. It disturbs ecological balance and cause hazards to public health. The sources of water can be classified as- Point source pollution which originates from a single, identifiable source, such as discharges pipe from a factory or sewage treatment plant and Non-point source pollution which is also called as 'area' or diffuse sources refers to diffuse contamination that does not originate from a single source. For example- sediment, pesticide or nitrates entering surface because of runoff from agricultural farms.

Water quality standards: Dissolved oxygen (DO), Biological oxygen demand (BOD), and Chemical oxygen demand (COD) are important parameters in the assessment of water quality.

1. **Dissolved oxygen (DO):** Water with dissolved oxygen below 8.0 mgL^{-1} may be considered as contaminated and below 4.0 mgL^{-1} heavily polluted.
2. **Biological oxygen demand (BOD):** It is indirect measure of water quality. It is a measure of the amount of oxygen required for biological oxidation by microbes in any unit volume of water at 20^0C in five days. Higher is the amount of oxygen consumed, greater is the degree of organic pollutants.
3. **Chemical oxygen demand (COD):** It is also an indirect measure of water quality. It is a measure of amount of oxygen required to oxidize all the pollutants (both biodegradable and non-biodegradable) in any unit volume of water at 20^0C in five days.

Types of water pollutants: Types of water pollution can be classified by the medium in which they occur such as surface water, ground water, etc.; the habitat in which they occur (such as rivers, lakes, etc.), and the source or type of contamination (such as nutrient pollution, thermal pollution, radioactive pollution, etc.). Water pollutants can be divided in various ways, one simple way is given below:

1. **Organic pollutants**: These comprise the remains of dead and rotting animals and plants. Some synthetic compounds also act as organic pollutant such as- polychlorinated biphenyls, pesticides.

2. **Inorganic pollutants:** It includes inorganic salts, alkalies, mineral acids, metals and their compounds.
3. **Microbiological pollutants:** These include microorganisms like viruses, algae, bacteria, protozoa etc.
4. **Radioactive pollutants:** It includes radioactive substances produced by nuclear power reactors and radioisotope. For example- Radium, thorium, uranium etc.

Types of water pollution: Water pollution may be classified as:

1. **Ground water pollution:** Ground water is present below the surface of ground. It generally considered being safe for drinking, agricultural and industrial purposes. But now-a days, it is no more safe and is heavily polluted in cities and industrial areas.
2. **Surface or fresh water pollution:** Earth's surface water consists of oceans, lakes, rivers, and other waterways. These bodies of water can be contaminated from industrial runoff and inadequate wastewater treatment systems, agricultural runoff, precipitation, seepage etc which is unsafe for humans, animals and plants alike. One of the main sources of pollution is the untreated industrial effluents that are dumped into surface water. As sanitation standards are generally poor, surface water is also contaminated by human waste, soap, detergents, paper, and cloth in addition to industrial pollutants. Additionally, waste is being dumped into water bodies from towns, cities, and rural areas. One of the main causes of water body pollution is the use of fertilizers, pesticides, herbicides, and other chemicals in agricultural practices, such as dichloro-diphenyl trichloroethane (DDT), benzene hexchloride (BHC), etc. In industries like power plants, water is used to dissipate heat from the water. Following its release into water bodies, this heated water has a negative impact on aquatic life. Besides heat, nuclear power plants dispose of nuclear wastes (radioactive material) into water bodies.
3. **Microbiological pollution:** Microbial contamination refers to contamination caused by microorganisms in water. In most cases, this type of pollution occurs naturally, and in many cases the bacteria, protozoa, and viruses are harmless or beneficial to the ecosystems in which they live. However, this is not always the case. , some microbial contaminants can upset the delicate balance of such environments, killing plants and animals and causing disease in those who consume or use the water.
4. **Nutrient pollution:** Fertilizers, pesticides, and other products used in agricultural processes often contain large amounts of nutrients such as phosphorus and ammonia. They are used in particular to protect plants from pests and diseases, or to promote plant growth and maximize yields. When these chemicals enter water sources through runoff, they can cause nutrient imbalances and promote the growth of some organisms (such as algae) while harming others.
5. **Suspended Matter:** Waste such as plastics, rubber, and other man-made materials that are improperly disposed of and that do not readily break down in water are known as particulate or suspended matter. Suspended solids settle to the bottom of water sources, damaging marine life, washing toxic chemicals into drinking water, or floating to the surface, preventing oxygen and sunlight from penetrating into the water

below. When broken down into particles, airborne toxic chemicals threaten the survival of aquatic plants and animals.

6. **Chemical Water Pollution:** Different chemicals are used in different activities such as agriculture, factories and households. Such chemicals seriously pollute and endanger water. Metal waste, chemicals and solvents are often discharged directly into nearby bodies of water. Also, the chemicals used by Farmer to protect plants from insects contaminate the water.
7. **Oxygen Depleting:** There are microbes in water. These include aerobic and anaerobic organisms. Too much biodegradable material (things that break down easily) encourages microbes to grow and consume more oxygen in the water. When oxygen is depleted, aerobic organisms die and anaerobic organisms continue to grow and produce harmful toxins such as ammonia and sulfides.
8. **Oil Spillage:** Oil spills typically affect wildlife only locally, but can spread for miles. The oil kills many fish and sticks to the wings of seabirds, causing them to lose their ability to fly.

Sources of Water Pollution: There are many sources of water pollution. Some of them are as follows:

(i). **Domestic wastes and Sewage:** Sewage is the waterborne waste derived from house (domestic waste) and animal or food processing plants. Discharge of untreated sewage into rivers is primary sources of pollution.

(ii). **Industrial wastes:** Industrial wastes contain a wide variety of organic substances and minerals including cyanides, arsenic, mercury, cadmium, carcinogens, which are toxic to human, animal and plant life. Agricultural drainage carries dangerous pesticide residues and unused fertilizer ingredients. When wastes are let out in the aquatic environment without adequate treatment, they cause water pollution.

(iii). **Oil spills:** Offshore exploration for petroleum is increasing at a rapid rate. The major pollutants due to offshore oil drilling are mercury and oil. The main cause of pollution due to offshore oil drilling is accidental oil spill. These spills may be caused by an oil wall blow out, a platform accident, a large marine pipeline rupture, or a heavily leaking tanker. In this way a large quantity of oil escapes to the environment.

(iv). **Thermal pollution:** Certain industrial processes utilize water for cooling and resultant warmed water has often been discharged into lakes or streams. Coal or oil fired generators and atomic energy plants result into large amounts of waste heat which is carried away as hot water and cause thermal pollution.

(v). **Silt pollution:** Intensive agriculture, earth moving for projects construction, poor conservation practices and downpour with resultant floods result in the increased production of silt in streams and lakes. This load of particulate matter cuts down primary productivity by decreasing the depth of light penetration.

(vi). **Marine pollution:** There are substantial evidence to indicate pollution of coastal waters and open oceans due to the dumping of domestic and industrial wastes, sewage, oil drilling in coastal waters etc. The oceans have the final settling basin for millions of tons of waste products from human activities. Due to oceanic pollution, the marine biotin has been seriously affected.

Table 1: Major Water Pollutants and their different Sources

Source of Pollutants	Pollutant
Organic wastes	Domestic sewage, decay of animals and plants, animal waste and excreta, waste and discharge from food processing factories
Pesticides	Chemicals required to kill insects, weeds, fungi, etc
Microorganisms	Domestic sewage and discharges
Heat	Water discharges after undergoing cooling in industries
Toxic heavy metals	Different factories and plants such as chemical factory
Plants nutrients	Chemical fertilizers
Radioactive substances	Mining of uranium containing minerals
Sediments	Soil erosion due to strip mining and agriculture

Effects of water pollution: Water pollution affects the aquatic ecosystem and human life as well. The various effects are as follows:

(i). **Sewage pollution:** The domestic sewage consists a rich amount of carbon, organic phosphorous and nitrogenous compounds. These elements favour the growth of algae which produce water blooms. It causes depletion of O_2 content, may cause algal obnoxious blooms, floating scums (blanket of algae etc), spread of water borne diseases. Pollution of water promotes vigorous growth of algae and other microbes which results in the development of yellow or grey scum on the surface of water. Sometimes water smells stingy and appears to be coloured. This is referred to as water bloom. Most of the oxygen evolved in algal photosynthesis it utilized by bacteria in oxidizing the organic matter present therein and the water reservoir thus gets depleted of oxygen. In poorly oxygenated conditions, with increased CO_2, fish, other animals and plants die and the clean water is turned into stinking water. Beside, sewage results into epidemics of such fatal diseases as cholera, typhoid, dysentery etc.

(ii). **Industrial pollution:** Most of the rivers and fresh water streams are polluted by industrial wastes which come along waste waters of different industries like fertilizer factories, petro-chemical factories, oil refineries, coal, washeries etc. Industrial wastes of these industries include metals like copper, mercury, zinc etc., chlorine, arsenic, detergents and many more inorganic and organic toxicants. All of these chemicals of industrial wastes are toxic to animals and may cause death or sublethal pathology of the kidneys, liver, reproductive system, respiratory system, nervous system of aquatic animals. Chlorine which is, added to water to control growth of algae and bacteria in the cooling system of power station may persist in streams to cause mortality of plankton fish. H_2SO_4 as acid waste from coal mines increases the hardness of water, has disastrous effect on live organisms and corrodes concrete etc.

(iii). **Effects on aquatic system:** Organic and inorganic wastes decrease the dissolved oxygen (DO) content of water bodies. DO content water is important for the survival of aquatic organisms. The demand of oxygen is directly related to increasing input of organic wastes and is referred to as biochemical oxygen demand (BOD) of water. Higher the BOD, lower would be dissolved oxygen (DO). Hot water of thermal plant and nuclear reactor decreases the decomposition of organic waste and kills the aquatic organisms. The temperature of the water body increases where oxygen content decreases with the rise in temperature. It reduces the 'DO' level of the aquatic system making it incapable of supporting life. Oil spill damage marine biodiversity and also damage coral reef. Industrial effluents result in the addition of poisonous chemicals such as arsenic, mercury, cadmium, lead etc which kill aquatic organisms and may reach human body through contaminated food (i.e, fishes etc) leads to biomagnifications.

(iv). Eutrophication: Eutrophication is the phenomenon of a sudden increase in organic and inorganic nutrient supply in an aquatic environment. These nutrients, which are primarily nitrogen and phosphorus, promote the growth of algae and grazing bacteria, resulting in oxygen depletion. Due to eutrophication there is stimulated luxuriant growth of algae (particularly blue-greens) in water. They form floating scums and water blooms. Decomposition of blooms leads to oxygen depletion in water. Aquatic life begins to die in an oxygen-depleted CO_2 rich aquatic environment, and a clean water body is transformed into a stinking drain. The best method is to treat waste water before discharging it into a body of water. Phosphorus and nitrate dissolved in water act as nutrients, accelerating the growth of algae, which can form a mat on the water's surface. Eutrophication refers to this increased productivity.

(v). Biological magnification: The increase in concentration of contaminated substances or toxic chemicals in the body of living organisms at each tropic level of a food chain is called biological magnification. Such pollutants are non-biodegradable. The contaminants might be heavy metals such as mercury, arsenic, and pesticides such as DDT and polychlorinated. Biomagnifications happens when toxic substances are consumed indirectly by organisms in the higher food chain consumes the lower organism containing such chemicals; the chemicals can get accumulated in the higher organism. Once they are absorbed by an organism, they cannot be metabolized and broken down or excreted out. In other words, it travels through the food chin harming every single stratum. For example:

Water ⟶ Zooplanktons ⟶ Fish ⟶ Humans

In aquatic ecosystems, toxins get consumed by smaller species like zooplanktons, which in turn consumed by fishes. The toxins then travel to human, in such a way that it affects every trophic level. Human beings at the top of any food chain are in the most dangerous situation.

(vi). Effects on human health: The heavy metal contamination of water causes serious ailments of human beings. Mercury poisoning, also known as Minamata disease is caused by consumption of fish captured from Hg- contaminated Minamata Bay in Japan. This disease was detected for the first time in 1952. People can get diseases such as hepatitis by eating seafood that has been poisoned. In many poor nations, there is always outbreak of cholera and diseases as a result of poor drinking water treatment from contaminated water. Lack of pure drinking water could result in a decrease of population numbers. Moreover, if wastes become scarce resources, people are likely to fight for their share and this may even leads to wars. Pathogen contaminated water is responsible for causing many infectious diseases like cholera, jaundice, typhoid, hepatitis etc. Excess of metals and non-metals also causes many diseases. Cadmium poisoning causes itai-itai disease (painful joints and bones). Skeletal fluorosis or knock knee disease is caused due to excess of fluorides. Excess of nitrates in water causes 'blue-baby syndrome'. This is because nitrate combines with hemoglobin of blood to form methaemoglobin which interferes with the oxygen carrying of the blood and it causes blue colouration of a skin.

Control of water pollution: Most cities of developed countries like USA, Britain, etc, and some cities of developing countries like India have evolved certain engineering systems, such as, septic tanks, oxidation ponds, filter beds, waste-water treatment plants and municipal sewage treatment plants for the removal of many harmful bacteria and other microbes, organic wastes and other pollutants from the sewage, before that is discharged into the water body. The various methods for the control of water pollution are discussed below:

1. **Sewage treatment:** One of the methods of preventing water pollution is to treat the sewage properly. This can be achieved by using septic tanks, oxidation ponds and filter beds. In rural and semi-urban areas, sanitary latrines should be provided for the public. Treating waste products before disposing of it in a water body helps reduce water pollution on a large scale. Agriculture or other industries can reuse this waste water by reducing its toxic contents.
2. **Industrial waste water treatment:** Most industrial facilities churn out a lot of waste water that is quite like domestic waste water and can also be treated by waste water treatment plants. Some industries generate waste water with very high concentration of nutrients like ammonia, toxic pollutants (e.g., organic compounds that are volatile heavy metals), organic matter (e.g., grease and oil), need extra and well suited treatment systems.
3. **Chemical treatment:** The main pollutants from agricultural drainage are poisonous pesticide residues and mineral fertilizers such as phosphates and nitrates. The concentration of pesticide is magnified several times as they pass through the food chain of aquatic plants and animals. Such pollution can be controlled if organic fertilizers containing nitrogen, phosphorous and potassium are used in place of mineral fertilizers.
4. **Stabilisation of the ecosystem:** This is the most scientific way to control water pollution. The basic principles involved are the reduction in waste input, harvesting and removal of biomass, trapping of nutrients, fish management and aeration.
5. **Removal of pollutants:** Various pollutants (radioactive, chemical, biological) present in water body can be removed by appropriate methods such as absorption, electrodialysis, ion exchange, reverse-osmosis etc.

Absorption: Activated carbon, a porous, highly adsorbent form of carbon with a huge surface area, is used to treat waste water. Because of adsorption, this treatment eliminates a lot of the substances that cause unpleasant tastes and odours.

Electrodialysis: In this procedure, large tanks equipped with membranes made of sheets of ion-exchange resins are used to expose the waste water to an electrical potential difference. These sheets only allow cations or anions to pass through them. As a result, the anions and cations in the waste water move through the membranes in the direction of the anode and cathode, respectively. The organic matter in the waste water is not removed by electrodialysis.

Reverse Osmosis: In this method, fresh water and waste water are separated using a semipermeable membrane (SPM), which is permeable to water but impermeable to dissolved materials. Waste water is subjected to pressure that is significantly higher than the osmotic pressure of the waste water, which forces pure water to the other side of the membrane. This process is known as reverse osmosis (RO). Both organic and inorganic matter are removed from the waste water.

Ion exchange: Ion exchange resins may be involved in the process. Cation-exchange resins exchange H^+ ions for metallic cations found in waste water, whereas anion-exchange resins exchange OH ions for chloride and other anions found in water. Sulphuric acid is used to regenerate cationic resins and sodium hydroxide is used to regenerate anionic resins, making this process convenient. Ion exchange process is highly effective and produces high quality water.

6. Marine pollution should also be checked, especially in sensitive coastal ecosystems. This can be done by avoiding oil spills, curbing developmental activities on the coastal lines and avoiding the dumping of toxic wastes.
7. The government has undertaken several projects to clean the rivers, the first of which was the Ganga Action plan.
8. Afforestation should be encouraged.

8.4.3 Soil pollution

Soil may be defined as “the upper loose layer of the earth suitable for plant growth”. The process of soil formation is very slow and is governed by geological, biological and climatology factors. There are several natural and synthetic materials that adversely affect the physical, chemical and biological properties of soil and seriously affect its productivity. Soil pollution can be defined as the occurrence of toxic chemicals in the soil and any substance that reduces the productivity of soil is called soil pollutant.

According to Environmental pollution centers, Soil pollution is, “the presence of toxic chemicals (pollutants or contaminants) in soil, in high enough concentrations to pose a risk to human health and the ecosystem. In the case of contaminants which occur naturally in soil, even when their levels are not high enough to pose a risk, soil pollution is still said to occur if the levels of the contaminants in soil exceeds the levels that should naturally be present”.

Sources of soil pollution: Soil pollution is an extremely complicated process. Polluted air and water combinedly effect the pollution of soil. Air polluting gases like SO_2, NO_2 etc; when reach on the earth surface with rain water cause soil pollution. Fallout from atmospheric pollution also contributes to soil pollution. Disposal of industrial and urban solid wastes is the major source of soil pollution. The industrial wastes are mainly discharged from coal and mineral mining industries, mental processing industries and engineering industries. They contain toxic metals such as lead, copper etc. Urban wastes comprise both commercial and domestic wastes including dries sludge of sewage. Agricultural practices also pollute the soil. Since agriculture is becoming more and more intensive, increasing quantities of fertilizers, pesticides and soil conditioning agents are used. The residues of these materials cause several soil pollution problems. Digested sewage sludge which is used as manure also causes soil pollution. Faculty sanitation and waste water are also responsible for soil pollution.

Causes of soil pollution: Soil pollution is a complex phenomenon, and it can be triggered by a variety of things and activities. Some causes of soil pollution are following:

1. **Industrial wastes:** These pollutants affect and alter the chemical and biological properties of soil. As a result, hazardous chemicals can enter into human food chain from the soil or water, disturb the biochemical process and finally lead to serious effects on living organisms.
2. **Urban wastes:** Every human produces a certain amount of personal waste products by way or urine and feces. Even the sewer systems end at the landfill, where the biological waste pollutes the soil and water.
3. **Accidental oil spills:** Oil leaks can happen during storage and transport of chemicals. This can be seen at most of the fuel stations. The chemicals present in the fuel deteriorate the quality of soil and make them unsuitable for cultivation.
4. **Acid rain:** Acid rain is caused when pollutants present in the air mix up with the rain and fall back on the ground. The polluted water could dissolve away some of the important nutrients from the soil and change the structure of the soil.
5. **Inorganic fertilizers**: Excessive use of inorganic nitrogen fertilizers leads to acidification of soil and contaminate the agricultural soil.
6. **Solid waste**: Disposal of plastics, cans, and other solid waste falls into the category of soil pollution. Disposal of electrical goods such as batteries cause an adverse effect on the soil due to the presence of harmful chemicals, lithium present in batteries can cause leaching of soil.

Effects of soil pollution: Some of the soil pollution effects are:

1. **Effect on Human Health:** Crops and plants are grown on polluted soil absorb much of the pollution and then pass these on to us. Long term exposure to such soil can affect the genetic make-up of the body, causing congenital illness and chronic health problems that cannot be cured easily. In fact, it can sicken the livestock to a considerable extent and cause food poisoning and a big period of time. Soil pollution

may cause a variety of health problems- headache, nausea, fatigue, skin rash, and eye irritation.

2. **Effect on plants:** The pollutants consumed by the plants from the soil, making them nutrition less. At the extreme level of consumption, they are becoming poisonous i.e., injurious to health. The acid rain is also one of the major soil pollution effects. Due to increased pH levels leads to death of plants growing in this soil.
3. **Effect on Economy:** Soil pollution results in degradation of crops grown. The crop produced in polluted soil is less or is of inferior quality, which affects on the sales of crop. Declining the income to an average farmer whose livelihood is entirely dependent on the crops.
4. **Effects on Ecosystem:** Soil pollution reduces soil fertility due to increase in alkalinity, salinity, pH and nitrogen fixation due to the reduce number of nitrogen fixers. Soil is an important habitat for different types of microorganisms, insects, etc. Thus change in the chemistry of soil can negatively impact the lives of the living organisms and result in the gradual death of many soil organisms (For e.g. - earthworms), which can lead to alteration of soil structure.

Control of soil pollution: Soil pollution has been a major cause of concern for many nations now. It is also essential for the public to have awareness of the harm they are knowingly or unknowingly causing. Strict penalties must be imposed on law violators.
There are different measures for the prevention and control of soil pollution are listed below:

1. **Domestic waste control:** Products such as glass, paper and fabric wrapping can be used indoors to reduce soil pollution. The household wastes such as plastics and the electronic waste being sent to the landfill.
2. **Waste management:** Soil pollution can be controlled by using proper disposal methods. The garbage from the factories should be sent to the purifying plants first and they should be immersed only after proper treatment.
3. **Reducing the use of artificial fertilizers and pesticides:** Organic farming practices should be increased. Biological fertilizers should be used instead of chemical fertilizers. Organic methods can also help to control crop pests and diseases, which can reduce soil pollution.
4. **Physical methods**: By using the correct temperature, indirectly or directly through the heating system, pollution fumes can escape from the evaporation process.

