Study Material for Bachelor of Technology

(B. Tech)

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(Common for All Branches)

Subject: Environmental Studies (CYL-101)

Unit-II: Ecosystems

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ECOSYSTEM

The portion of the Earth which sustains life is called the biosphere. The biosphere is vast and cannot be studied as a single entity. It is divided into many distinct functional units called an ecosystem.

AN ECOSYSTEM

An ecosystem is a system, or a group of interconnected elements, formed by the interaction of a community of organisms with their environment.

Components of an Ecosystem

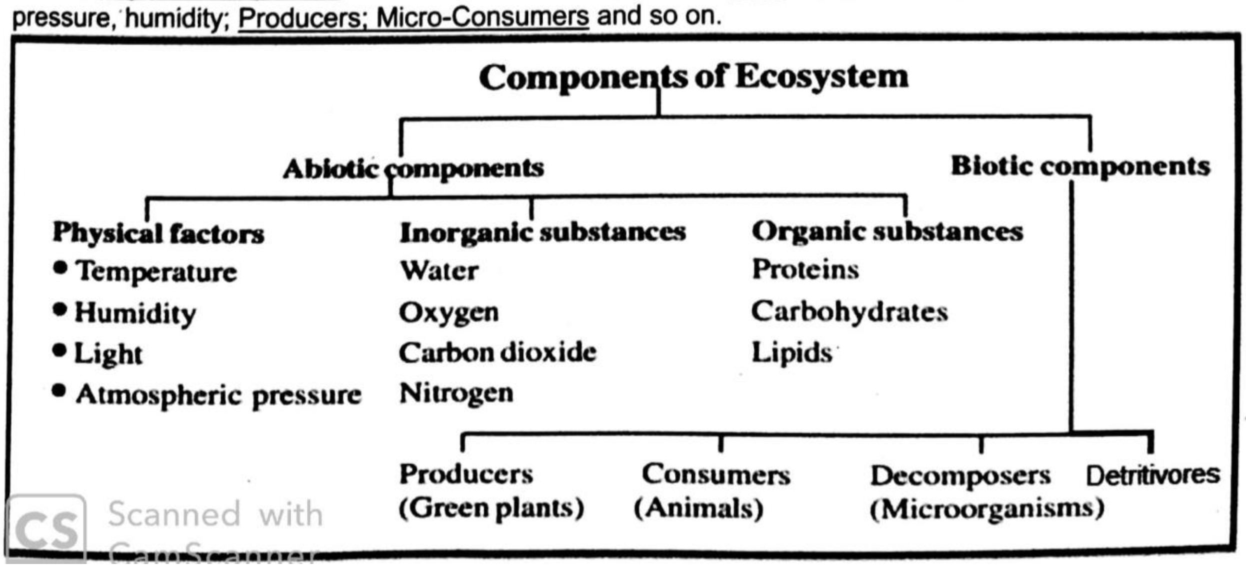
An ecosystem is referred to as the systems involving the habitation of local flora and fauna. It is a subset of Biosphere, wherein various species, their populations and communities interact with each other along with non-living things like land, sunlight, wind, humidity to name a few, called as abiotic elements, (whereas, the living things are called as biotic elements).

In nature, several communities of organisms live together and interact with each other as well as with their physical environment as an ecological unit. It is called an ecosystem. A.G. Tansley coined the term 'ecosystem' in 1935.

These biotic and abiotic elements continuously produce and exchange materials. The interaction between them involves input, transfer and storage of energy and nutrients. However, as a result of these complex processes, the components of an ecosystem tend to attain a state of equilibrium, thereby becoming self-sustaining and controlled by limiting factors.

Photosynthesis: The process begins when sunlight is absorbed by chlorophyll and other pigments in the plant. The plants use energy from sunlight to combine carbon dioxide from the atmosphere with water from the soil to make carbohydrates, starches, and cellulose. This process converts the energy of sunlight into energy stored in chemical bonds with oxygen as a by-product. This stored energy is the direct or indirect source of energy for all organisms in the ecosystem.

A pond is an excellent example of an ecosystem. It includes inorganic aspects like Oxygen, Nitrogen, Water; organic compounds like Protein, Carbohydrates, Lipids; physical factors like temperature, pressure, humidity; Producers; Micro-Consumers and so on.



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Ecosystem - Abiotic Components (Nonliving): The abiotic component can be grouped into the following three categories:-

1. **Physical factors:** Sunlight, temperature, rainfall, humidity and pressure. They sustain and limit the growth of organisms in an ecosystem.
2. **Inorganic substances:** Carbon dioxide, nitrogen, oxygen, phosphorus, sulphur, water, rock, soil and other minerals.
3. **Organic compounds:** Carbohydrates, proteins, lipids and humic substances. They are the building blocks of living systems and therefore, link the biotic and abiotic components

Ecosystem - Biotic Components (Living):

The biotic factors with which an organism interacts depend on whether it is a producer, a consumer or a decomposer. Their classification can be shown as follows –

- Humans are also biotic factors in ecosystems. Other organisms are affected by human actions, often in adverse ways.
- We compete with some organisms for resources, prey on other organisms, and alter the environment of still others.

Producers: Producers are also known as Autotrophs or self-feeders. Producers manufacture the organic compounds that they use as sources of energy and nutrients. Most producers are green plants or algae that make organic compounds through photosynthesis.

Consumers: Only producers can make their food. They also provide food for the consumers and decomposers. The producers are the source of the energy that drives the entire ecosystem. Organisms that get their energy by feeding on other organisms are called Heterotroph. Based on food preferences, they can be grouped into three broad categories.

The living components of the ecosystem which depend on producers for their nutrition are called consumers. All the animals and certain plants are included in this category.

- **Primary consumers** - All the herbivorous animals like rodents, cow, elephants, deer, goats etc, which directly consume the plants are called primary consumers. Among the aquatic animals, certain kinds of Fish, Crustaceans, Molluscs etc. which survive on phytoplankton are also primary consumers. Herbivorous animals are important animals because all other animal's life is dependent on these primary consumers.
- **Secondary consumers** - Carnivorous and omnivorous animals belong to this category. Carnivorous predate on herbivorous animals. Omnivorous animals eat herbivorous animals as well as plants. Sparrow, Crow, Fox, Wolves, Cat, Dogs, Snakes etc. belong to this category.
- **Tertiary consumers** - They are strictly carnivorous animals that prey upon carnivores, herbivores, and omnivorous organisms. Lions, Tigers, Vultures etc. are regarded at tertiary consumers.

- Herbivores (e.g. cow, deer and rabbit etc.) feed directly on plants
- Carnivores are animals which eat other animals (e.g. lion, cat, dog etc.) and
- Omnivores organisms feed upon both plants and animals e.g. human, pigs and sparrow.

Detritus: Some consumers feed on living plants and animals. Others get their energy from dead plant and animal matter are called Detritus (Detrivores). They are also called Saprotrophs. The Detrivores are further divided into detritus feeders and decomposers.

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Chemosynthesis (a particular type of producers - chemosynthetic bacteria)

- A few producers, including specialised bacteria, can extract inorganic compounds from the environment and convert them to organic nutrients in the absence of sunlight. This process is called chemosynthesis.
- In some places, on the floor of the deep