8.4.4 Noise Pollution

Noise is an unwanted sound or sound without agreeable musical quality. Noise is generally defined as an unwanted sound into the atmosphere. It is that form of sound energy which is not appreciated by human ears. The word noise has been derived from latin word ‘nausea’ which meant unpleasant sound. Sound travels in pressure waves and effects ear drums. The intensity of sound is measured in decibel (dB). Some people feel discomfort with sound of 85 dB, whereas most do not feel discomfort with sound of 115dB. Pain is usually felt at 145dB. According to World Health Organization (WHO), a level of 45 dB is considered a safe noise level for city. By international standard, a noise level up to 65 dB may be taken as tolerable. Noise level above 80 dB causes noise pollution. Noise is a physical form of pollution and has no persistent effects on the life-supporting systems but it has direct effects on the recipients. Modern civilization creates more and more noise and now it has become a major environmental pollutant. The World health Organization stated that “noise must be recognized as a measure threat to human well being”.

Sources of noise pollution: The main sources of noise pollution are industries, transport vehicles and home appliances. Trains, trucks, buses, motor cycles, cars, scooters, jet planes etc, are major sources of noise pollution. Modern domestic gadgets such as food blenders, exhaust fans, desert coolers, air-conditioners, vacuum cleaners, television, radios, dish washer etc.

Table 2: Intensity of Sound and Noise Sources

Noise Source	Intensity of Sound (dB)
Breathing	10
Sound of leaves	20
Whispering	30
Normal conversation	30-40
Homes and Restaurant	45-50
Loud conversation	65
Lawn mower	60-80
Vacuum cleaner	80
Traffic noise	60-90
Heavy trucks	90-100
Thunderstorm	110
Rock music	120
Jet take off (100 m distance)	120
Jet engine (at 25 m distance)	140
Rocket Engine	170-180

Effects of noise pollution: Noise is a form of pollution causing greatest concern to public. Continued exposure to high levels of noise results in permanent hearing loss, and there is increasing evidence that noise may have other physiological and psychological effects. The various effects of noise pollution on human beings are given below-

1. **Hearing problems:** Any unwanted sound that our ears have not been built to filter can cause problems within the body. The short-term auditory effects of noise include some temporary loss in hearing at high noise levels. Explosions or other high intensity sounds may cause immediate deafness by rupturing the ear drums or damaging the cochlea.
2. **Health issues:** Noise can create sleep disorders. Frequent and prolonged sleep disturbances can result in physical, mental or emotional illness. Noise pollution can cause dilation in the pupils of the eye. Noise pollution also takes a toll on the heart. This could lead to side-effects like elevated heart beat frequencies, palpitations, breathlessness etc.; insomnia as a result of lack of undisturbed and refreshing sleep.

3. **Trouble communicating:** High decibel noise can put trouble and may not allow two people to communicate freely. Constant sharp noise can give you a source headache and disturb your emotional balance.

Control of noise Pollution: Some control measures to combat noise pollution are as follows-

1. Industrial noise pollution can be controlled by reduction of noise at source, sound proofing of the noise producing machinery or equipment.
2. Control of noise at source may be achieved by designing and fabricating silencing devices and their use in air-craft engines, tracks, cars, auto-scooters and industrial machines.
3. A uniform law should be introduced for controlling and abatement of noise.
4. The use of loud speakers and other noise producing activities should be banned during nights.
5. Noise-free zones should be introduced for controlling and abatement of noise.
6. Public awareness to the hazards of noise should be aroused.

8.4.4 Radioactive pollution:

Radioactive pollution is defined as the increase in the natural radiation levels caused by human activities. It is physical pollution of air, water and soil with radioactive materials for example- uranium, thorium, radium etc. Radiation substances are also major source of environmental pollution. Radioactive pollution is a sub-category of what is broadly known as radiation pollution. Radioactive materials cannot be destroyed and hence they have cumulative effect. Radioactive pollution is the chief type of radiation pollution caused by radionuclides as they emit hazardous radioactive rays, namely x-rays, beta-rays and gamma rays, which are ionizing radiations capable of causing genetic mutations in living organisms.
Radioactive pollution occurs when there is presence or deposition of radioactive materials in the atmosphere or environment, especially where their presence is accidental and when it presents an environmental threat due to radioactive decay. Radioactive pollution refers to the increase in radiation that is injurious to life. The main radiation hazard comes from ionizing radiations (x-rays, beta rays etc).

Types of radiation: Radiation is classified as being ionizing or non-ionizing. Electrically charged molecules and atoms are called ions. The radiation that can produce ions is called ionizing radiation. Both types can be harmful to human and other organisms.

(i). Non-ionizing radiation: It is electromagnetic radiation with a comparatively long wave length. In comparison to ionizing radiation, non-ionizing radiation is generally regarded as less dangerous, such as microwave, radio wave, and ultraviolet. However, some types of non-ionizing radiation, like ultraviolet, can harm biological molecules and result in health issues.

(ii). Ionizing radiation: It is the short-wavelength radiation or particle radiation produced by some unstable isotopes as a result of radioactive decay. For example- Alpha and beta particles or gamma rays. They can cause other items to release their electrons.

They can damage biomolecules such as nucleic acid, protein, lipids causing cancer and even death.

Human exposure to radiation is usually measured in rems (Roentgen equivalent man) or mili rems (10-rems), a measure of the biological damage to tissue. In S.I. units, the exposure is measured in Sieverts (SV). One rem equals 0.0100 SV. They give an estimate of the potential damage radiation might do to a sample of living tissue. The effects of large dose (1000 to 1000,000 rems) are easily seen and can be quantified, because there is a high incidence of death at these levels, moderate dose (10- 100 rems) are known to increase the risk of cancer and birth defects. The higher the dose, the higher the incidence of abnormality. Lower doses may result in momentary cellular changes, but it is difficult to demonstrate long term effect.

Table 3: Biological effects of radiations

Source	Dose	Biological Effect
Nuclear bomb blast or exposure in a nuclear facility	100,000 rems/incident	Immediate death
	10,000 rems/incident	Coma, death within one or two days
	1000 rems/incident	Nausea, lining of intestine damaged, death in one to two weeks
X rays for cancer patients	100 rems/incident	Increased probability of leukemia
	10 rems/incident	Early embryos may show abnormalities
Upper limit for occupationally exposed people	5 rems/year	Effects difficult to demonstrate
X ray of the intestine	1 rem/procedure	Effects difficult to demonstrate
Upper limit for release from nuclear installations (except nuclear power plants)	0.5 rem/year	Effects difficult to demonstrate
Natural background radiation	0.-0.3 rem/ year	Effects difficult to demonstrate
Upper limit for release by nuclear power plants	0.005 rem/year	Effects difficult to demonstrate

Sources of radiation pollution: The elements which emit ionizing radiations are known as radioactive elements. There are three main types of ionizing radiations which are emitted from radioactive compounds-alpha particles, beta particles and gamma rays. Alpha particles are positively charged and alpha rays arise from the disintegration of unstable isotopes of elements having atomic weight >150 and travel only a few centimeters in the air and produce large amount of energy by collisions. Beta particles are negatively charged. Beta rays are high speed electrons travelling a few meters in air. Gamma rays are electromagnetic radiations of short wavelengths with much more energy. These rays travel great distances. Other ionizing radiations are x-rays which are similar to gamma rays. Sources of environmental radiations are natural and man-made.

1. **Natural Sources:** This includes cosmic rays that reach the surface of the earth from space and terrestrial radiations from radioactive elements present in the earth's crust.

The primary sources of natural radiations are the ores of Uranium and thorium. These contain a wide variety of radioactive nuclides. Many radioactive elements such as radium 224, uranium 235, uranium 238, thorium 232, radon 222, potassium 40, carbon 14 occurs in rocks, soil and water.

2. **Man-made sources:** Man-made radiation originates from the activities of man associated with the use of radioactive materials. The important man-made sources are as follows:
   (i). Radioactive wastes generated during the mining and processing of radioactive minerals. Radioactive waste is spread through the earth's atmosphere. It is called fall out. Example nuclear attack on Hiroshima and Nagasaki.
   (ii). Nuclear power plants emit radiation to very small extent except accident (Chernobyl incident and Fukushima Japan). Nuclear weapons tests produce large amount of radioactive elements into the environment and make other materials also radioactive. They include strontium 90, cesium 137, iodine 131 etc. The radio nuclides settle down with rain contaminating the soil and water bodies. These enter into food chain causing serious problems to the living organisms.
   (iii). The nuclear power plants produce a lot of nuclear radio-active wastes. The disposal of these wastes has become a global problem. Some countries producing large quantity of nuclear wastes dump in ocean near other countries.
   (iv). Radio-isotopes are also prepared artificially either by nuclear fusion or by nuclear fission. If these radio-isotopes are not properly handled, these emit radiations causing pollution.
   (v). Mobile phone produces radiations which can also cause cancer.
   (vi). A number of radioactive isotopes are used in medicine either for treatment or diagnostics. These can be left to decay over a shorter period after which they are disposed as normal waste.

Other Sources: The cell phones, cordless phones, cell phone towers, TV's, Computers, microwave ovens, military and aviation radars, broadcast antennas, wireless internet and satellites are all sources of radiation. And so are the common medical x-rays. Infact, the use x-rays for medical diagnosis constitutes an important source of radiation pollution as they are highly penetrating in nature and are detrimental to the living cells. Some of the radioactive elements (isotopes) are used in experimental laboratories for scientific researches which cause radioactive pollution.

Effects of radioactive pollution: Man is the final victim of radioactive pollution and is at the end of all reactions and interactions. Effect of radioactivity was noted in early 20th century (1909) when minor working in uranium mines suffered skin burning and cancer. Marie curie, the Nobel prize laureate for discovery of radioactivity in 1903, became victim of radioactivity and died of leukemia.

Direct contamination occurs through exposure to radiation by radioactive particles in air, radioactive gases, and absorption of contaminants by respiratory tract. Indirect contamination occurs by the consumption through food chain.

1. **Effect on Human:** The biological effects of radiation may be somatic or genetic. The somatic effects are the direct results of the action of radiation on the body cells and tissues. Such effects occur within an individual's life time and appear in the form of skin damage, eye cataracts, damage to liver, spleen and thyroid, and reduced fertility. However, most genetic effects are brought about by man-made radiations. The greatest damage is on the dividing cells, causing cancers, abnormal births and mutations affecting future generations.
2. **Effects on Wildlife:** The higher-level organisms get more affected than insects and flies. Herbivores especially cattle, graze the contaminated land. The radionuclides enter their metabolic cycles and affects their DNA's this ends up having a mutated animal generation with a higher risk to health issues by just a small amount of radionuclides.
3. **Effects on vegetation**: Effect of radiation on vegetation is worse. Due to the increase in ultraviolet waves which is directly proportional to the amount of exposure damage the plants. Different parts get affected differently. The stomata stop to stop the evaporation during the increase of radiation. When the chromosomes are hit the reproduction is disturbed, resulting plants in altered shapes, size and health. Many affected plants deleted by high amount of exposure.
4. **Effects on Sea life:** The power plants releasing radio isotopes into the water since decades. Few are cesium, radon, crypton, ruthenium, zinc and copper. These radionuclides can be detected in the soft tissues or on the bones of the fishes. Radioisotope of ruthenium found in sea-weed.

Control of radioactive pollution: Radioactive is not only affects the individual but also future generation. As there is no cure for radiation damage, all efforts should be made to prevent radioactive pollution. It can be reduced by the following ways-

1. Leakages from reactors, careless handling, transport and use of radioactive fuels, fission products and radioisotopes should be totally stopped.
2. Radioactive pollution weeds to the stored in specialized containers, which do not break easily and which do not allow radiation to seep out.
3. Proper use of radiation technology in hospitals to avoid injuries to technicians and patients.
4. Industrial wastes may be discharged into the environment only after necessary treatment so that the radioactivity is at a lower level. Radioactive wastes can be buried into mine repositories, subsea-bed, ice sheet, very deep hole or thrown into space or transmutated. The wastes may be sealed in concrete-filled steel drums and discharged to a depth of 1000 fathoms (1 fathom= 6 feet) or more in sea.
5. Use of nuclear weapons should be completely banned.

8.4.5 Solid Waste Pollution

Solid waste is any trash, refuse, or sludge that comes from a waste water treatment facility, a water supply treatment facility, a pollution control facility, or other wasted materials from business, industrial, commercial, mining, agricultural, and community activities. Every action we take leaves some type of garbage behind.

Solid wastes are useless and unwanted substances that are discarded by human society. The solid waste includes glass containers, plastic containers, polythene, automobile spares, and building materials etc. that are thrown away as garbage. Solid waste is generated from industrial, residential and commercial activities in a given area and may be handled in a variety of ways. The solid wastes are causing a great problem globally. In India also several million tons of solid waste is dumped along highways and other places in large cities, there is a problem of disposal of these wastes.

Types of solid waste: Some major types of Solid waste are as follows:

1. **Muncipal solid waste**: It is solid waste from a city, town or village that requires routine collection and transport to a processing or disposal site. It contains food waste, paper, plastic, news paper, glass bottles etc. It is non-hazardous.
2. **Hazardous waste**: Hazardous wastes are the substances which causes hazard to plants, animals and human beings. Few of the common hazardous waste is biological wastes, radioactive substances, chemicals, explosives and flammable wastes. It can cause harm to human and the environment. Some of them are pesticides, heavy metals, gasoline, alcohol, acids, base etc.
3. **Industrial waste**: Food processing industries, chemical and pharmaceutical units, breweries, sugar mills, paper and pulp industries, fertilizers and pesticide industries are major ones which discharge toxic wastes.
4. **Agricultural wastes:** The waste generated by agriculture includes waste from crops and livestock. Some agro-based industries produce waste e.g., rice milling, production of tea, tobacco etc. Agricultural wastes are rice, husk, degasses, ground nut shell, maize cobs, straw of cereals etc.

Factors affecting solid waste pollution: People have a habit of using various things and throwing them away. In affluent societies, per capita consumption is so high that people throw away many items on a regular basis, significantly increasing solid waste. The per capita generation of MSW (Municipal Solid waste) in class one cities is in between ranges from 100 to 500 gm/day/cap. The mixed solid waste other than fecal matter (produced at an average rate of 500g per capita per day wet weight). is thrown out in a dump to be collected by municipal workers. It is estimated that 291 class I, and 345 class II towns together generate 52,000 tonns of MSW/day, which corresponds to per capita generation of 0.346 kg/day. Out of this only about 2832 tonns/day of MSW gets properly treated. Waste collection efficiency is less than 50 % in many cities. According to Central Pollution Control Board (CPCB) solid waste generated in small, medium and large cities is –Small cities-0.1kg, Medium cities-0.3-0.4 kg, large cities- 0.5 to 0.6 kg.

Effects of solid waste pollution: Due to improper waste disposal systems particularly by municipal waste management teams, waste heap up and become a problem. People clean their homes and places of work and litter their surroundings which affect the environment and the community. This type of dumping of waste material forces biodegradable materials to not decompose under improper, unhygienic and uncontrolled conditions. After a few days of decomposition, a foul smell is produced and it becomes a breeding ground for different types of disease causing insect as well as infections organisms. Solid wastes from industries are a source of toxic metals, hazardous wastes, and chemicals. When released to the environment, the solid wastes can cause biological and physicochemical problems to the environment and may affect or alter the productivity of the soils in that particular area. Leachates from refuge dumps perlocates into the soil and contaminate underground water. Rats dwelling with infectious solid wastes may spread diseases like plague etc.

Solid waste management: The process of collecting, treating, and disposing of solid wastes is known as solid waste management. Solid waste includes garbage from the home, the agriculture, or even industries. After being collected at the source, the garbage is further separated and sorted according to known hazardous and recyclable items and hazardous waste that needs to be processed, treated, and disposed of appropriately.

Solid waste should be managed properly. Solid waste can be disposed to land or oceans. Solid waste can also be recovered and reprocessed, a procedure popularly known as recycling. Before disposal or recovery however, the waste must be collected. The principles of solid waste management are Reduce, Reuse and Recycle. The proper management of solid waste is to collect waste from different places, store in the specific places and dispose and use them properly. Collection, disposal and recovery form a part of the solid waste management.

(i). **Collection:** The common method for collection is through trucks. Collection of solid waste by trucks, it’s loading and transport to dumping or recovery site requires much time and energy. Several other devices are thus used to cut down the collection cost.

(ii). **Disposal:** Disposal of solid waste is done commonly through a sanitary landfill, incineration landfill, composting, recycling, pyrolysis etc. The dump is the most popular means of solid waste disposal. Open dumping places far from cities are more suitable for disposal of solid waste.

Sanitary landfill: a method of disposing of trash and garbage in which the waste is buried beneath layers of soil and other materials to minimize contamination of the surrounding area. Each day, the trash had to be placed in trenches and covered with soil. Because it is safer and cleaner than open air-piles, this model is known as a sanitary landfill. Methane is produced as a result of this process, which aids in producing electricity.

Incineration: It is the process of burning municipal solid waste in a well-designed furnace under proper temperature and operating conditions. Reduce municipal waste by weight by approximately 90%, 75%.

Composting: Bacterial decomposition of the organic components of municipal waste leads to the formation of humus and compost, a process called composting. It helps in the disposal of solid waste and the production of valuable manure for crops. It is also known as biodegradation.

Recycling: It is the process of collecting and processing waste materials or turning them into new products. For example, aluminum cans, paper, plastic, wood, iron, scrap iron, bottles, etc.

Pyrolysis: It is the thermal decomposition of waste into gas and solid phases in the absence of the external oxygen/air supply. This process usually takes place at temperatures around 500-600°C. During pyrolysis, plastics and tires are decomposed into small molecules of pyrolysis oil, pyrolysis gas and soot. Pyrolysis oil recovered from the process can be used as diesel generator fuel or burner fuel.

(iii). Resource Recovery: In this process, waste is cleaned, sold to an industry, transported, remanufactured and sold once again to consumers. Materials like paper, metals, glass, organics can be easily recycled. The process aims at reducing energy loss, consumption of new material and reduction of landfills.

8.5 SUMMARY

Environmental pollution may be defined as "undesirable change in physical, chemical or biological conditions of our air, water and soil which may have harmful effect upon human life, or that on desirable species or that may waste or deteriorate our raw material resources. Pollutants which affect the environment are- carbon monoxide (CO), Sulphur dioxide (SO_2), nitrogen dioxide (NO_2), hydrocarbons, particulate matter etc. Pollution are classified as -Air pollution, water pollution, soil pollution, noise pollution, radioactive pollution, solid waste pollution etc. Air pollution may by describe as the imbalance in the quality of air, so as to cause ill effects. Water pollutants adversely affect the physical, chemical and biological health of the aquatic ecosystems, quality of ground water and human health. Proper collection and disposal of domestic sewage is the most important step for preventing water pollution. Soil pollution usually results from different human activities, such waste dumping, agricultural practices, deforestation, mining operations and urbanization. The dumping of solid waste creates both aesthetic and public health problems. Recycling of solid wastes, burning of waste, and utilizing heat to worn residential units, generation of electricity is the best way to control soil pollution. Noise is that form of sound energy which is not appreciated by the human ears. The main sources of noise are various industries, transport vehicles, home appliances etc. Continued exposure to high levels of noise cause hearing loss and various other physiological and psychological effects. Radioactive pollution is a phenomenon of physical pollution to all-life supporting system like air, water and land. Radioactivity is spontaneous disintegration of a radioactive substance which results in the emission of radioactive rays. As there is no cure for radiation damage, all efforts should be made to prevent radioactive pollution. Solid waste pollution is a type of pollution in which the pollutant includes- glass containers, crockeries, plastic containers, polythene etc. Most of the solid waste item can be recycled. Several laws have been enacted in India for controlling environmental pollution.

8.6 GLOSSARY

Air pollution: Degradation of air quality and natural atmospheric condition.

Eutrophication: Release of large amounts of organic matter or phosphate and nitrate into water resulting in lowering of dissolved oxygen concentration.

Pollutant: Substance that causes pollution.
Sewage: Liquid and solid wastes from home and industries.
Noise pollution: The release of unwanted or undesirable sound into the atmosphere is called noise pollution.
Biological magnification: Biological magnification is the process by which specific chemicals accumulate in living things to concentrations that are higher than those found in the inorganic, non-living environment.
Water pollution: Water pollution is the contamination of water sources with substances that make the water unsuitable for drinking, cooking, cleaning, swimming and other activities.
Radioactive pollution: When radioactive substances are introduced or deposited into an environment where their presence is unanticipated or the levels of radioactivity are unwanted, it is referred to as radioactive pollution.
Photochemical smog: Photochemical smog is a type of smog that occurs when the sun's ultraviolet rays react with nitrogen oxides in the atmosphere.
Peroxyacetyl nitrate (PAN): Peroxyacetyl nitrate is an unstable highly oxygenated compound found only in the atmosphere. It is an important intermediate in the formation of ozone, an air pollutant.
Radioactive fallout: Fallout is the radioactive material produced by a nuclear explosion or reactor accident that is released into the atmosphere and eventually falls to Earth. This fallout consists of tiny radioactive particles of dust, dirt and other debris.
Hydrocarbons: Hydrocarbons are organic compounds composed entirely of only two types of atoms: carbon and hydrogen. Hydrocarbons are usually colourless gases with a very weak odor.
Particulate matter: Particulate matter is a dangerous mixture of solid and liquid particles in the air.
Aerosols: Aerosols are suspensions of fine solid particles or droplets in air or another gas.
Metallurgical processes: Metallurgical processes include the refining of metals and the production of metal alloys.
Acid rain: Acid rain consists of water droplets that are highly acidic due to disproportionate amounts of sulphur and nitrogen emitted by air emissions, particularly from vehicles and manufacturing processes.

8.7 SELF-ASSESSMENT QUESTIONS

8.7.1: Multiple choice Questions

1. Eutrophication causes decrease in:
   (a) Dissolved hydrogen (b) Dissolved salts
   (c) Dissolved oxygen (d) All of these
2. Biological oxygen demand is a measure of:
   (a) Amount of oxygen needed by green plants during night
   (b) Amount of carbon monoxide in separately combined with haemoglobin
   (c) Industrial wastes poured into water bodies

(d) Extent to which water is polluted with organic compounds

3. Sound becomes a hazardous noise pollution if its level is above:
   (a) 30 db (b) 80 dB
   (c) 120 dB (d) 150 dB
4. Pollution of water is caused by-
   (a) Industrial effluents (b) Sewage
   (c) Form run off (d) All of these
5. Which of the following is secondary air pollutant?
   (a) SO_2 (b) CO_2
   (c) PAN (d) Aerosol
6. Minamata disease in Japan was the result of water pollution by:
   (a) Lead (b) Radioactive substances
   (c) Mercury (d) DDT
7. Biological magnification' is the phenomenon of:
   (a) Increase in concentration of pesticides (chlorinated hydrocarbons) at successive trophic levels
   (b) Increase in concentration of sewage in water
   (c) Increase in biological activity of micro-organisms
   (d) Biodegradation of sewage waste
8. Acid rain is mainly a mixture of –
   (a) Sulphuric acid and nitric acid (b) Hexane and methane
   (c) Acetic acid and bromine (d) Ascorbic acid and citric acid
9. Carbon monoxide is a major pollution of-
   (a) Air (b) Water
   (c) Noise (d) Soil
10. Global warming is caused due to ___________ concentration of CO_2 in air
    (a) Increased (b) decreased
    (c) Both a and b (d) None

8.7.2 True or False

1. DDT is a biodegradable pollutant.
2. Air is polluted mainly through combustion.
3. BOD is assessed to measure the pollution lead of soil.
4. The best example of a biodegradable pollutant is the domestic sewage which can be rapidly decomposed by natural processes.

Answer Keys:

8.7.1: 1-(c), 2-(d), 3-(b), 4-(d), 5-(c), 6-(c), 7-(a), 8-(a), 9-(a), 10-(a)
8.7.2 : 1-False, 2-True, 3-False, 4-True

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8.10 TERMINAL QUESTION

8.10.1 Short Answer type questions:

1. What are major gaseous pollutants? How do they affect vegetation and human life?
2. What are important sources of air pollution in India?
3. Write short note soil pollution.
4. What is radioactivity? Discuss the man-made radioactive pollution.
5. Write a brief account of solid waste pollution.
6. Discuss biological magnification.

8.10.2 Long Answer type questions:

1. Define Soil pollution. What are the control measures used for controlling soil pollution.
2. What is Water pollution? Give an account of various types of water pollutants.
3. What do you mean by air pollution? Discuss in detail about the harmful effects of air pollution?
4. Describe the sources of air pollution and discuss its prevention and control measures.
5. What is noise pollution? Mentions the steps which can reduce noise pollution.

UNIT-9- GLOBAL ENVIRONMENTAL PROBLEMS AND CONSERVATION STRATEGIES

Contents:

9.1 OBJECTIVES

The present topic provides an overview of global environmental problems and outlines of conservation strategies. After reading this topic, learners will be able to answer the:

- Global environmental problems
- Population explosion
- Climate change
- Loss of biodiversity
- Depletion of ozone layer
- Acid rain
- Pollution of international water
- Conservation strategies of global environmental problems

9.2 INTRODUCTION

In early 1896, Svante Arrhenius, a Swedish scientist predicted that excessive and uncontrolled anthropogenic activities would disrupt the way of the sun interacts with the earth, which would eventually lead to the causes of climate change and global warming. Looking at the present scenario of climate and environmental issues, it seems that his prediction proved to be correct. Global warming, loss of biodiversity, pollution, ozone layer depletion etc are some current burring issues of global environmental problems. All these are not the problems of a particular area or region or country, whereas these are global problems where the whole world is stakeholder and all human beings, plants, animal diversity and our planet paying for it. In analyzing the problems and formulating policy, one has to distinguish between global and universally occurring environmental problems. According to the German Global Change Council "Global environmental problems can be attributed directly or indirectly by human who are the major cause of changes in the oceans, in the atmosphere and on land. These alterations of composition affect the natural metabolic cycle, terrestrial and aquatic ecosystems, as well as the economy and society (WBGU 1995).

Now the world has become aware to restoring damaged, so over the past few decades has set several protocols, conventions and treaties improve global environmental health. The interest in global environmental problems has grown considerably in both practical and theoretical terms, particularly in view of the United Nations Conference on Environment and Development in Rio (UN, 1992). The adopting of global perspective is the only adequate approach to address the causes of environmental problems. For example, if we talk about the profound anthropogenic greenhouse effect that threatens the global climate system. It can be deal only with the international collaboration through the international harmony, agreements, joint efforts and targets.

It is precisely this need that makes an ecologically effective, economically efficient, and socially acceptable solution an enormously difficult proposition. Many national and international standardization and rules are implemented by the internationally or nationality to sustain the environmental health. A major problem facing international environmental policy is that its goals must be implemented by means of voluntary action and enforced by states. There should be mechanisms to induce states to enforce international environmental policy.

In this chapter, we will discuss about all the global environmental problems and their management policies implemented by the nationally and globally in detail.

9.3 POPULATION EXPLOSION

There has been a great deal of talk in recent year about the “population explosion”. It is said that the human population is increasing so rapidly that widespread famine is inevitable in the near future. Apart from this, there are so many of other adverse impacts of overpopulation on human society and the environment. There is an urgent need to control the human population to sustain the ecosystem of earth. This is a very controversial topic, as it linked with the individual’s sentiments, religion, economics, social and political issue.

In this chapter, we will simply look at some of the available information about what has happened to the human population in the past and then we will try to apply some of the principles of ecology to explain the changes in population and talk about the possibilities for the future.

9.3.1 Demography

Demography is the account and statistical analysis of the vital process and movements of human populations. By considering the total human population of the world one finds that the generalized population formula is appreciable: population equals biotic potential minus environmental resistance (Verma and Agarwal 2008). Human population shows an uneven or clumping pattern of distribution on earth. The density of human population in a village, district, provenance, country or any area can be obtained by dividing the total number of people living in the given region by the total land area of that region. The average number of people per square unit of land area tells us how dense the population in a given area is.

According to usage by the demographers, biotic potentials can be expressed in terms of **fecundity**, which is defined as the theoretical or the maximum capacity of the individual to reproduce. **Fertility** is the actual reproductive performance of a given population.

Human **birth rate** is the fertility expressed as the average numbers of live births per thousand population per year. Since not all age groups in a population have equal fertility.

Human mortality rate is the average number of individuals who die per thousand population per year. Again, demographers often use more sensitive measures, for different mortality rates. Both the very young and very old segments of the population have higher mortality rates.

9.3.2 History of human population growth

The ecology of human and trend of growth in population can be studied at the following three levels: primitive man, agricultural man and industrial man.

A. Primitive man: Around 30,000 B.C mankind has spread from Africa to every other parts of the world. Around 9000 years ago, the total human population has been very limited, usually estimated at less than 20 million. Ecologically, the primitive man was and still is omnivorous, in a simple word they were a primary consumer as well as a secoundry or tertiary consumers. However, it does not mean that man could eat everything but that they could eat almost any kind of food and plant products (fruit, tuber, root, seed etc.). Primitive humans are the part of almost all food chains. In fact, as long as man remained at this stage of cultural development, he was just another member of the complex food web of the community. The human population soon reached some maximal population levels in balance with the rest of the community. After that, human began to use fire, they obtained their fuel from the tree wood.

B. Agricultural man: After that around 7000 B.C. certain groups of primitive man began to modifying their environment by domesticating food animals and cultivating some specific plants. They have started hunting wild animals that harm their cultivated products or domesticated animals. During the agricultural revolution, a most sustain a way of life evolved, which allowed the construction of a permanent dwelling in which man could seek shelter. As the life sustain the mortality rate of the newborns decreased and the human population increase rapidly. Around 8000 B.C., the human population is estimated approximately 5 million and by reaching 1650 A.D, it become more than 453 million. The average rate of increasing population this period (7000 B.C to 1650 A.D.) was about 50,000 per year (Verma and Agarwal 2008).

C. Industrial man: As human population is increasing, they constantly modifying their environment accordingly. With the invention of wheel, there seems to be great deal of revaluation in human. Life has become more comfortable. They were move easily in search of food and better environmental conditions. Thus this migration allowing human to gathered in a large population in a favorable place. The discovery and utilization of non-renewable sources (oil and coal) permitted to human population to increase beyond the limits. After this industrial revolution saw that development of tools and machines that resulted in the construction of more and better housing, textile, production of more and better food items, food storage, prevention, transportation techniques and many more. After the development of new techniques and researches in the field of medical science, the mortality rate of the human population decreased and the birth rate became higher than before.

The human population is increasing at an alarming rate. It is estimated that if the current birth rates and death rates are maintained, the human population will reach more than six billion by 2025 A.D. Hence, there is an urgent need to implement family planning measures to maintain the quality of human life and availability of resources.

9.3.3 Factors regulating human population

Human surpass animals in being able to control his environment in some degree but human beings are also control by a number agencies. Some of the major causes are given below:

1. **Scarcity of food:** Due to the unfavorable weather, crop failure, insect attack, and many other reasons, the human population is largely affected, especially on those particular area where the dense human population is resides. Malnutrition may lead to physical impairment with greater susceptibility to disease and death.

2. **Shelter:** Inadequate shelter in extremely cold and hot weather is an important factor to regulate the population.

3. **Natural calamities:** Floods, droughts, earthquake, hurricanes, volcanic eruption etc are some natural calamities claim great toll of human population.

4. **Enemies:** large predatory animal like lion, tiger, leopard, poisonous snakes etc cause many deaths in less civilized regions.

5. **Wars:** Warfare is a form of competition between human races or nations for land, power, resources, trade routes or other desired reasons of human environment. Wars have remained a major mortality factor throughout human history, not only by causing direct battle causalities, but also by stimulating disease and famine.

6. **Disease:** It is the only single cause to control or reducing the human population in a large extends. Diseases like bubonic plague, cholera, typhus, small pox, malaria, yellow fever, sleeping sickness etc has been among the great killers of human population throughout the world in history. A recent example of widespread disease is COVID-19 which has been declared as pandemic by the WHO in 2019. It is a viral disease and cause of nearly 2.6 million deaths worldwide and 121 million people have been infected with the virus since March 2021 (Source: WHO, 2021).

7. **Other reasons:** Explosion, fire, pollution, transport accidents cause many death in modern civilization.

9.4 CLIMATE CHANGE

Climate change refers to a significant long-term change in the global climate. It comprises increase in temperature across the globe or simply called global warming motivated by the uncontrolled human activities including the emissions of greenhouse gases that resulting large-scale shifts in weather patterns. The global warming is the slow increase in the average temperature of the earth's atmosphere because an increased amount of the energy (heat) striking the earth from the sun is being trapped in the atmosphere and not radiated out into space. The major percentage of global warming is shared by the emission of gases in which carbon dioxide and methane contributing more than 90% and causing greenhouse effect. The burning of fossil fuels (coal, oil, and natural gas) is the prime source of these emissions followed by agriculture, deforestation, and manufacturing as an additional contributors.

The increase in land temperature due to global warming is almost twice the global average increase, resulting consequences as expansion of desert land, heat waves, wildfires, change in the pattern of precipitation, rising sea level and changes to land and ocean carbon sinks etc. The Arctic and snow capped areas of polar region are also not untouched by the effects of climate change. Temperature rise also amplified the melting permafrost, glacial retreat and sea ice loss in these regions (IPCC 2019). Apart from above mentioned, the warmer temperatures have also other adverse impacts like causing more intense storms and weather extremes, increasing rates of evaporation, relocation or extinction of many species as their environment changes. Destruction of coral reefs and Arctic region is the most immediate burning examples of the climate change. Climate change have not only the ecological and environmental impacts but also threatens the socio-economic status of the humans including food and water scarcity, extreme heat, floods, infectious diseases, displacement and economic losses. These human impacts have led the World Health Organization to call climate change the greatest threat to global health in the 21st century.

The Intergovernmental Panel on Climate Change (IPCC) has concern about climate change and published a series of reports which highlighted the noteworthy increases in these consequences as warming continues to 1.5°C or beyond (IPCC 2018). Limiting climate change or mitigation consists of reducing greenhouse gas emissions and removing them from the atmosphere can be the best approach to minimize or reduce the impacts of this global problem. Methods to reach the goal include reduce the utilization of fossil fuels, enhanced energy efficiency, promote the low-carbon energy sources such as wind and solar energy, forest preservation and tree fostering (Bargali et al. 2019; Bisht et al. 2021). Adaptation of these methods could only be the techniques for restoration of environmental conditions, ecological protection and better disaster management.

Greenhouse gases

The surface of the earth absorbs the sunlight and subsequently emits it as heat. Greenhouse gases (GHGs) absorb and reemit infrared radiation, slow down the rate at which it can pass through the atmosphere and escape into space (NASA 2019) which ultimately increases the earth temperature. The most common GHGs are:

- **Carbon dioxide or CO_2:** It refers to as a main GHG, contributing a major share (almost 55%) of the total long-term GHGs. CO_2 is produced whenever something is combusted. The primary source of CO_2 emissions is burning of fossil fuels to maintain the constant supply of energy in heating, transport, electricity and manufacturing. In addition, deforestation and manufacturing processes of aluminum, steel, cement, fertilizer etc also release the CO_2 by the chemical reactions. United States Environmental Protection Agency used CO_2 as marker because of its ubiquity. CO_2 is assigned a Global Warming Potential (GWP) of 1.

- **Methane or CH_4:** It is itself an important GHG and produced mainly by the combustion processes and furthermore by the anaerobic decomposition, pig manure ponds, in paddy fields, wastewater, coal mining, as well as oil and gas extraction. Methane breaks down in approximately 10 years, but is a pioneer of ozone. Methane has a GWP of 28-36.

- **Nitrous oxide or N_2O:** It produced as a byproduct of fertilizer manufacturing and a large amount is come from the microbial decomposition of inorganic and organic fertilizer. The combustion of certain materials and many industrial processes also enhance the production of this gas. Nitrous oxide persists a long lasting in the atmosphere and its GWP is 265-298.

- **Fluorinated gases:** They do not have any natural sources of production these gases because these are purely man-made. These were fashioned as replacements for ozone depleting refrigerants. It has proven that these are extremely long lasting in the atmosphere and extremely warming GHGs. At the 100 year point of comparison, their GWPs range from 1,800 to 8,000 and some variants top 10,000.

- **Sulphur hexafluoride or SF_6:** It is used for special medical events, but mainly for what is called a dielectric, especially dielectric liquids. It is used as insulators in high voltage applications such as grid switching gear and transformers. SF_6 remain persists in the upper atmosphere for last thousands of years and has a GWP of 22,800.

Uncontrolled anthropogenic activities, especially burning fossil fuels and extracting have amplified the significant amount of GHGs in the atmosphere, resultant the environmental imbalance (Jonathan 2020). The concentrations of methane and CO_2 in 2018 had increased by about 160% and 45%, respectively since 1750 (World Meteorological Organization 2020). The GHGs have very adverse impacts in all forms of life including flora, fauna and environment. Some are mentioned in Fig 9.1.

Even though prolong emissions of greenhouse gas and deforestation, our Earth is self sustainable in some extent, particularly its forests wealth, remain a noteworthy carbon sink for CO_2. The processes of photosynthesis by the green plants and carbon sequestration by the vegetation and soil compensate the GHGs contributions. The land serves as sink of carbon and is estimated to remove approximately 29% of annual global CO_2 emissions (IPCC 2019). In addition, the ocean also provides a reservoir of carbon sinks through a two-step process. In the first step: carbon dioxide dissolves in the water. After that, the ocean's overturning circulation distributes it deep into the ocean's interior, where it accumulates over time as part of the carbon cycle. It is estimated that the world's oceans have sequestered 20 to 30% of CO_2 over the last two decades (Bindoff et al., 2019).

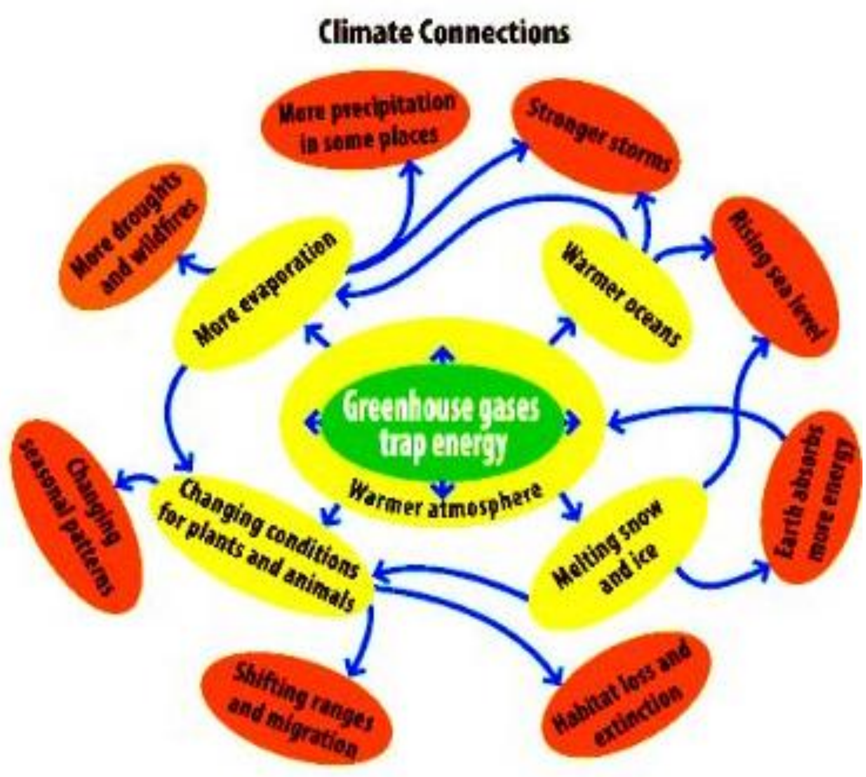

Fig 9.1: Impacts of GHGs (Source: US Environmental Protection agency)

Impacts of climate change

The climate change has the impacts on all forms of lives on the earth including our physical environment. Some are discuss briefly:

(A) Impacts on physical environment: The climate change has the significant impact of our physical environment. This adversely affecting weather conditions, oceans and ice. When we considered the climatic data from past decades and analyze it with today's climate data through the modern observations, we can clearly see changes in Earth's environmental conditions. Some abnormal events like heat waves and droughts appear more common, extremely wet or dry phase during the monsoon, intense rainfall in some regions, cloud bust is likely more common in mountainian region, increasing frequency of typhoons and hurricanes are some consequences of climate change.

The receding and shrinking of glacial is caused rising of global sea level, melting of ice in Greenland and Antarctica due to thermal expansion, increasing warmness of oceans etc change the water cycle of the nature and niche and habitat of many species. Higher concentrations of atmospheric CO_2 have led to alter the ocean chemistry. The oceans become more acidic due to the higher concentration of dissolve CO_2 (Deutsch et al., 2011) and deficient of oxygen because oxygen is less soluble in warmer water. The combine effects of higher dissolve CO_2 and less O_2 cause deoxygenation, eutrophication, loss of biodiversity, migration or relocation of many species, expanding hypoxic dead zones as a result of algal blooms.

(B) Impacts on nature and wildlife: The high concentration of CO_2 in atmosphere, undetermined seasonal changes, drought, intense rainfall and heat waves has reduced the productivity of ecosystem. Climate change also spreading out the drier climate zones for example expansion of deserts in the subtropics (Turner et al., 2020).

The warming has determined a lot of impacts on freshwater and terrestrial species resulted extinction and migration of many species. The oceans are large water bodies, therefore, they warm up slowly as compared to terrestrial region but the rate of migration of species in oceans toward the colder poles is faster than the migration of terrestrial species (Smale et al. 2019). The heat waves extensive are bleaching the beautiful coral reefs (IPCC SROCC 2019). The ocean's organisms like seabirds, fishes, kelp, corals and many more species are frequently facing the challenges of global warming. Acidification of ocean water due to the increasing level of dissolved CO_2 in the water adversely impacting those organisms that produce skeletons and shells like mussels and barnacles.

The more common occurrence of destructive algae bloom is the outcome of climate change. The anoxia, comprehensive mortality of marine life, destruction and disruption of food webs by eutrophication are other noteworthy impacts. Coastal ecosystems are also the subject of meticulous pressure, with roughly half of wetlands having gone as a consequence of climate change and other anthropogenic activities.

(C) Impacts on humans: The impact of climate change on humans has also been detected worldwide in the form of shifting in precipitation due to the warming. The provincial impacts of climate change are commonly observed in all continents. Continuous emission of GHGs leads to further warming and long-lasting changes in the climate system. The climate change affects the humans as:

(i). Food and health: The climate change affects the human health both directly and indirectly. In direct impact, extreme climatic conditions foremost cause of injury and loss of life while famine and malnutrition due to crop failure are the indirect impacts of climate change.

In addition, various diseases such as dengue and malaria are transmitted more easily in a warmer climate. The older people and young children are the most vulnerable to scarcity of food together with severe heat. It is estimated by The World Health Organization (WHO) that approximately 250,000 accompanying deaths/ year in between 2030-2050 due to the excessive heat and increases the number of cases of diarrheal disease, malaria, dengue, coastal flooding, and childhood under nutrition (Springmann et al. 2016) very frequently. Quality of water and air is another major health concerns associated with climate change.

Globally reduction in the yield of some major crops (soybeans, wheat and maize) was observed between 1981 and 2010, affecting food security (Zhao et al. 2017). Warming of sea water crash the fish stocks globally. The provinces at a high risk of climate change those are reliant on glacier water, those already dried out and those small islands of water stress.

(ii) Migration: Gradual but persistent environmental change and sudden natural disasters both influence the nature and extent of human migration in search of better environment and socio-economic conditions.

(iii) Economic impact: The climate change has significant impacts on economy of the world. Global losses unveil speedily intensifying costs due to unpredictable weather events since past decades. However, this warns an increasing vulnerability of social systems to climate change. In a modeling conducted in 2019 revealed that climate change had add on global economic disparity.

Mitigation and adaptation strategies of climate change

(i) Mitigation: The impact of climate change can be mitigated by minimizing the emission of GHGs and by promoting the sinks of those GHGs from the atmosphere. To facilitate limiting the global warming, it requires comprehensive systemic changes on energy, transport, cities, land, buildings, and industry. In order to lessen the stress on ecosystems and improve their carbon sequestration potential, agriculture and forest policy must be change, for example, maintaining natural ecosystems by massive forest plantations.

(ii) Clean energy: By using clean energy, the production and impact of GHGs can be reduced. The long-term decarbonisation situations summit to rapid and important asset in renewable energy (i.e., solar and wind power, bioenergy, geothermal energy, and hydropower (Hsiang et al., 2013; Ranson 2014). Onshore wind and photovoltaic solar are adding some new and cheapest power generation. The utilization of low carbon fuel substitution and electric vehicles in transportation are the best approach to mitigate the impact climate change and improving human health by minimizing air pollution.

(iii) Energy efficiency: Limiting energy requirements is an additional important characteristic of decarbonisation and plans (Kopp et al. 2017). Besides, the directly reducing emissions, energy demand reduction measures provide more flexibility for low carbon energy development.

(iv) Carbon sequestration: Carbon capture and storage (CCS) may be able to play a significant role in limiting CO_2 emissions. Forests are the natural carbon sinks which have the potential to sequester significantly larger amounts of CO_2 beyond naturally occurring levels. Tree planting and reforestation on barren land or non-forest area are among the most mature sequestration techniques. Apart from the carbon sequestration they insure the food security and other by products too. Soil and coastal line area are also help in carbon sequestration.

9.5 LOSS OF BIODIVERSITY

Biodiversity refers to the total number of species present in a given area. It includes both the genetic and species diversity of the organisms occurring in a particular geographical area. The loss of biodiversity is a decline in the number of individuals**,** biological communities**,** loss of variety within species and loss of genetic variability, in given geographic area or ecosystem**.** So, it always imposed overall the negative impact on the productivity and restoration of ecosystem.

In recent times, the composition of both biotic and abiotic components of the ecosystem is undergoing drastic changes. For example: deforestation leads to reduce the shading, change in soil moisture and temperature gradients, loss of natural habitats of many living organisms, and changes in nutrient dynamics that are provide by the ecosystem as ecosystem services (Padalia et al., 2018, 2022). The consequences of these changes direct the abrupt population declines in some species. Declines in genetic diversity that accompany rapid falls in population may increase inbreeding, which could produce a further decline in genetic diversity or biodiversity loss.

Loss rate of biodiversity

It is estimated by the scientists that the present speed of loss of biodiversity is estimated to be hundred to thousand times higher than the naturally occurring background extinction rate, faster than at any other time in human history (Carrington 2021) and probable to still rise in the forthcoming years. The speedily increment in extinction affecting almost all form of life including amphibians, reptiles, birds, mammals and many more etc.

You can calculate by a statement discussed here that how much is situation become depressed and worst. In 2006, many more species were classified as endangered or threatened or rare; furthermore, scientists have projected that millions more species are at risks which have not been formally recognized. In 2021, about 28 percent of the 134,400 species evaluated using the IUCN Red List criteria are now listed as threatened with extinction, a total of 37,400 species compared to 16,119 threatened species in 2006 (IUCN 2021). Some examples of rate of loss of biodiversity are:

- A scientist, Malcom MacCallum, estimated that the existing rate of extinction of amphibians could be 211 times the background extinction rate.
- A testimony of BBC on a global-scale study published in the journal *Science* that found climate change could wipe out 20% of the world's lizard species by 2080.
- According to a joint research conducted by the Zoological Society of London and International Union for Conservation of Nature that 19% of the world’s reptiles are predictable to be threatened with extinction,
- A research article published in journal *Science*, notified commercial seafood and fish species may all crash by 2048.
- A report published in 2013 estimated that 100 million sharks are being killed each year.
- The report of UN’s 3rd Global Biodiversity Outlook also proclaimed that the shallow-water wetlands (i.e., swamps, marshes and shallow lakes) have decreased considerably in several parts of the world.
- A 20-year study has revealed that introduction of non-native species and deforestation has led to about 12.5% of the world’s vegetation to become critically rare.

Causes of loss of biodiversity

The major causes of loss of biodiversity can be divided into two categories:

(a). Natural biodiversity loss: Natural ecological disasters or disturbances, such as flood, hurricanes, earthquake, volcanic eruption, wildfire etc alter the ecosystems drastically by abolishing regional populations of some species and renewing entire biological communities. However, these disturbances are temporary, as natural disturbances are common and ecosystems have adapted more readily to their challenges. The diversity of a particular region is depends on the natural cycle. Seasonal changes affect the biodiversity of the region. For example, the abundance of food and favorable environmental conditions during the summer season trigger reproduction in many species, which ultimately increases the biodiversity. Conversely food shortage and other harsh environmental conditions during the winter season reduce biodiversity as migratory animals leave those regions, warm adapted insects and other organisms die due to extreme winters. Additionally, seasonal changes also alters the food chain as adverse conditions reduce plant and invertebrate populations (plankton and insects) that serve as food for other forms of life. Loss of biodiversity is commonly linked with more enduring ecological changes in landscapes, ecosystems, and the global biosphere.

(b). Anthropogenic biodiversity loss: The disturbance caused by the humans is called anthropogenic disturbance. These possess more long lasting and severe impact on environment. Humans depend on agriculture to full fill their food requirements. It is estimated that approx. 51 million square km of land (half of the world's habitable land) has been changed into agriculture land of which around 40 million square km land is utilized for grazing purpose by herbivorous animals and other livestock. The substantial conversion of natural terrestrial ecosystems has turn down in number of vertebrates which causes enormous loss of biodiversity across the world. The humans population doubled in number between 1970 to 2014. The recent research estimated that existing rate of species loss varies between 100 and 10,000 times the background extinction rate. In addition, a report published by Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services in 2019 claimed that up to 1 million flora and fauna are facing extinction due to excessive human disturbance. Wetland filling, forest clearing, stream channeling & rerouting, concrete construction etc are some frequently occurring efforts that create a substantial change in the ecological course of a landscape. As the population increased, human beings in search of essential livelihood requirements transformed the aquatic as well as terrestrial ecosystems to get maximum benefits from them.

Researchers have identified five important drivers of biodiversity loss. The thread to biodiversity can be summarized in the following points (Fig 9.2).

(i) Casual factors: The uncontrolled human population growth is the main cause of the loss of biodiversity. The increasing population consumes the natural resources which exert the extra pressure on the environment. The over exploitation of resources eventually leads to migration or extinction of many species on that particular region.

(ii) Indirect drivers: There are so many of indirect causes of loss of biodiversity. The primitive humans were migrants and traveled from place to place in search of food and shelter. They were completely dependent upon the forest for their daily requirements. But with the evolution of human beings they got settled in a group and stared living a more stable life. They started agriculture by clearing forests and domesticated some livestock as well. Sooner, urbanization and industrial revaluation make human life easier at the cost of health of the environment.

The hazards produced from the industries as waste cause the different type pollution (water, land, air, sound etc), and complete or partially destruction of so many of species. The whole ecosystem is polluted by various ways and nowadays the situation has become even more pathetic.

(iii) Direct pressures: The direct causes of biodiversity loss include habitat loss and degradation, introduction of invasive species, overexploitation of resources, pollution and climate change.

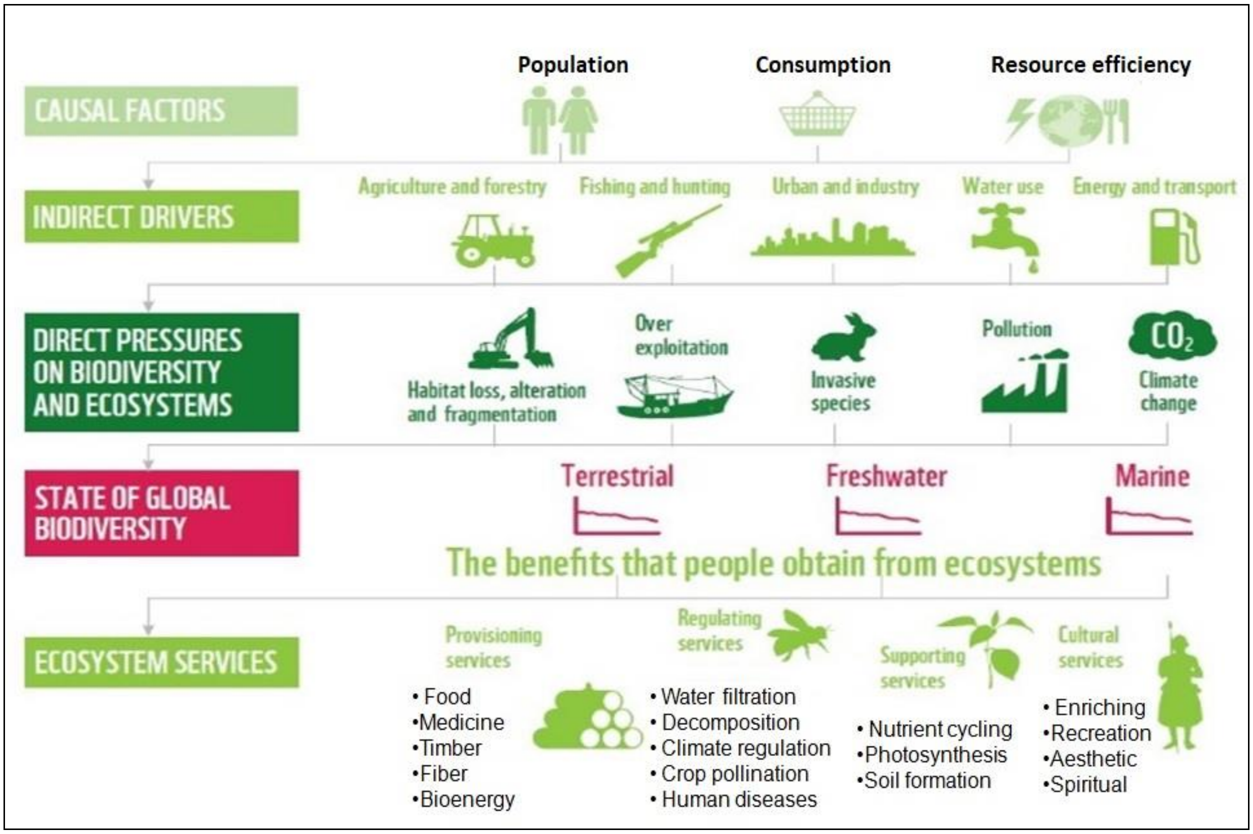

Fig 9.2: Impacts of GHGs (Source: US Environmental Protection agency)

The construction, urbanization, industrialization, deforestation, loss of natural habitat, filling or destruction of wet lands, polluted air, water and land, human greed etc are the major causes of habitat loss of many species. If those species could not migrate or adapt the new environment, they become vulnerable, threatened, and extinct or whip out species.

The invasive species are those species which are not the native species but introduce to a particular region by deliberately or accidently. These species significantly disrupt or modify entire ecosystem for their luxurious growth and impose the adverse effects on the native species of the ecosystem. Invasive species trigger the decline of population of the native species and become the cause of biodiversity loss.

The natural resources full fill many requirements of humans and animals. But the overexploitation of the resources causes loss of biodiversity. In addition pollution is also share a major proportion of loss of loss of diversity. It can be diluted, dispersed, recycled, decomposed, or stored in some harmless form contributes to biodiversity loss by producing health problems in exposed organisms. In some situations, exposure may occur in doses high enough to kill outright or create reproductive problems that threaten the endurance of the species. Global warming coupled with climate change altered the climate of the earth. The major cause of global warming, their effects, ecological and economic impact is already discussed in this chapter in detail.

(iv) State of global biodiversity: There has been drastic decline in biodiversity around the world. The different types of ecosystems including terrestrial, fresh water, marine and wet land ecosystem have adversity affected and their diversity continues to decline. It is estimated in a survey that **o**ver the years, in central Asia and Europe has seen massive decline in biodiversity. As much as 42% of terrestrial plant and animal species have vanished in the last decade. Another sector that is under threat is freshwater and wet land ecosystem. The human activities, including land use, natural resource extraction and pollution, are major reasons for this decline, apart from climate change.

(v) Ecosystem services: Nature serves a lot. They provide lots of benefits to human as ecosystem services. We can categories these services into 4 categories viz., **Provisioning** Services (refers to basic needs of life including food, fruits, vegetables, trees, livestock); **Regulating Services** (includes climate regulation, decomposition, erosion, pollination, water and air purification, carbon storage, flood control**); Cultural Services** (includes cultural, intellectual, and social development**); Supporting Services (**allow the Earth to sustain basic life forms including formation of soils water cycle, nutrient cycling, photosynthesis**).** The overexploitation of all these benefits from the nature is cause the major biodiversity loss. Excessive human interference causes damage the ecosystem and its regulatory factions.

Effects of loss of biodiversity

(i) Ecological effects: The burden of biodiversity loss is most prominent on those species whose populations are constant declining. The individuals threatens and genes loss are the lasting survival of a species, while mates become inadequate and pressure from inbreeding rise when directly linked survivors mate. In addition, the comprehensive destruction of populations increases the risk that a particular species will become extinct.

Diversity in organisms plays an important role in maintaining a healthy ecosystem. Reduction in the diversity threatens the functioning and structure of the ecosystem Declining biodiversity diminish the productivity of an ecosystem (the quantity of food energy which is transformed into biomass) and quality of the ecosystem services (sustainability of soil, water purification, availability of food, shade, climate regulation etc).However, all ecosystems are competent to cope with some degree of stresses with loss of biodiversity. But beyond a critical level of species exclusion or depreciation, the ecosystem can become destabilized and collapse.

The reduction in diversity produces a sort of “ecosystem homogenization” across the regions and biosphere as well. Specialist species (i.e., species tailored to narrow habitats, inadequate food resources, or other precise conditions of environmental) are repeatedly most vulnerable to dramatic population declines and extinction when conditions change. In contrast, some species (i.e., livestock, pets, crops, and ornamental plants) favoured by humans along with generalist species (i.e., species adapted to a broad selection of habitats, food resources, and environmental conditions) become the major component of ecosystems depart from by specialist species. As specialist species and unique species (as well as their interactions with other species) are lost across a broad area, each of the ecosystems in the area loses some amount of distinctiveness and complexity, as the structure of their food chains and nutrient-cycling processes become increasingly similar.

(ii) Social and economic effects: The loss of biodiversity distresses the human society and economic systems as well. Humans depend on a variety of animals, plants, and other organisms for health system, food, shelter, and their accessibility as commodities is important to many cultures. The depletion in biodiversity among these vital natural resources pressures global food security and the expansion of new pharmaceuticals to combat upcoming new diseases.

Financial reduction among frequent food crops may be more obvious than loss of diversity of ecosystems and landscapes distant from global markets. About 75 % of food crops have become wiped out since 1900, mainly due to an overreliance on a few high-yield crop varieties. The loss of diversity among crops threatens food security, as varieties can be vulnerable to various pests, many disease, impact of climate change and introduction of invasive species. Similar tendency take place in livestock production, where high-producing improved breeds of domestic animals and poultry are preferred over lower-producing, wilder breeds. The mainstream health care system as well as the traditional medicines can be derivative from chemicals isolated from the plants and animals. Thus the vanished species symbolize the lost of opportunities to cure and treat of many disease.

9.6 DEPLETION OF OZONE LAYER

Ozone is considered as the protective layer of the earth. This layer is occurs about 9 to 18 miles (15 to 30 km) above the Earth surface and concentrated mostly in the stratosphere layer of the Earth's atmosphere. Ozone (O_3) is a naturally occur molecule constructed by the three atoms of oxygen. Ozone molecules are constantly being destroyed and created in stratosphere. The formation of new ozone molecules are constantly built by the action of the sun's ultraviolet radiation on oxygen molecules (known as photochemical reactions).

The ozone layer is very important for the earth's environment because ozone this layer absorbs the harmful ultra ultraviolet (UV-B and UV-C) radiation (causing skin diseases, genetic complications, cancers, cataracts in terrestrial and marine living organisms including some crop destruction) of the Sun and preventing it to reaching on the earth (Fig 9.3). For the ecosystem, the ozonic umbrella is of vital importance because its absorption of ultraviolet radiation prevents the latter from reaching the surface of the earth, where it would be lethal to most living organisms. Moreover, because of its extra heat ozonosphere also act like a blanket that reduces the cooling rate of the earth and thus adds to the effect of water vapour.

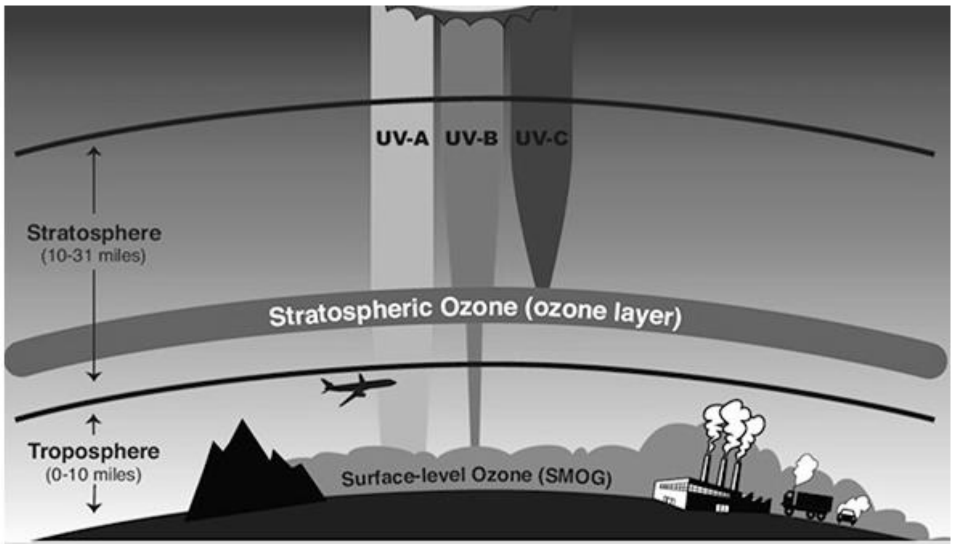

Fig 9.3: The ozone layer in the stratosphere shield life on Earth from UV-B and UV-C radiation, the most harmful varieties of UV radiation (Credit: NASA; Source: UCAR-Center for Science Education)

Depletion of ozone layer

Destruction or reduction of ozone layer is called depletion of ozone. Although formation of new ozone molecules and the destruction of old ones is a natural phenomena and these two processes take place simultaneously in a set proportion, therefore, it has no adverse effect on the overall thickening of the ozone layer. But ozone can be destroyed more quickly than it is naturally created when some other agents (mainly contain chlorine and bromine atoms) come in contact with the ozone layer. These destructive agents are called ozone-depleting substances (ODS). ODS which liberate chlorine includes methyl chloroform, carbon tetrachloride, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) etc while bromine is mostly released by methyl bromide and halons. They drastically destroy the ozone molecules. It is estimated by the scientist that 1 atom of chlorine can wipe out over 100,000 ozone molecules before it eliminated from the stratosphere layer.

CFCs or Freon are inert in normal chemical reactions but they get accumulated in greater amounts at higher altitudes and there in the stratosphere there inert gaseous compounds release chlorine or bromine atoms under the influence of intense short wave ultraviolet radiation. Each atom of chlorine/ bromine chain then reacts with huge number of ozone molecules that converting ozone to oxygen. The reduction in stratospheric ozone permits greater penetration of

UV light at the earth's surface. Some scientists feel that this intensified radiation will cause a significant increase in skin cancer and eventually have lethal effects on many organisms, including man.

The protective ozone layer is also considered by many ecologists to be endangered by supersonic jets, the SSTs. The jet engines of supersonic aircraft flying at high altitudes release nitrogen oxide which catalytically destroys ozone molecules.

Ozone hole

The ozone hole is not actually a hole but quite a thinning of the ozone layer. The term 'ozone hole' refers to the depletion of the protective ozone layer in the upper atmosphere, especially in the polar regions of the Earth. This phenomenon was firstly discovered in 1985 in the Antarctic region. The main cause of the formation and extending of ozone hole is ozone depleting chemicals- chlorofluorocarbons (CFCs) with halons, which persist in the atmosphere for decades to over a century.

The ozone is primarily produced in tropical latitudes. The air circulation patterns in the lower stratosphere move ozone toward the poles, where its concentration builds up. In addition, strong winter polar vortices are also imperative to directed ozone at the poles. The air becomes extremely cold and heavy during the chilling and dark winter in polar region which provide all the suitable conditions for the polar stratospheric cloud formation. These clouds generate the circumstances for severe destruction of ozone layer by providing a surface for chlorine to change into ozone-destroying form. Here, the atoms of the CFCs coalesce into ice particles in the clouds. In the spring season, when the sun comes out, the melting of ice releases the ozone-depleting molecules from surface of the snowflakes. CFCs react with the ozone and breaking the molecular bonds in UV radiation-absorbing ozone. All living organisms underneath the ozone hole are harmed by the direct solar radiation causing serious health problems.

Seasonal variation has a significant impact on the size of the Antarctic ozone hole. Over the course of an annual cycle, sometime the size of the hole become larger and other time is smaller. This is because, as we discussed in the above paragraph, at the onset of spring, the CFCs atoms which were trapped in the ice are released by the melting of ice and start destroying of the ozone.

Effects of depletion of ozone layer

The depletion of ozone has significant impacts of all living forms of life including our environment. Some noteworthy impacts are discussed here in brief.

- It has harmful impact on the human health, animals, environment and marine life.

- Some studies reveal that increasing amount of UV radiation causes the higher risk of skin, eye and immune system related troubles viz., sunburns, quick ageing, cancer, development of malignant melanoma, eye cataracts, blindness and weekend.

- Planktons and zooplankton are also significantly affected by the exposure to UV radiation. These are higher in the aquatic food chain. If the planktons declines, it would likely have wide-reaching effects for all marine life in the lower food chain.

- UV-B rays depressingly influence plant growth and agricultural production. It may lead to diminish the physiology plant including growth and photosynthesis process. They have also the morphological impacts as well in plant like less flowering, reducing leaf size area and lower quality crops. Decline in plant productivity would in turn affect soil erosion and the carbon cycle (Manral et al. 2018; Bargali et al. 2019).

Solutions to ozone layer depletion

Depletion of ozone is not a local problem or a regional problem but it is a huge and an international environment problem. Every countries of the Earth is more or less is affected by the global warming and the ozone depletion. Therefore collective protective measurements must be implemented jointly by the world community.

An international initiative taken by the world community known as the Montreal Protocol, was an agreement signed by more than 70 countries in 1986 to address the global problem of ozone devastation and to cut down the production of ozone-depleting substances (ODS). The set goals of Montreal Protocol are to reducing production of CFCs 20% by 1993 and 50% by 1998. Since the agreement was signed, these targets have been strengthened to call for the elimination of the most dangerous CFCs by 1996 and for regulation of other ozone-depleting chemicals.

Apart from the international initiative, every individual should also take action to avert the depletion of the ozone layer. By adopting of natural methods to get rid of pests in instead of using uncontrolled application of chemical pesticides can help to restore the environment. The use of vehicles should be lessening as much as likely because they emit a large amount of greenhouse gases that cause the ozone depletion as well as global warming. We should use eco-friendly products. Maintain air conditioners, as their malfunctions cause CFCs to escape into the atmosphere.

9.7 ACID RAIN

Acid rain, or acid precipitation or acid deposition, includes any form of precipitation (viz., rain, fog, hail, snow or even dust) possessing a pH of about 5.2 with acidic components (i.e., as sulfuric or nitric acid) that fall to the earth from the atmosphere. In most of the case, acid rain is the outcome of the anthropogenic activities. The acid rain reduces the pH of the sensitive landscapes and water bodies that untimely cause of loss of biodiversity.

Causes of acid rain

Acid rain fallout when oxides of sulfur (SO_2) and nitrogen (NO_x; the combination of NO and NO_2) are released into the atmosphere and transported by air currents and wind. The oxide of sulfur and nitrogen react with water, oxygen and other chemicals to form sulfuric and nitric acids. These then mix with water and other materials before falling into any substrate. Majority of acid rain is caused by the human activities including burning of fossil fuels, coal, Vehicles and heavy equipments, refineries and other industries etc while a very small portion of the SO_2 and NO_X that cause acid rain is from natural sources like volcanic eruption.

Forms of acid deposition

The acid rain deposited into the earth in two forms;

(i) Wet Deposition: It is the most common type of deposition where the acid rain comes in contact to the substances with containing moisture in it viz., rain, fog, hail and snow etc. It is the most common type of deposition.

(ii) Dry Deposition: Sometime the deposition of acid occurs in the form of gases and acid particles, this type of deposition is called dry deposition. These acidic particles or gases can accumulate on vegetation, architectural objects and water bodies or transport by water or wind to built large particles that damage ecosystem. These accumulated acids are washed away by the next rain shower, where it is carried or transported into another place and harm the plants and wildlife. The concentration of dry acid deposition depends on the amount of rainfall received by a particular area. For example: a region receives several inches rainfall per year have much lower ratio of dry to wet deposition as compare to the desert.

Process of formation of acid rain:

Oxides of nitrogen and sulphur are produced during combustion of fuels and finally converted into nitric acid and sulphuric acid, respectively (Fig 9.4).
In gaseous phase, sulphur dioxide is oxidized by reacting with hydroxyl radical (OH·) by means of an intermolecular reaction.

$$SO_2 + OH\cdot \rightarrow HOSO_2$$

Which is followed by:

$$HOSO_2\cdot + O_2 \rightarrow HO_2\cdot + SO_3$$

$$SO_{3\,(g)} + H_2O_{\,(l)} \rightarrow H_2SO_{4\,(aq)} \text{ (Sulphuric acid)}$$

NO_2 reacts with OH forming nitric acid

$$NO_2 + OH\cdot \rightarrow HNO_3 \text{ (Nitric acid)}$$

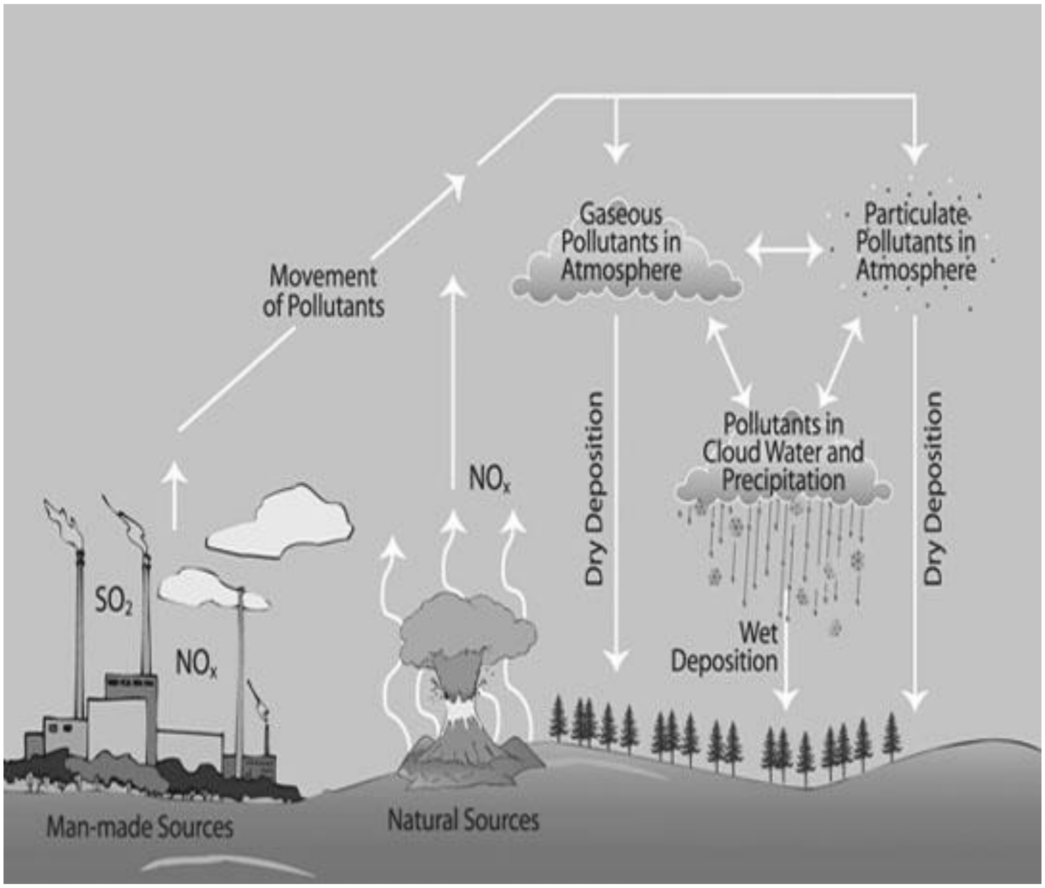

Fig 9.4: Formation of acid rain from air pollutant gases
(Source: https://www.worldofchemicals.com/615/chemistry-articles/everything-about-acid-rain-you-need-to-learn.html)

Cloud Droplets Chemistry: It has been estimated that the loss rates of sulphur dioxide is accelerated in the occurrence of clouds due to containing water droplets by the clouds.

Hydrolysis: Sulfur dioxide dissolves in water. Thereafter, series of hydrolyses equilibrium reactions take place:

$$SO_2(g) + H_2O \rightleftharpoons SO_2\cdot H_2O$$
$$SO_2\cdot H_2O \rightleftharpoons H^+ + HSO_3^-$$
$$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$$

Oxidation: Large number of aqueous reactions is there that oxidizes sulfur, leading to the production of sulfuric acid. The most important oxidation reactions take place with oxygen, hydrogen peroxide and ozone.

Effects of acid rain

Acid rain has a multiple harmful impacts on the environment as well as in all living organisms. It also reduces the visibility through the air. The strength of the effects depends on the acidity of the water, type of the deposition, the concentration of the acid rain and buffering capacity of the soils involved. Some impacts of the acid rain are discussed here in brief:

A. The Effects of Acid Rain on Ecosystems:

As we all know that the ecosystem is a complex structure where one species is related to another. So, if something harms of any component (i.e., biotic and abiotic) of the ecosystem, it can certainly affect everything else.

(i) Effects on the terrestrial ecosystem: Some trees like ashes, maple, spruce etc vulnerable to acid deposition. The acidic rain not directly kills the tree but weaken the tree through the dieback, bleaching of leaf chlorophyll, reducing the functionality of the leaves, limiting the nutrients uptake, and exposing tree to toxic substances. It may also erode cuticle and leaching the nutrients from the leaves. The collective all these effects finally impose the adverse effects on the forest community.

(ii) Soil acidification and buffering capacity: Acid rain affects the biogeochemical processes of the soil such as production and leaching of carbonic, organic and nitric acids, humus, weathering and uptake of minerals.

The soil may neutralize some or all the acidity of the acid rainwater. This ability of soil called buffering capacity, and without this soil become more acidic in nature. The higher the base saturation, the more buffering capacity of soils has to absorb the H^+ ions. Acidic water dissolves the nutrients and helpful minerals in the soils and then washed them away before vegetation can use them.

(iii) Effects of acid rain on aquatic ecosystem: The acid rain imposes adverse impacts on ecology of aquatic environments including both fresh and marine water ecosystem. It can be harmful to all aquatic living organisms. As acidic water floods through the soil, it can leach aluminum from soil and then mix into streams and lakes. Several studies have declared that when more acid rain is introduced into an ecosystem there is a great release of aluminum. Some species of aquatic life can tolerate moderate concentration of acidic water and aluminum deposition but most of the species are intolerant or sensitive for the both. Usually, the young ones of the most species are more susceptible than adults. The high H^+ concentrations in lakes and ponds lead to high mortality of adult fish, sometimes complete destruction of fish species and most fish eggs do not hatch. Even, if a species of fish or other organism can tolerate moderately acidic water, it has found difficulties to follow their normal food chain. For example, the critical pH of frog is around 4, but the mayflies they usually eat are more intolerant and cannot survive at a acidic medium below pH of 5.5.

B. Effects of acid rain on materials

One of the most significant adverse impacts of acid rain is accelerated weathering of many precious statues and buildings, especially limestone marble. The damage monuments need special care to save them acid rains. Metals also corrode when exposed to acid rain. It is the matter of great concern. The effect of acid rain on the Taj Mahal in India is an example of how acid rain affects buildings and monuments.

C. Other effects of acid rain

(i) Visibility: In the atmosphere, oxides of nitrogen and sulphur can be convert into nitrate and sulphate particles, while some oxides of nitrogen (NO_x) form ozone while react with other pollutants. All these elements collectively make the air hazy and create difficulties in visibility.

(ii) Human Health: For human beings walking in acid rain, or even swimming in a lake affected by acid rain, is no more dangerous. However, when it contains higher concentration of sulfate and nitrate particles as well as SO_2 and NO_X, they can be harmful. The oxides of nitrogen and sulphur form fine particles of nitrate and sulfate that people can inhale causing serious lungs diseases and life threatening. Shortness of breathing and asthma are the most common consequences of weakening of the lungs. Many scientific studies have revealed that these pollutants affect the functioning the heart as well which causes heart attack, cardiac arrest and other heart related diseases in humans.

9.8 POLLUTION OF INTERNATIONAL WATER

Water is the necessity of life and without it life cannot be imagined. Water covers around 71% of the earth’s total area where 97% of water found in the ocean (too saline for drinking and agriculture). Only 3% is fresh water and out of them almost 2.5% is unavailable as locked in polar ice, glaciers and atmosphere, soil, or lies too far under the earth's surface to be extracted at an affordable cost and rest are highly polluted. Therefore, only 0.5% is available for us as fresh water.

The terms international waters or trans-boundary waters refers to any kind of water bodies (viz., fresh water and marine water) that transcend international boundaries. Lakes, rivers, underground water, wetlands, marine ecosystems, oceans, seas and estuaries are some examples of International water (International Waters Archived 2009). Both freshwater and marine ecosystems cross the national borders, therefore, many countries share common groundwater aquifers, lakes, rivers, wetlands, coral reefs, oceans etc. Internationally, more than 360 aquifers and 300 watersheds traverse the political boundaries of two or more countries and cover almost half of the Earth’s land surfaces.

Water quality is one of the main challenges that societies will face during the 21st century, threatening human health, limiting food production, reducing ecosystem functions, and hindering economic growth. Water quality degradation translates directly into environmental, social and economic problems. The availability of the world's scarce water resources is increasingly limited due to the worsening pollution of freshwater resources caused by the disposal of large quantities of insufficiently treated, or untreated, wastewater into rivers, lakes, aquifers and coastal waters. Furthermore, newly emerging pollutants like personal care products and pharmaceuticals, pesticides, and industrial and household chemicals, and changing climate patterns represent a new water quality challenge, with still unknown long-term impacts on human health and ecosystems.

Healthy freshwater and marine ecosystems are vital to supporting life and they strengthen, link ecosystems, human health, and key economic sectors, yet they are facing unprecedented pressure. Ocean ecosystems disturbed by pollution, acidification climate change, habitat loss, fishing, shipping, and seabed mining. Often oceans are considered as so vast that they are virtually unlimited in their ability to accumulate the waste products of human civilization. But there are substantial evidence to indicate global pollution of coastal waters and open oceans due to dumping of domestic and industrial wastes, sewage, oil drilling in coastal waters, spilling of oil tankers etc. the oceans have in fact, become the final setting basin for millions of tons of waste products from human activities. Table 5.1 showing the list of some sources of industrial and agricultural pollutants that polluted of water reservoir.

Table 5.1: Examples of industrial and agricultural pollutants discharged into the international water bodies (after Southwick, 1976)

S.N.	Pollutants	Source
1.	Petroleum and industrial hydrocarbons	Offshore wells, oil tankers, industrial wastes
2.	Hydrocarbons (airborne)	Vehicles, industries, power plants
3.	Air borne lead	Vehicles
4.	Mercury	Industrial operations
5.	Aldrin-Toxaphene (converted into dieldrin)	Agricultural and public heath operations
6.	Benzene hexachloride	Agricultural and public heath operations
7.	DDT	Agricultural and public heath operations
8.	Polychlorinated biphenyls (PCBs)	Plastic industries

This tremendous burden of pollutants is evidently affecting the health and integrity of the word's oceans. Due to the international water pollution the marine biota has been seriously affected. Scientist estimated that it causes decline in the overall productivity. They also observed a serious shrinkage of coral reefs in many tropical areas of the world and a displacement of these rich and varied communities with turbid and relatively barren waters. There has occurred a decline in populations of many fishes due to oceanic pollution. Oil spills have killed water birds, mammals, fish and vegetation.

Freshwater ecosystems are also facing the challenges of urbanization, pollution, climate change, and increasing demand of human populations. Protecting these ecosystems and ensuring that they are sustainably managed, therefore, requires that various countries take joint actions to secure a healthy environment for present and future generations. Given the vital role of freshwater and marine ecosystem and the pressure they encountering, well built management addresses are essential.

Conservation strategies

The GEFs International Water Focal area has a unique consent: sustain transboundary assistance in shared freshwater and marine ecosystems. The GEF has established successful in building trust between states that often find themselves locked in complex and long-lasting freshwater-use or marine resource disagreement and attaining lasting profits. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) aims to protect and ensure the quantity, quality and sustainable use of these transboundary water resources by facilitating and promoting cooperation. It is implemented in water-rich as well as water-scarce countries. GEF investment in International Waters has three key objectives:

Strengthening National Blue Economy Opportunities: The GEF helps countries identify sustainable public and private national investments in the Blue Economy, through funding of collective management of coastal and marine systems and implementation of the full range of integrated ocean policies, legal and institutional reforms. The Blue Economy concept identifies the oceans as areas for potential sustainable development of existing and new sectors, including tourism, extractive industries, renewable energy production, fisheries and aquaculture, coastal development and marine transport.

Improving Management in the Areas Beyond National Jurisdiction: The complex ecosystems in the Areas Beyond National Jurisdiction — commonly called the high seas, those areas of ocean for which no one nation has sole responsibility for management — making the sustainable management of fisheries resources and biodiversity conservation especially challenging. Urgent action is needed to improve conservation and sustainable use of the open oceans that covers 40% of the planet, and are increasingly threatened by over-fishing of iconic pelagic migratory species, maritime navigation, ocean energy facilities, bottom trawling on seamounts, pollution, and extraction of minerals and hydrocarbons. Building on GEFs past experience in successfully supporting an applied ecosystem-based approach to fisheries management of deep sea fisheries, including seamounts, as well as regional tuna fisheries management organizations in the high seas.

Enhancing water security in freshwater ecosystems: Transboundary river basins cover about 50% of the earth’s land surface and are home to about 40% of the world’s population. More than 1 billion people live in river basins where human water use has surpassed sustainable limits. Cooperation on water, therefore, is vital to most international basins to support the need for water, food, energy, and ecosystems security and increase resilience for each nation. Shared groundwater resources are especially hard to manage due to the limited knowledge of the resource and its 'invisibility.' With mounting pressures on water resources and increasing pressures from climate variability and change managing surface and groundwater is the only sustainable path. GEF support in freshwater basins will therefore focus on three areas of strategic action: advance information exchange and early warning; enhance regional and national cooperation on shared freshwater surface and groundwater basins; and invest in water, food, energy and environmental security.

9.9 CONSERVATION STRATEGY

The word conservation refers to the "management of human use of organisms or ecosystems to ensure such use is sustainable, as well as the protection, maintenance, rehabilitation, restoration, and enhancement of populations and ecosystems".

The state of the world environment is in its alarming time. Conservation measurement practices are urgently needed to protect the environment. The objectives of conservation must be achieved as a matter of urgency because the planet's capacity to support people is being irreversibly reduced in both developing and developed countries; destruction of soil causes deforestation and poor land management, conversion of farmlands into buildings and roads is appearing more common in every year; over exploitation of consumable recourses, the resource base of major industries is shrinking: tropical forests are contracting so rapidly that by the end of this century the remaining area of unlogged productive forest will have been halved; the coastal support systems of many fisheries are being destroyed or polluted.

To overcome the impact of destruction of nature, conservation strategies can facilitate the setting of goals and the development of action plans for the sustainable use of resources, usually by seeking broad-scale consensus through comprehensive consultations. Destruction of natural environment is not the problem of only one county but all the countries have to come together to deal with it. In the context of joint efforts of conservation, World Conservation Strategy (WCS) awakens a hope. The WCS aimed at providing a framework and policy guidance for resource conservation. The WCS was created by the International Union for the Conservation of Nature (IUCN), the United Nations Environment Program (UNEP), and the World Wildlife Fund (WWF). The World Conservation Strategy defines living resource conservation, explains its objectives, its contribution to human existence and the barriers to its achievement. It sets out the priority requirements to achieve each objective. The WCS proposes national and subnational strategies to meet the priority requirements, describing a framework and principles for those strategies. It also proposes an integrated method of assessment of land and water reimburses and outlines a procedure for the rational allocation of land and water uses.

The WCS recommends anticipatory environmental policies, cross-sectoral conservation policy, broader system of national accounting in order to integrate conservation with development at the policy making level. This organization also reviews the legislation concerning living resources, suggests general principles for organization within government, improving the organizational capacities for soil conservation and marine living resources. WCS promotes the greater public participation in planning and decision making concerning living resource use, environmental education programmes and campaigns to build support for conservation.

WCS suggests ways to increase the number of trained personnel, proposes more management-oriented research and research-oriented management, so that the most urgently needed basic information is generated more quickly, to help rural communities to conserve their living resources, as the essential basis of the development they need.

The main purposes of the World Conservation Strategy are to encourage a more focused approach to the management of resources (renewable and nonrenewable sources) and to set the guidance on how this can be implemented to conserve the resources by three main groups:

- Government policy makers and their advisers
- Development practitioners, including NGOs, private sectors, industries, trade unions, donors and agencies.
- Conservationists and others directly concerned with living resources

Aim:

There are three principle aims of the World Conservation Strategy (IUCN/UNEP/WWF, 1980 P1)

1. **Ecological balance:** To maintain essential ecological processes and life-support systems (such as soil regeneration and protection, the recycling of nutrients, and the cleansing of waters), on which human survival and development depend.
2. **Preserve genetic diversity:** (the range of genetic material found in the world's organisms), on which depend the functioning of many of the above processes and life-support systems, the breeding programmes necessary for the protection and improvement of cultivated plants, domesticated animals and microorganisms, as well as much scientific and medical advance, technical innovation, and the security of the many industries that use living resources.
3. **Sustainability**: to ensure the sustainable utilization of species and ecosystems (notably fish and other wildlife, forests and grazing lands), which support millions of rural communities as well as major industries.

The main obstacles to achieving conservation are:

a. The belief that living resource conservation is a limited sector, rather than a process that cuts across and must be considered by all sectors.

b. The consequent failure to integrate conservation with development;

c. A development process that is often inflexible and needlessly destructive, due to inadequacies in environmental planning, a lack of rational use allocation and undue emphasis on narrow short term interests rather than broader longer term ones.

d. The lack of a capacity to conserve, due to inadequate legislation and lack of enforcement; poor organization (notably government agencies with insufficient mandates and a lack of coordination); lack of trained personnel; and a lack of basic information on priorities, on the productive and regenerative capacities of living resources, and on the trade-offs between one management option and another;

e. The lack of support for conservation, due to a lack of awareness (other than at the most superficial level) of the benefits of conservation and of the responsibility to conserve among those who use or have an impact on living resources, including in many cases governments.

f. The failure to deliver conservation-based development where it is most needed, notably the rural areas of developing countries:

In addition, the Strategy recommends international action to promote, support and (where necessary) coordinate national action, emphasizing in particular the need for:

a. stronger more comprehensive international conservation law, and increased development assistance for living resource conservation (section 15)

b. International programmes to promote the action necessary to conserve tropical forests and drylands (section 16), to protect areas essential for the preservation of genetic resources (section 17), and to conserve the global "commons"-the open ocean, the atmosphere, and Antarctica.

c. Regional strategies to advance the conservation of shared living resources particularly with respect to international river basins and seas (section 19).

9.10 NATIONAL CONSERVATION STRATEGIES

The WCS challenged individual nations and the wider international community to face the crisis of resource depletion by integrating conservation and development. While it clarified threats to the environment through irrational and unmanaged resource use and allocation, it did not layout specific solutions.

Instead it offered a process through which nations could respond to the priorities cited in the WCS to create their own national and regional conservation strategies. Many responded, and by the 1986 Conference on Conservation and Development (Ottawa), nations from all continents were prepared to present the results of their own strategy development. By 1986, such nations as Indonesia, Australia, and Zambia had nation- ai-level strategies in place.

The aim of a national or regional conservation strategy is to provide a framework for reviewing conservation priorities and obstacles, and to identify means to integrate conservation objectives into the mainstream of national and regional planning. As well, such strategies typically provide the means to co-ordinate the efforts of government agencies with conservation and social organizations to achieve shared objectives. Each national conservation strategy is a unique expression of that country's needs and objectives.

However, most strategies aim to fulfill three common functions, deriving from the WCS priorities:

- to establish priority requirements for achieving the three conservation objectives.
- to identify obstacles to meeting these requirements
- to propose cost-effective means of overcoming these obstacles

A nation's conservation strategy is best viewed as an operational document, setting policy directions and actions for achieving the three conservation objectives. Yet, the process by which the strategy is developed is also very important, and the WCS offers guidance for the planning and analysis through which conservation strategies are formulated. The process of developing a national conservation strategy begins with three steps:

1. **Strategic review**: In developing conservation strategy, planners review their national development objectives in light of the three conservation objectives. The status of – and threats to- living resources are an integral part of this review. Specific measures to reach the objectives are identified. The strategic review is also the time to identify the main obstacles to achieving development and conservation objectives and limiting threats to resources. Where there is a conflict, or in cases where neither set of objectives is being met, the strategy may establish a set of priority requirements aimed at ensuring that development planning and conservation are compatible. Also, this step can include a review of the state of the nation's living resources; ecosystems and species at risk are identified, and priority requirements for their protection established (IUCN/ UNEP/WWF1980;1991).

2. **Analysis.** The next step in developing a conservation strategy is to carry out an indepth analysis of practices and to identify areas for change. This analysis critically examines development activities – current and anticipated - with respect to the three conservation objectives and the priority requirements established during the strategic review. Analysis of activities can also measure their performance against the development objectives established during the review. It can highlight for change activities inconsistent with

conservation and development objectives and promote practices that would further the objectives. Economic and financial analyses are normally included in this step; an operational conservation strategy relies on an understanding of the financial resources available to implement needed change. Finally, the analysis can incorporate an examination of the political and social resources - including legislation, public support, and organizations - available to further the objectives and priority requirements of a conservation strategy.

3. **Action planning.** Once the strategic review has established objectives and priority requirements and analysis has identified areas for change, an action plan should be formulated. The action plan proposes means of supplying the economic, social, and political resources necessary to meet the conservation objectives. The plan can also identify responsibilities for implementation, and explicitly authorize appropriate ministries, agencies, and organizations to carry out the required actions. Where possible, time lines and measurable objectives are incorporated into an action plan. This plan is also the foundation for a program of legislative and policy measures, which will forward the objectives of the conservation strategy and facilitate its implementation

The purpose of these steps is to begin a process of understanding how specific elements of a nation's development strategy impact on conservation objectives. Through review, analysis, and development of action plans, countries can formulate conservation strategies that refer specifically to national objectives, needs, and resources. This approach recognizes that each country will be facing unique conservation challenges and strategies for achieving the three objectives of conservation must address these challenges in ways that are meaningful and supportable in the national context. While the WCS provide a framework, it rests with each country to develop a national strategy and provide the necessary resources and political commitment to advance its implementation.

9.11 SUMMARY

The present topic provides an overview of demology, global environmental problems and outlines of conservation strategies. Demography is the account and statistical analysis of the vital process and movements of human populations. The history of human is around 30,000 BC from primitive man to industrial man. There are many factors regulating the human population e.g., scarcity of food, shelter, natural calamities, enemies, diseases, pollution and many other anthropogenic causes control the demography of a region. The excessive interference of the human causes the destruction of the environment. Excessive and uncontrolled anthropogenic activities would disrupt the natural processes of the earth, which would eventually lead to the causes of imbalance in earth’s ecosystem.

Global warming, loss of biodiversity, pollution, ozone layer depletion, acid rain etc are some current burring issues of global environmental problems. All these are not the problems of a particular area or region or a country, whereas these are global problems where the whole world is stakeholder and all human beings, plants, animal diversity and our planet paying for it. The adopting of global perspective is the only adequate approach to address the causes of environmental problems. It can be deal only with the international collaboration through the international harmony, agreements, joint efforts and targets.

Climate change refers to a significant long-term change in the global climate. It comprises increase in temperature across the globe by the uncontrolled human activities including the emissions of Greenhouse Gases (GHGs) that resulting large-scale shifts in weather patterns. The main GHGs are carbon dioxide, methane, nitrous oxide, fluorinated gases and sulphur hexafluoride. Uncontrolled burning of fossil fuels and extracting have amplified the significant amount of GHGs in the atmosphere. The impact of climate change can be mitigated by minimizing the emission of GHGs and by promoting the sinks of those GHGs from the atmosphere, promote the utilization of clean energy. Carbon capture and storage (CCS) is also play a significant role in limiting CO_2 emissions. Forests are the natural carbon sinks which have the potential to sequester significantly larger amounts of CO_2 beyond naturally occurring levels.

Biodiversity refers to the total number of species present in a given area. It includes both the genetic and species diversity of the organisms occurring in a particular geographical area. It is estimated by the scientists that the present speed of loss of biodiversity is estimated to be hundred to thousand times higher than the naturally occurring background extinction rate, faster than at any other time in human history and probable to still rise in the forthcoming years. There are many causes of loss of biodiversity which includes the natural phenomena like flood, hurricanes, earthquake, volcanic eruption, wildfire etc. Apart from this, the major cause is anthropogenic activities which are more long lasting and severe impact on environment. Loss of biodiversity threatens not only the functioning, structure, productivity of the ecosystem but distresses the human society and economic systems as well.

Ozone is considered as the protective layer above the Earth surface and concentrated mostly in the stratosphere layer of the Earth’s atmosphere. Destruction or reduction of ozone layer is called depletion of ozone. Although formation of new ozone molecule is natural process but ozone can be destroyed more quickly than it is naturally created when some other agents come in contact with the ozone layer. These destructive agents are called ozone-depleting substances (ODS) includes methyl chloroform, carbon tetrachloride, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) etc while bromine is mostly released by methyl bromide and halons. The depletion of ozone has significant impacts of all living forms of life including our environment, human health, animals, environment and marine life, increase the risk of skin, eye and immune system related troubles in humans including sunburns, quick ageing, cancer, development of malignant melanoma, eye cataracts, blindness and weekend.

Acid rain includes any form of precipitation possessing a pH of about 5.2 with acidic components (i.e., as sulfuric or nitric acid) that fall to the earth from the atmosphere. Acid rain occurs when oxides of sulfur and nitrogen are released into the atmosphere and carried by air currents. Majority of acid rain is caused by the human activities including burning of fossil fuels, coal, vehicles and heavy equipments, refineries and other industries etc while a very small portion of the SO_2 and NO_X that cause acid rain is from natural sources like volcanic eruption. The acid rain deposited into the earth in two forms i.e., wet deposition and dry deposition. Acid rain has a multiple harmful impacts on the environment as well as in all living organisms. It also reduces the visibility through the air, affects the terrestrial and aquatic ecosystem, soil, important monuments, visibility and human health.

The terms international waters or trans-boundary waters refers to any kind of water bodies that transcend international boundaries. Lakes, rivers, underground water, wetlands, marine ecosystems, oceans, seas and estuaries are some examples of International water. Internationally, more than 360 aquifers and 300 watersheds traverse the political boundaries of two or more countries and cover almost half of the Earth's land surfaces. The pollution of freshwater resources caused by the disposal of large quantities of insufficiently treated, or untreated, wastewater, personal care products, pharmaceuticals elements, pesticides, industrial and household chemicals into rivers, lakes, aquifers and coastal waters. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) aims to protect and ensure the quantity, quality and sustainable use of these transboundary water resources by facilitating and promoting cooperation.

The destruction of natural environment is not the problem of only one county but all the countries have to come together to deal with it. In the context of joint efforts of conservation, World Conservation Strategy (WCS) awakens a hope. The WCS aimed at providing a framework and policy guidance for resource conservation. The WCS was created by the International Union for the Conservation of Nature (IUCN), the United Nations Environment Program (UNEP), and the World Wildlife Fund (WWF). The WCS recommends anticipatory environmental policies, cross-sectoral conservation policy, broader system of national accounting in order to integrate conservation with development at the policy making level. This organization also reviews the legislation concerning living resources, suggests general principles for organization within government, improving the organizational capacities for soil conservation and marine living resources. Conservationists and others directly concerned with living resources.

9.12 GLOSSARY

Acid rain: rain or other forms of precipitation that is unusually acidic.
Afforestation: planting new forests on lands that have not been recently forested.
Anthropogenic: man-made, not natural.

Atmosphere: The Earth's atmosphere consists of the troposphere, stratosphere, mesosphere, thermosphere, exosphere and magnetosphere.

Biomass: The quantity of organic material present in unit area at a particular time mostly expressed as tons of dry matter per unit area; organic matter that can be used as fuel.

Biotic: relating to, produced by, or caused by living organisms.

Birth rate: the fertility expressed as the average numbers of live births per thousand population per year.

Carbon pool: a storage reservoir of carbon.

Carbon sink: any carbon storage system that causes a net removal of greenhouse gases from the atmosphere.

Carbon source: opposite of carbon sink; a net source of carbon for the atmosphere.

Carbon stocks: the quantity of carbon held within a carbon pool at a specified time.

CFC or Chlorofluorocarbons: one of the more widely known family of haloalkanes.

Deforestation: the conversion of forested areas to non-forest land for agriculture, urban use, development, or wasteland.

Demography: the account and statistical analysis of the vital process and movements of human populations.

Ecological niche: the habitat of a species or population within its ecosystem.

Ecological sustainability: the capacity of ecosystems to maintain their essential processes and function and to retain their biological diversity without impoverishment.

Ecosystem: a dynamic complex of plant, animal and microorganism communities and their non-living environment all interacting as a functional unit.

Emissions: substances such as gases or particles discharged into the atmosphere as a result of natural processes of human activities.

Energy efficiency: using less energy to provide the same level of energy service.

Enhanced greenhouse effect: the increase in the natural greenhouse effect resulting from increases in atmospheric concentrations of greenhouse gases due to emissions from human activities.

Epidemiology: the study of factors affecting the health and illness of populations, and serves as the foundation and logic of interventions made in the interest of public health and preventive medicine.

Fertility rate: number of live births per 1,000 women aged 15 to 44 years cf. birth rate, mortality rate.

Fertility: the actual reproductive performance of a given population.

Food chain: the feeding relationships between species within an ecosystem.

Forest: land with a canopy cover greater than 30%.

Fossil fuel: any hydrocarbon deposit that can be burned for heat or power, such as coal, oil and natural gas (produces carbon dioxide when burnt); fuels formed from once-living organisms that have become fossilized over geological time.

Genetic diversity: one of the three levels of biodiversity that refers to the total number of genetic characteristics.
Greenhouse effect: the process in which the emission of infrared radiation by the atmosphere warms a planet's surface.
Greenhouse gases: any gas that contributes to the greenhouse effect included carbon dioxide, methane, nitrous oxide, ozone, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.
Hydrocarbons: chemicals made up of carbon and hydrogen that are found in raw materials such as petroleum, coal and natural gas, and derived products such as plastics.
Insecticide: a pesticide used to control insects in all developmental forms.
Microorganism: an organism visible only through a microscope.
Mortality rate: the average number of individuals who die per thousand population per year.
Nutrients: chemicals required for the growth of organisms.
Ocean acidification: reduction in ocean water pH.
Phytoplankton: plant plankton cf. Plankton.
Plankton: microscopic organism suspended in water and a valuable component of aquatic food chain.
Productivity: the capacity of a given area to produce biomass; different ecosystems.
Sequestration: the removal of carbon dioxide from the Earth's atmosphere and storage in a sink as when trees absorb CO_2 in photosynthesis and store it in their tissues.
Sewage: water and raw effluent disposed through toilets, kitchens and bathrooms.
Soil acidification: reduction in pH in soil.
Sustainability: the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Tropical: occurring in the tropics (the region on either side of the equator) having hot and humid environment.

9.13 SELF ASSESSMENT QUESTIONS

9.13.1 Multiple choice questions

1. This process is functional in removing carbon dioxide from the atmosphere
   a. Lightning b. Deforestation
   c. Burning of fossil fuels d. Photosynthesis
2. Mainly, Ozonosphere is depleted by
   a. CFCs b. Excess CO_2
   c. Ozone d. Excess CO
3. This is not a possible adverse effect of global warming
   a. Sea level rise b. An increase of UVB radiation
   c. Retreat of glaciers d. Extraordinary weather patterns
4. CFCs have a continuing effect on the ozone layer as

a. They are efficiently absorbed by atmospheric water vapours
b. They are being produced in increasing amounts all over the world
c. Cl atoms formed by them are used up in reactions causing degradation of the ozone
d. Cl atoms formed by them only act as catalysts in reactions causing degradation of the ozone

5. Which of the following is not a major greenhouse gas?
   a. Ozone b. Water vapour
   c. Methane d. Carbon dioxide
6. Ultraviolet radiations from sunlight cause a reaction producing
   a. Carbon monoxide b. Ozone
   c. Fluorides d. Sulphur dioxide
7. Acid Rain is caused by emissions of
   a. Sulphur dioxide b. Nitrogen oxide
   c. Both a and b d. Carbon dioxide
8. The adverse effect(s) of acid rain is (are)
   a. Causing paint to peel b. Corrosion of steel structures
   c. Killing insects d. All of the above
9. For which of the following reason, it is necessary to secure a large area for forest?
   a. Absorption of carbon dioxide b. Conservation of wild
   c. More rain d. Ecological balance
10. Among the following climatic factors, which one has the least effect upon a terrestrial ecosystem?
    a. Temperature variation b. Wind
    c. Conditions of sunlight d. Availability of water

9.13.2 True and false

1. The acidic air pollutants reach the Earth's surface because of wet deposition only.
2. Hydro electric power is a renewable source of energy.
3. The Kyoto Protocol is an international treaty which relates to climate change.
4. Carbon dioxide is a greenhouse gas.
5. Deforestation refers to the loss of soil cover.
6. Energy derived from running water is a called nuclear energy.
7. Tropical zone has the maximum rate of deforestation
8. The Earth summit was organised by United Nations Conference on Environment and Development (UNCED) in Rio.
9. World Environmental day is celebrated on 5th June at every year.
10. Environment includes abiotic and Biotic component.

9.13.3 Fill in the blanks

1. The Ozone hole over Antarctica was discovered in ________.

2. The first protocol to ban the emissions of choloro fluorocarbons in the atmosphere was made in ________.
3. When was the World Wildlife Fund founded ________.
4. Rio Summit is associated with ________.
5. ________ is the actual reproductive performance of a given population.
6. Carbon dioxide is called as ________ because it traps infrared radiation
7. Some effects of SO_2 and its transformation products on plants include destruction of ________.
8. If ________ pollution continuous at its present rate, it will eventually make oxygen molecules unavailable to water plants.
9. Biologists celebrate 5th June as ________.
10. Substances that are easily broken down into harmless substances by decomposers are termed ________.

Answer Key:

9.13.1: 1(d); 2(a); 3(b); 4(d); 5(a); 6(b); 7(c); 8(d); 9(d); 10(b)
9.13.2: 1. False; 2. True; 3. True; 4. True; 5. False; 6. False; 7. True; 8. True; 9. True; 10. True
9.13.3: 1. 1985; 2. Montreal protocol; 3. 1961; 4. Convention on Biological Diversity; 5. Fertility; 6. greenhouse gas; 7. Chlorophyll; 8. Water; 9. World Environment Day, 10. biodegradable

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9.16 TERMINAL QUESTIONS

9.16.1 Short Answer Type Questions

1. What do you understand by population explosion?
2. What do you understand by green house gases?
3. Write the impacts of loss of biodiversity.
4. What do you understand by the depletion of ozone layer?
5. What do you understand by the international water? Write a brief note

9.16.2 Long Answer Type Questions

1. What do you understand by climate change? What are the major impacts of climate change and its mitigation techniques?
2. What are the major causes of loss of biodiversity? Discuss the effects of decline in biodiversity in detail.
3. Write a detailed note on the depletion of ozone layer, its impacts and restoration process.
4. What is acid rain? Write a detailed note on the process of formation of acid rain and its impacts.

UNIT-10- MANAGEMENT ECOSYSTEMS FOR SUSTAINABLE LIVING

Contents:

10.1 OBJECTIVES

The present topic provides an overview on management ecosystems for sustainable living. After reading this topic, learners will be able to answer the:

- What is sustainable development?
- Concept and principles of sustainable development
- How to meet daily requirements from ecosystem with a sustainable approach
- What is ecological urbanization
- How to cope up the problems of ecological urbanization

10.2 INTRODUCTION

Sustainable living is a way of life which aims to limit an individual's or society generally consumption of natural and personal resources on the planet. Its consumers or recipients frequently try to lower their environmental footprint (including carbon footprint) by modifying their transport, energy usage, and/or nutrition. Its supporters strive to live in a way that is consistent with sustainability, natural balance, and a respectful symbiotic relationship with the natural ecology of the Earth. The overall principles of sustainable development are closely followed by the practice and general philosophy of ecological living.

Furthermore, long-term economic expansion creates jobs and strengthens economies. A sustainable society, on the other hand, is one that can go on indefinitely. Its consumption level should be in line with environmental and resource balance. It should guarantee equality, freedom, and a decent standard of living to its population. As a result, adopting measuring standards that describe individual, societal, and environmental health is a pressing requirement, and our next generation bears the burden. They should consider and act in the interests of the ecology to which they are connected.

It is vital to gain a better grasp of the structure and functioning of the ecosystems from which we draw resources for our survival if we are to live in a sustainable manner. As a result, swift and long-term empirical investigations should be conducted to evaluate the services provided by these ecosystems. It is important to gain a better understanding of the structure and functioning of ecosystems from which we draw resources for our existence if we are to live in a sustainable way. Consequently, quick and long-term empirical investigations need to be conducted to evaluate the services provided by these ecosystems.

So, in this chapter, we will discuss in detail how we can use ecosystem or environment with a sustainable approach and how to manage ecosystem for sustainable living.

10.3 CONCEPT OF ECOSYSTEM MANAGEMENTS

Ecosystem management is a natural resource management technique that attempts to preserve the long-term viability and persistence of an ecosystem's functions and services while also meeting economical, political, and cultural demands (Szaro et al. 1998; Gary et al. 2013). The concept of ecosystem management emerge as in 1990s as a result of an increasing understanding of ecosystem complexity, as well as humans' reliance and influence on natural systems (Berkes et al. 2000).

10.3.1 Principles of ecosystem management

The long-term sustainability of ecosystems' production of products and services, known as "intergenerational sustainability" (Chapin et al. 2002), is a key premise of ecosystem management. Understanding the function of humans as ecosystem components, as well as the application of adaptive management, is crucial. Ecosystem management can be utilised in intensively managed ecosystems as well as part of a plan for wilderness conservation.

The most important ecosystem management guiding ideas and common themes (Lackey 1998; Edward 1994) are:

- *Ecological limits:* Ecological borders are clearly and formally defined, and management is site-specific, which may necessitate collaboration across political and administrative lines.
- *Systems thinking:* Rather than focusing on one level of biological hierarchy in an ecosystem, management takes a comprehensive approach (e.g., only conserving a specific species; only preserving ecosystem functioning).
- *Ecological integrity:* Management focuses on conserving natural disturbance regimes and other critical processes that support resilience, as well as maintaining or restoring native biological diversity.
- *Monitoring:* The effects of management approaches are tracked, allowing for evaluation and, if necessary, modification of their outcomes.
- *Data collecting:* For effective management, extensive ecological research and data collection are required (e.g., species diversity, habitat types, disturbance regimes, etc.).
- *Interagency cooperation:* As ecological boundaries often cross administrative boundaries, management requires cooperation among a range of agencies and private stakeholders.
- *Organizational change:* Successful management implementation necessitates changes in land management agencies' organisation and operations.
- *Adaptive management:* Management is an iterative process in which methods are constantly reevaluated in light of new scientific information.

- *Values:* Humans have a critical role in directing management objectives, which represent a stage in the formation of social values and priorities.
- *Humans and nature:* Humans and nature are inextricably intertwined, and ecological processes shape and are shaped by humans and vice versa.

10.3.2 Ecosystem management approaches

There are a variety of ways for implementing the maintenance and restoration of natural and human-modified ecosystems. Ecosystem management is preceded by command and control management and traditional natural resource management. Different approaches and processes involved in implementing ecosystem management include adaptive management, strategic management, and landscape-level conservation. Some are discuss here:

- **Command and control management:** Command and control management is a linear problem-solving strategy in which a perceived problem is managed by using controlling devices such as laws, threats, contracts, and/or agreements to fix the problem (Holling et al. 1996). This top-down strategy is employed in many fields and is best suited for dealing with relatively straightforward, well-defined problems with a clear cause and effect and broad societal agreement on policy and management targets (Knight et al. 1997).

- **Natural resource management:** The term "natural resource management" is often used to refer to the management of a single resource for human use rather than the management of an entire ecosystem. Natural resource management strives to meet production is consumed for a resource without harming the ecosystem or risking the resource's long-term viability. Because of its emphasis on natural resources, socioeconomic variables have a considerable impact on this management strategy. Natural resource managers first assess an ecosystem's overall condition, and if the ecosystem's resources are healthy, they calculate the optimal level of resource extraction. At different spatial and temporal scales, the status of each resource in an ecosystem can change, as can ecological traits like watershed and soil health, as well as species diversity and abundance.

- **Adaptive management:** It is based on the idea that anticipating future ecological influences and disturbances is difficult and uncertain. As a result, an ecosystem should be managed to retain the highest level of ecological integrity possible, and management approaches should be adaptable to new information and experience. An adaptive management strategy begins with the formation of hypotheses regarding an ecosystem's functioning, followed by the use of management tools to test these hypotheses. The applied methods are then assessed to see if ecosystem health has improved or deteriorated and additional analysis allows for method modification until the ecosystem's needs are met. Adaptive management is thus an iterative process that promotes "informed trial-and-error" (Pahl-Wostl, 2007).

- **Strategic management:** It advocates the formulation of goals that will sustain an ecosystem while keeping socioeconomic and politically relevant policy factors in mind when it comes to ecosystem management. This technique varies from other types of ecosystem management in that it promotes stakeholder participation and relies on their input to design the optimal ecosystem management strategy. Strategic management stresses analysing and reviewing any repercussions of management intervention on an ecosystem, as well as flexibility in altering management protocols in response to new information, similar to other techniques of ecosystem management.

- **Landscape-level conservation:** Landscape-level (or landscape-scale) conservation is a method that considers wildlife needs at a broader landscape scale when implementing conservation initiatives (Donaldson et al. 2017). In human-dominated areas, balancing the demands of wild flora and animals with the needs of humans can be difficult (Paul and Dirk 2004). Globally, human-caused environmental degradation is becoming more of an issue, which is why landscape-level approaches to ecosystem management are so crucial. Traditional conservation strategies that focus on individual species may need to be adjusted to include habitat preservation that takes into account both human and ecological factors.

10.4 PRINCIPLES OF SUSTAINABLE DEVELOPMENT

The root of sustainable development can be trace back to 1972 Stockholm Conference in Sweden where economic growth or development was the first time linked to environment, emphasizing the need for efforts at International level.

Development should be environmentally sound and sustainable. The need of social and economic equity for achieving sustainable development was also emphasized at this conference. Such a concept was followed up further that led to the creation of World Conservation Strategy (1980) and finally to UNCED (Earth summit) in 1992 at Rio de Janerio, Brazil.

In September 2015, the General Assembly of the United Nation adopted the 2030 Agenda for sustainable development that included 17 sustainable development goals (SDGs). Building on the principle of “leaving no one behind”, the new agenda emphasizes a holistic approach to achieving sustainable development for all. The 17 sustainable developments goals are:

- No poverty
- Zero hunger
- Good health and well being

- Quality education
- Gender equality
- Clean water and sanitation
- Affordable and clean energy
- Decent work and economic growth
- Industrial, innovation and infrastructure
- Reduce inequality
- Sustainable cities and communities
- Responsible consumption and production
- Climate action
- Life below water
- Life and land
- Peace and justice strong institutions
- Partnership to achieve the goal

10.4.1 What is sustainable development?

It is the capacity of the earth's various system including human cultural systems and economics, to survive and adapt to changing environmental conditions. Sustainable development implies "a charge in all aspects of life in a way that causes little damage to environment.” Sustainable development follows "a form of growth and development in Society that meets the current human needs preserving the natural resources for meeting the needs of future generation as well”. As defined in the Brundtland Commission report (WCED, 1987), sustainable development is meeting the needs of the present without compromising the ability of future generations to meet their own needs.

10.4.2 Principles of sustainable development

We can develop more sustainable economics and societies by following the four major ways that nature has adapted and sustained itself for several billion years.

How can we live more sustainable? According to ecologist, we can find out how nature has survived and adapted for several billion years and copy its strategy. Figure 10.1 summarized the four major ways in which life on earth has survived and adapted for several billion of years. Table 10.1 gives an expanded description of these principles i.e., how nature works and summarize how we can live more sustainably by mimicking these fundamental but amazingly simple lessons from nature in designing our societies, products and economics.

Biologists have used these lessons from their ecological study of nature to formulate four guidelines for developing more sustainable societies.

1. Our life, lifestyle and economies are totally dependent on the sun and the earth. We need the earth but our earth needs not us. As a species we are very expandable.

2. Everything is connected to, and interdepended with everything else. The primary goal of ecology is to discover what connections in nature are the strongest, most important and most vulnerable for us and other species.

3. We can never do just one thing. Any human intrusion into nature has unexpected and mostly unintended side effects. When we alter nature, we need to ask "Now what will happen".

4. We cannot indefinitely sustain a civilization that depletes and degrades the earth's natural capital but we can sustain one that lives off the biological income provided by the earth's natural capital.

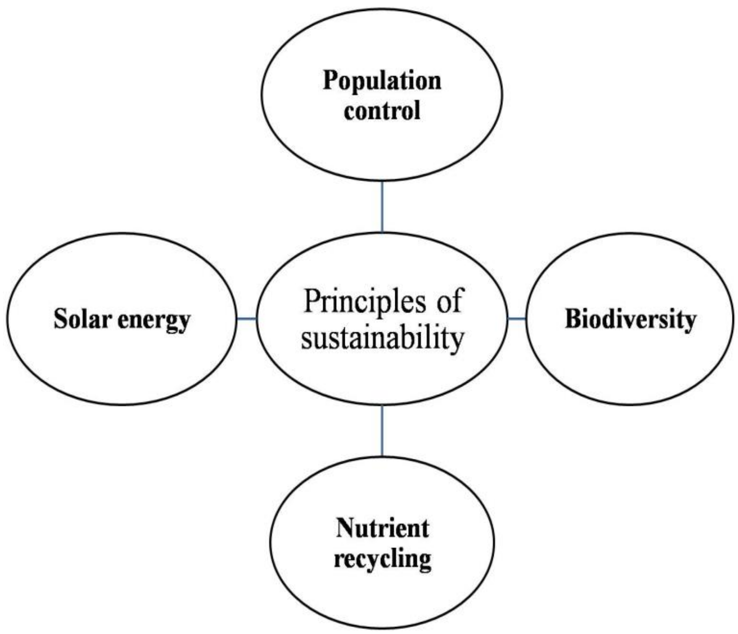

Fig. 10.1: Four interconnected principles of sustainability derived from learning how nature sustains itself (Source: Sharma 2011)

Increasingly, environmental scientists and ecologists are urging that we base our efforts to prevent damage to the earth life support system on the precautionary principle: When evidence indicates that an activity can seriously harm human health or the environment, we should take precautionary measures to prevent or minimize such harm, even if some of the cause and effect relationship have not been fully established scientifically. This principle is based on the commonsense idea behind many adages such as "Better safe than sorry" "look before you leap" "First, do no harm" and "slow down for speed bumps".

As an analogy, we know that eating too much of certain types of foods and not getting enough exercise can greatly increase our chances of a heart attack, diabetes and other disorders. The exact connections between these health problems, chemicals in various foods, exercise and genetics are still under study and often debated. People with such conditions could use this uncertainly and unpredictability as an excuse to continue overeating and not exercising. In reality, the wise course is to eat better and exercise more to help and prevent potentially serious health problems.

Table 10.1: Implications of the four principles of sustainability, derived from observing nature for the long-term sustainability of human societies. These four operating principles of nature are connected to one another. Failure of any single principle can lead to temporary or long term unsustainability and disruption of ecosystems and human economies and societies.

SN.	How nature works	Lesson for us
1.	Runs on renewable solar energy	Rely mostly on renewable solar energy
2.	Recycle nutrients and wastes. There is little waste in nature	Prevent and reduce pollution and recycle and reuse resources
3.	Uses biodiversity to maintain itself and adapt to new environmental conditions.	Conserve biodiversity by protecting ecosystem
4.	Controls a species population size and resource use by interactions with its environment and other species	Reduce human births and wasteful resource use to prevent and depletion and degradation of resources.

Although we need to project possible unintended effects carefully, we can never predict all the unintended effects of our actions and technologies. We must always be willing to take some risks. Otherwise, we would stifle creativity and innovation and severely limit the development of new technologies and products.

10.4.3 Human impacts on Natural resources: Causes of unsustainability

The chief cause of unsustainability is the exponential growth of human population and over exploitation of natural resources. In developing countries, resource exploitation occurs chiefly to meet the needs of ever increasing human population for food fuel fodder and shelter. The various human activities (such as agriculture, deforestation, land clearing for urbanisation and industrialisation, over fishing, over use of fresh waters etc.) targeted to meet such needs result into environmental degradation and social disintegration.

To provide resources for growing numbers of people, we have modified, cultivated, built on, or degraded a greatly increasing number and area of the earth’s natural systems. Excluding Antarctica, our activities have, to some degree, directly affected about 83% of the earth’s land surface. Figure 10.2 compares some of the characteristics of nature and human dominated ecosystem.

We have used technology to alter much of the rest of nature to meet our growing needs and wants in the following eight major ways (Table 10.2).

1. We have reduced biodiversity by destroying fragmentation, degrading and simplifying wildlife habitat. We have cleared forests, dug grasslands and fill the wet lands for our own benefits. This into loss of overall biodiversity and the degradation of the earth's natural capital.

2. We have used, wasted or destroyed an increasing percentage of the earth's net primary productivity that supports all the consumers including humans. This is the main reason we are crowding out or eliminating the habitats and food supplies of a growing number of species.

3. We have unintentionally strengthened some populations of pet species and disease causing bacteria. Indiscriminate use of pesticides and antibiotics has speeded up natural selection among rapidly reproducing pest and bacterial populations leading to resistance to these chemicals.

4. We have eliminated some predicators. Some ranchers want to eradicate bison or prairie dogs that compete with their sheep and cattle. They also wants to eliminate coyotes, eagles and other predators that occasionally killed their cattle.

5. We have occasionally or deliberately introduced some alien species to a region. Most of these species such as food crops and domestic livestock are beneficial to us but a few are harmful to us and other species.

6. We have some renewable resources faster than they can be regenerated. Ranchers and nomadic hunters sometimes allow livestock to overgraze grasslands until erosion converts these communities to less productive semi-desert or desert. Farmers sometime deplete soil of its nutrients by excessive crop growing. Some fish species are over harvested. Illegal hunting and poaching endangers wildlife species with economically valuable parts such as elephant tusks, rhinoceros horns, and tiger skin. In some areas, fresh water is being pumped out of underground aquifers faster than it is being stock up.

7. Some human activities interfere with the normal nutrient elements cycling and energy flow in ecosystems. Soil nutrients can erode from monoculture crop fields, tree fostering, constructions and many other reasons. Our input of CO_2 into carbon cycle have been increasing sharply mostly from burning fossil fuels and from cleaning and resulted burning forest and grassland. This and other inputs of greenhouse gases from human activities can trigger global climate change by altering energy flow through the

troposphere. The human input of nitrogen into the nitrogen exceeds the earth's natural input. We are also alerting energy flow through the biosphere by releasing chemicals into the atmosphere that can increase the amount of harmful ultra violet energy reaching the troposphere by reducing ozone levels in the troposphere.

8. While most natural ecosystems based on the sun energy, human based modified ecosystems have become increasingly dependent on nonrenewable energy from fossil fuels. Fossil fuel systems typically produce pollution, add the GHGs to the atmosphere and wasted a great deal of energy. We are confronted by two major challenges:

(i). We need to balance between simplified, human altered communities and the more complex natural communities on which we and other species depend.

(ii). We need to slow down the rates at which we are simplifying, homogenizing and degrading nature for our purpose. Otherwise, what is at risk is not the resilient earth but rather the quality of life for our own species and the existence of the other species we drive to premature extinction. We cannot save the earth; it can get alone very nicely without us, just as it has done for 3.7 billion years. However, by learning how the earth works and by working with its natural process, we can sustain the quality of life for the human species and avoid the projected premature extinction of as many as half of the world's species during this century as a result of the eight factors just discussed above.

Table 10.2: Major ways humans have altered the rest of nature to meet our growing populations, needs and wants

1.	Reduction of biodiversity
2.	Increasing use of the earth's net primary productivity
3.	Increasing genetic resistance of pest species and disease causing bacteria
4.	Elimination of many natural predators
5.	Deliberate or accidental introduction of potentially harmful species into communities
6.	Using some renewable resources faster than they can be replenished
7.	Interfering with the earth's chemical cycling and energy flow processes
8.	Relying mostly on pulling fossil fuels

10.4.4 International efforts on sustainable development

The various international programmes targeted for sustainable development are as follows:

World conservation strategy: The International Union for Conservation of Nature and Natural Resources (IUCN), the United Nations Environment Programme (UNEP), and the World Wide Fund for Nature (WWF) developed a long rang plane of world conservation strategy for conserving the world's biological resources. The plan was expanded and followed by "Caring for the earth: A Strategy for sustainable living" which included a set of principles and strategies of sustainable society based on practical integration of environmental, social and economic concerns. Its primary goals were to maintain essential ecological processes and life support systems, to preserve species and genetic diversity to ensure the use of the species and ecosystems in a sustainable manner and to improve the quality of the human life.

Characteristics	Natural systems	Human modified systems
1. Complexity	1. Biologically diverse	1. Biologically simplifies
2. Energy resources	2. Renewable solar energy	2. Mostly non-rewable fossil fuel energy
3. Waste production	3. Little, if any	3. High
4. Nutrients	4. Recycled	4. Often lost or wasted
5. Net primary productivity	5. Shared among many species	5. Used, destroyed, or degraded to support human activities

Fig. 10.2: Some typical characteristics of natural and human-modified systems (Source: Sharma 2011)

World commission on environment and development: The concept of sustainability became stronger during 1980s. The United Nations established a commission, the World Commission on Environment and Development in 1983, frequently referred to as the Brundtland Commission, after Gro Harlem Brundtland, the head of the commission and former prime insister of Norway. It proposed a global agenda to address the World's environmental problems and people's concerns, relating to living conditions, resources, populations pressure, international trades, education and health.

The Brundtland commission Report, *Our Common Future*, defined sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development has three principal dimensions: economic, social and environmental. Our economic front, the poverty should be eradicated through the optimal efficient use of natural resources. The concept of needs refers in particular to the essential needs of the world's poor. The social aspect refers to a socially sustainable system based on distributional equity, uplifting the welfare of people, improving access to basic health and education service, gender equity, political accountability and participation. It also refers to the development of various cultures, diversity, pluralism and effective grass roots participation in decision-making.

The environmental aspect is concerned with the conservation and enhancement of the physical and biological resource base avoiding and depletion of non renewable resources. Environmental sustainability has main focus on maintenance biological diversity, atmospheric stability and ecosystem function and survives.

United Nations Conference on Environment and Development (UNCED)/ Earth summit

The issue of sustainable development has been dealt in a series of UN-based conferences. At the United Nations Conference of Environment and Development held in Rio de Janerio 3-14 June, 1992 most of Heads of states and governments of various counties of the world signed the Framework Convention on Climate Change and Conservation of Biological Diversity; endorsed the Rio Declaration and the forest principles. The Summit adopted Rio Declaration and Agenda 21, for achieving sustainable development in the 21st century. It reflects a global consensus and political commitment at the national and international level on environment and development cooperation. The Rio concept of sustainable development includes:

- Equal consideration of environment, society and economy for all.
- Intergenerational solidarity-consideration of the needs of future generations.
- Intergenerational solidarity-consideration of the needs of poor.

The Rio summit follows up

The Rio summit was follow by the several other conferences with a focus on sustainable development; The South Asia cooperative Environment Programme (SACEP), September 1992, Colombo; The SAARC summit, Dec 1992, Dhaka; The Global Conference on Sustainable Development of small Island Developing state, Barbados, 1994; the International Conference on population and Development Cario, 1994; the World Summit on Social Development on Women, Beijing, 1995; and the secound UN Conference on Human Settlements, Habitat II, Istanbul, 1996. All these conferences and many other events have raised considerable awareness and contributed to the concept of sustainable Development.

Commission on sustainable Development

The United Nations Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow up of UNCED; to oversee the implementation of the earth summit agreements on sustainable development at local, national and international levels. The CSD is functional commission of the UN Economic and Social Council (ECOSOC), with 53 members. A five years review of Earth Summit progress took place in 1997 by the United nations General Assembly meeting in special session, followed in 2002 by a ten year review by the world summit on sustainable development. Unfortunately the commission become a stagnant body and failed to unite North and South.

World Summit on sustainable development

The United Nations World Summit on Sustainable Development (WSSD) was held in Johannesburg, South Africa, 26 August to 4 September 2002. The WSSD urged in its plan of implementation that “States should take immediate steps to make progress in the formulation and elaboration of national strategies for sustainable development and begin their implementation by 2005.

Sustainable development in India: Perspective and Strategies

As indicated earlier environmental sustainability has been an integral part of the Indian culture. The need for conservation and sustainable use of natural resources has been expressed in Indian scriptures more than thousand years ago and also reflect in our constitutional, legislative and policy framework along with international commitments.

India also focused on increasing air and water pollution, degradation of land and forest and loss of biodiversity. The various measures initiated for environment protection by India including the following major points:

1. Stockholm declaration by former Indian prime minister. The only visiting head of state participating in UN conference on Human Environment in Swefen in 1972, fully supporting the idea of the conference.

2. Making sustainability as an intrinsic component of every planning process. The Ninth five year plan (1997-2002) recognized a close relationship between environment, health and development and suggested initiatives for enduring environmental sustainability. Principles of sustainable development were also followed in successive Tenth-five year plan also (2002-2007).It included:

    - Reduction of poverty
    - School education for all children.
    - Reduction in gender gap
    - Control of human population growth
    - Increase rate of literacy
    - Reduction in mortality rate of infants
    - Increase in forest cover
    - Drinking water access to village
    - Cleaning of major polluted rivers

3. Setting of department of Environment in 1980 that was upgraded to a full fledged Ministry.
4. Environment protection act in 1986.
5. The National Conservation Strategy and Policy Statement and Development in 1992.
6. A signatory to convention on Biological diversity (CBD).
7. Biological Diversity Act 2002 with National biological Diversity Authority for conservation of biodiversity sustainable use of its components and equitable share of its benefits.
8. Acceded to Montreal Protocol and setting up ozone cell in MoEF.
9. Ratification of United Nations Framework Convention on Climate Change (UNFCCC).

10.5 LIMITATIONS

There are several challenges to sustainable development. These are as follows:

1. **Technology, science, and research constraints:** Not all promising technologies take sustainability into account or no technology is completely sustainable. These are ways to make our life easier and reduce some negative impacts (e.g., carbon emission or energy use) but the end result is that the more progress we make, the more energy we need to maintain it.
2. **Economic growth:** The capitalistic rights of comprehensive economies in the developing as well as developed countries impose a number of economic restrictions to anticipate the sustainable solutions. A sustainable solution that does not result in economic growth and financial benefits will most likely not be implemented or implemented.
3. **Public policies:** The sustainability based on how much public policies are willing to support social, economic and environment. It is merely potential when there is an equivalent input. Unless there is more constancy on all these aspects, we are unable to confer sufficient interest to the burning issues of world protection.
4. **Social awareness:** The vast majority of the population, especially in poor countries, is unaware of the importance of supporting social-sustainability solutions, which is a well-made and commonly known point. Because most of them are trying to meet their own needs, they are willing to give up on broad aspirations or don't have time to consider the bigger picture. Consequently, raising social consciousness in such a way that the general public understands the daily consequences of environmental degradation is the way to go.

It is a well made and widely known point that the general public, especially in developing countries, is not aware of the importance of supporting social-sustainability solutions. This is because most of them are struggling to make ends meet in their lives and they are willing to sacrifice any big goal or they do not have the luxury of looking at the big picture. So, social awareness is the way to go here in a way to make the public understand the daily disadvantages of eco-degradation. The above said factors lead to global problems of: economic disparity and social injustice, air and water pollution, global warming & climate change, loss of biodiversity and ozone depletion. Many of the above said effects are long term and irreversible with consequence for future generation.

10.6 ECOLOGICAL URBANIZATION

Urbanization is a process that transforms undeveloped territory into towns and cities, and it's been declared as "one of the most environmentally devastating types of global change." However, metropolitan regions constitute the world's fastest increasing environmental sector. Towns and cities are spreading as human populations grow, while wilderness and even farmlands are dwindling.

Every aspect of a natural ecosystem is affected by urbanisation. As structures displace plants, land cover, drainage, and nutrient cycles are all fundamentally affected and even characteristics like temperature can be altered. Many species natural habitats are being destroyed, degraded, or fragmented. The remnant vegetation is frequently fragmented, disjointed, and lacks the mature complexity of a long-established natural region, all of which impair diversity and wildlife resiliency.

Unfortunately, the locations where people build communities are also rich in wildlife- we, like other animals, are looking for good environmental resources. Running water, good soils, livable climates, proximity to coasts, and transportation routes are all things we look for. These ideal conditions are frequently also the most biologically diverse. Our most damaging kind of change is disproportionately harming some of our most ecologically valuable lands.

10.6.1 Causes of urbanization

Urbanization occurs either organically or planned as a result of individual, collective and state action. Living in a city can be culturally and economically advantageous since it can provide more options for accessibility to the labour market, better education, housing, and safety conditions, as well as lower commute and transit time and costs. Density, proximity, diversity, and marketplace competition are all factors that contribute to a healthy urban environment. However, there are also negative social consequences associated with urban living, such as alienation, stress, higher living costs, and mass marginalisation. The major reasons for the growing rate of urbanisation are:

- **Economic opportunities:** Cities are centralised in monetary terms, commodities, luxury, and possibilities. Many people from the countryside travel to the city to seek their fortune and enhance their social standing. In metropolitan locations, businesses that offer jobs and trade wealth are increasingly concentrated. Overseas currency enters a country through ports or banking institutions, which are usually located in cities, whether the source is trade or tourist.

- **Quality of life:** This is extremely subjective and may well exceed that of the city. Farming has always been vulnerable to unpredictably changing environmental circumstances, and survival can be difficult in times of drought, flood, or plague. Elderly individuals may be forced to relocate to cities with medical professionals capable of meeting their medical demands. A variety of high-quality educational possibilities, as well as the potential to join, create, and seek out social communities, are all factors in urban migration. Cities provide a wider range of services, including specialised services that are not available in rural locations.
- **Gender equality:** Urbanization also creates opportunities for women that are not available in rural areas. This creates a gender-related conversion where women are engaged in paid employment and have access to education. However, women are sometimes still at a disadvantage due to their unequal position in the labour market, their inability to secure assets independently from male relatives and exposure to violence (UNFPA. 2012).

10.6.2 Impacts of urbanization

The increasing population density and needs of urban areas exacerbate poor air and water quality, insufficient water supply, waste disposal issues, and high energy use. The following are the three major effects of urbanisation:

(A) Economic effects

As cities develop, effects can include a dramatic increase and change in costs, often pricing the local working class out of the market, including such functionaries as employees of the local municipalities.

Suburbanization tendencies in developing countries are also being fueled by urban challenges and infrastructural advances, even while the trend for core cities in these countries is continuing to become denser. Although urbanisation is frequently considered as a negative trend, yet there are benefits in terms of reduced commuting and transit costs as well as improved job, education, housing, and transportation prospects. (Nowak 1997)

In many developing countries where economies are growing, the growth is often erratic and based on a small number of industries. In order for young people in these nations to access possibilities in these industries, constraints such as a lack of access to financial services and business consulting services, trouble obtaining loans to start a firm, and a lack of entrepreneurial skills exist.

(B) Environmental effects

Urbanization has the following impacts on environment:

a. **Habitat fragmentation:** Urbanization can have a huge consequence on diversity by causing a division of habitats and thereby alienation of species, a process known as habitat fragmentation. Depending on the various factors, such as level of urbanization, both increases and decreases in "species richness" can be seen (McKinney 2008). This means that while urbanisation may be harmful to some species, it can also aid in the growth of others. Habitat fragmentation can help to filter species that have a limited ability to disperse.

b. **Urban heat island:** The existence of urban heat islands has become a growing concern over the years. An urban heat island is formed when industrial and urban areas produce and retain heat. Much of the solar energy that reaches rural areas is consumed by evaporation of water from vegetation and soil (Padalia et al. 2018; 2021 Bargali et al. 2019). In cities, where there are less vegetation and exposed soil, most of the sun's energy is instead absorbed by buildings and asphalt; leading to higher surface temperatures.

c. **Food waste:** Food waste refers to the discarding of food items that are no longer usable owing to unused items, expiration, or spoiling. Increased food waste can cause environmental issues such as increased methane gas generation and disease vector recruitment (Adhikari et al. 2006). Landfills are the third greatest source of methane emissions (EPA, OA, US (2015)), raising concerns about its influence on the ozone layer and human health. Increased fermentation is caused by the accumulation of food waste, which raises the risk of rodent and bug migration. An increase in disease vector movement increases the risk of disease spreading to humans (Venkateswaran 1994).

d. **Water quality:** Another effect of huge urbanization of populations on the environment is the incidence of eutrophication of water bodies. Eutrophication is a process that results in hypoxic water and algal blooms, which can be harmful to aquatic life existence. Harmful algal blooms, which create harmful toxins, grow in eutrophic, nitrogen- and phosphorus-rich environment. They dominate surface water in these optimum conditions, making it difficult for other species to absorb sunlight and nutrition.

   Acid rain is also a typical occurrence in heavily populated areas around the world. Chemicals are washed directly into rivers, streams, and seas, causing water quality to deteriorate and marine habitats to be harmed.

   The oceans are one of the major CO_2 sinks on the planet. This has been beneficial to the environment by reducing greenhouse gas emissions, but it has also contributed to the perpetuation of acidification. pH changes prevent the synthesis of calcium carbonate, which is necessary for many marine species to maintain their shells or skeletons. This is notably true for many mollusk and coral species. Nevertheless, some organisms have been capable of adapting to a more acidic environment and survive (Feely 2010).

(C) Health and social effects

Improvements in public cleanliness, sanitation, and access to health care are connected with urbanisation, as are changes in occupational, nutritional, and activity patterns. It can have a mixed influence on health patterns, reducing certain issues while exacerbating others (Eckert and Kohler 2014).

a. **Nutrition:** The creation of food deserts is one such result. Food deserts in developed countries often correspond to areas with a high-density of fast food chains and convenience stores that offer little to no fresh food. Obesity, diabetes, and other chronic diseases are linked to a lack of availability to healthful foods and high fat, sugar, and salt intake. Overall, BMI and cholesterol levels rise dramatically in tandem with national wealth and urbanisation.

b. **Respiratory diseases**: In addition, urbanisation has been linked to an increased incidence of asthma. Globally, as populations shift from rural to urban society, the number of individuals affected by asthma rises. This research suggests that urbanisation may have a negative impact on population health, especially in terms of asthma vulnerability (Ponte et al. 2018). According to researchers, this disparity in hazard ratios is attributable to higher levels of air pollution and exposure to environmental allergens found in metropolitan regions, which cause asthma in the children and elderly (Lin et al. 2017).

c. **Mental health:** Increased stress is a typical form of individual psychological stress that occurs as a result of urbanisation and is thought to be caused by perceived uncertainty. Changes in social organisation are assumed to lead to decreased social support, greater aggression, and congestion as a result of urbanisation.These elements have been hypothesized to play a role in increasing stress. It is important to remember that urbanization and population density do not in themselves cause mental health issues. Mental health issues are exacerbated by the interaction of urbanization with physical and social risk factors.

d. **Crime:** The high crime rate in urbanised areas is caused by a number of factors, including per capita income, income disparity, and overall population size. There's also a link between unemployment, police spending, and crime, though it's not as strong. The existence of crime has the potential to generate additional crime. Because most crime occurs in city centres, the farther you are from the city's centre, the less likely you are to be a victim of crime (Bruinsma 2007).

   In urbanised areas, migration is also a factor that might increase crime. People from one region are displaced and compelled to relocate to a city. They've been thrust into a new environment, complete with new social conventions and ideals. This can result in a loss of social cohesion as well as an increase in crime (Malik 2016).

10.6.3 Solutions to urbanization problems

1. **Creating sustainable and environmentally friendly cities:** Governments should adopt certain laws that supply environmentally sound cities and smart growth approaches. Governments also must support and encourage investments in green infrastructure, sustainable industries, recycling and environmental campaigns, pollution management, renewable energy, green public transportation, and water recycling and reclamation, as well as an economy based on sustainable environments.
2. **Access to key services:** Urban stakeholders must guarantee that all residents in urban areas have appropriate access to essential social services such as education, health, sanitation, and clean water, as well as technology, energy, and food. They should aim to create and implement job possibilities and wealth-generating activities so that people may make a living and pay for the upkeep of the services.
3. **Job creation:** In order to mitigate the negative effects of rapid urbanisation while also maintaining natural ecosystems, private investments in natural resource utilisation and job creation should be promoted. More jobs for urban people can be created through tourism promotion and sustainable natural resource use. Foreign and private investment in environmentally friendly development projects that create jobs may also be eligible for subsidies and grants.
4. **Population control:** Key stakeholders in urban areas must offer counseling and campaigns for efficient medical facilities and family planning to facilitate to lessen the uncontrolled rates of population. Medical health clinics oriented towards family planning options should be made accessible throughout the urban region with the aim of controlling diseases and population growth.

10.7 SUMMARY

Sustainable living is a way of life which aims to limit an individual's or society generally consumption of natural and personal resources on the planet. Its supporters strive to live in a way that is consistent with sustainability, natural balance, and respect for the natural ecology of the Earth.

The concept of ecosystem management emerge as in 1990s as a result of an increasing understanding of ecosystem complexity, as well as human’s reliance and influence on natural systems. Ecosystem management is preceded by command and control management and traditional natural resource management. Different approaches and processes involved in implementing ecosystem management include adaptive management, strategic management, and landscape-level conservation. Biologists have study of nature to formulate four guidelines for developing more sustainable societies, i.e., (i). Our life, lifestyle and economies are totally dependent on the sun and the earth (ii). Everything is connected to, and interdepended with everything else. (iii). We can never do just one thing. (iv). We cannot indefinitely sustain a civilization that depletes and degrades the earth’s natural capital but we can sustain one that lives off the biological income provided by the earth’s natural capital.

The chief cause of unsustainability is the exponential growth of human population and over exploitation of natural resources. To cope up with the harms many International, National and local initiatives have been taken or taking by the governments and local authorities to maintain the ecological balance and sustainability. The International Union for Conservation of Nature and Natural Resources (IUCN), the United Nations Environment Programme (UNEP), and the World Wide Fund for Nature (WWF) developed a long rang plane of world conservation strategy for conserving the world’s biological resources. World commission on environment and development, United Nations Conference on Environment and Development (UNCED)/ Earth summit, The Rio summit, Commission on sustainable Development, World Summit on sustainable development etc are some International efforts.

India, as indicated earlier environmental sustainability has been an integral part of the Indian culture, also focused on increasing air and water pollution, degradation of land and forest and loss of biodiversity. The Ninth five year plan (1997-2002) recognized a close relationship between environment, health and environmental sustainability, setting of department of Environment in 1980 that was upgraded to a full fledged Ministry, Environment protection act in 1986, The National Conservation Strategy and Policy Statement and Development in 1992, signatory to convention on Biological diversity (CBD), Biological Diversity Act 2002 with National biological Diversity Authority for conservation of biodiversity sustainable use of its components and equitable share of its benefits, acceded to Montreal Protocol and setting up ozone cell in MoEF, ratification of United Nations Framework Convention on Climate Change (UNFCCC) are some initiatives taken by the Indian Government from time to time.

Urbanization is a process that transforms undeveloped territory into towns and cities, and it's been declared as "one of the most environmentally devastating types of global change. There are several causes of the rapid urbanization in the present era. Economic opportunities, quality of life and gender equality are the major motivations among them.

The increasing population density and needs of metropolitan regions have a negative impact on ecological, mental and social health of the society. The impacts of modernization of rural areas into urban areas include poor air and water quality, insufficient water supply, waste disposal issues, high energy use, habitat fragmentation, heat island, more frequent acid rain, low nutritional value of food, many respiratory and heart diseases, mental illness, and pressure.

To overcome the problems of urbanization and meet the demand of the daily requirements local or national governments must have implemented or adopted certain laws that support the environment healthy. Creating sustainable and environmentally friendly cities, access to key services for rural citizens, creating new job opportunity in undeveloped regions, and population control measurements can be the best approach to overcome the problems of urbanization.

10.8 GLOSSARY

Acid rain: rain or other forms of precipitation that is unusually acidic.

Adaptation: a characteristic of an organism that has been favoured by natural selection.

Afforestation: planting new forests on lands that have not been recently forested.

Algal bloom: the rapid and excessive growth of algae; generally caused by high nutrient levels combined with other favourable conditions. Blooms can deoxygenate the water leading to the loss of wildlife.

Biodiversity: the variety of life in all its forms, levels and combinations; includes ecosystem diversity, species diversity, and genetic diversity.

Carbon dioxide: a gas with the chemical formula CO2; the most abundant greenhouse gas emitted from fossil fuels.

Carbon pool: a storage reservoir of carbon.

Carbon sink: any carbon storage system that causes a net removal of greenhouse gases from the atmosphere.

Climate: the general variations of weather in a region over long periods of time; the "average weather" cf. weather.

Consumer: organism, human being, or industry that maintains itself by transforming a high-quality energy source into a lower one cf. Producer, primary production.

Energy management: A program of well-planned actions aimed at reducing energy use, recurrent energy costs, and detrimental greenhouse gas emissions.

Family planning: the planning of when to have children, and the use of birth control and other techniques to implement such plans.

Fertility rate: number of live births per 1,000 women aged 15 to 44 years cf. birth rate, mortality rate.

Food desert: are places that are not served by grocery stores, often because they are lower class areas, and therefore not profitable. The residents often don’t have access to transport. They are ideal settings for urban farms.

Forest – land with a canopy cover greater than 30%.

Urbanization: increase in the proportion of a population living in urban areas

Cities: otherwise referred to as densely populated areas.

Rural areas: otherwise referred to as thinly populated areas

Environment: The surroundings or conditions in which a person, animal, or plant lives or operates

Renewable energy: Energy that is collected from renewable resources, tex wind, wave and solar energy

Solar energy: Energy harvested from the sun, can be solar heating, photovoltaics, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis

Sustainable resources: Renewable resources which can be used again and again

10.9 SELF ASSESSMENT QUESTIONS

10.9.1 Multiple Choice Questions

1. Where was the sustainable development explained for first time
   (a) World Development Report (b) Brundtland Commission Report
   (c) First Earth Summit Report (d) Human Development report
2. Which of the following is not a sustainable development goal target to be achieved by 2030
   (a) Gender equality (b) Zero hunger
   (c) Good health and wellbeing (d) Space research
3. In "agenda 21" of Rio summit is related to:
   (a) Sustainable development (b) Polluter-pays principle
   (c) Environmental education (d) Preservation of ozone layer
4. Which household waste has an excellent recycling potential?
   (a) Vegetable scraps (b) Metal
   (c) Plastic (d) Rubber
5. Which of the following is not a part of sustainable development goal target to be achieved by 2030.
   (a) Providing free primary and secoundry schooling for all
   (b) Universal access to a quality education
   (c) Equal access to affordable vocational training
   (d) Free higher education to all
6. Which of the following do not form part of a strategy of sustainable development?
   (a) Relying more on organic farming
   (b) Reducing the use of personal vehicles and promoting public transport
   (c) Safeguarding the habitats of indigenous communities, flora and fauna
   (d) Not compromising on the needs of the present generation with respect to future generations
7. Which of the following are to be managed for sustainable development?
   (a) Industries (b) Forests
   (c) Crops (d) Resources
8. One of the conventional sources of energy is
   (a) Wind energy (b) Tidal energy
   (c) Hydroelectric energy (d) None of the above

9. At the Central Government level, which agency was assigned the role of overseeing the implementation of sustainable development goals in India?
   (a) The Energy Resource Institute (TERI)
   (b) NITI aayog
   (c) Center for Environment And Sustainable Development India (CESDI)
   (d) The comptroller and Auditor General of India (CAG)
10. How many sustainable development are there in the UN Agenda 2030?
   (a) 14 (b) 15
   (c) 16 (d) 17

10.9.2 True and False

1. Urbanization is the result of migration of population from village to cities.
2. General assembly of UN adopted the 2030 agenda for sustainable development that includes 15 sustainable goals.
3. Metal and rubber are harder to recycle and recycling plastic is even more difficult and not economical.
4. Population density is also a major cause of unsustainability.
5. Urbanization is a process that transforms undeveloped territory into towns and cities

10.9.3 Fill in the Blanks

1. Sustainable development was developed for the first time in the Brundtland Commission Report in ________
2. The first earth summit took place in ________ in June 1992.
3. The Montreal Protocol was singed in ________.
4. _________ and _________ are the major cause of urbanization.
5. ____________ can help to filter species that have a limited ability to disperse.

Answer key

10.9.1: 1.(b); 2.(d); 3.(a); 4.(a); 5.(d); 6.(d); 7.(d); 8.(d); 9.(b); 10.(d)
10.9.2: 1.True; 2. False; 3. True; 4. True; 5. True
10.9.3: 1.1987; 2. Rio de Janeiro; 3. 1987; 4. Economic opportunities, Quality of life; 5. Habitat fragmentation

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10.12 TERMINAL QUESTIONS

10.12.1 Short Answer Type Questions

1. What do you understand by sustainable development?
2. Discuss the principle of ecosystem management in brief.

3. What are the principles of sustainable development?
4. Highlight the major cause of ecosystem unsustainablity.
5. Describe the impacts of urbanization on human health.

10.12.2 Long Answer Type Questions

1. What do you understand by ecological urbanization? What are the major causes of it and also discuss the impacts of urbanization in detail.
2. What is sustainable development? Discuss its causes and limitations in detail.
3. Discuss the International and National initiatives of sustainable development in detail.
4. Write a detailed note on ecosystem management?

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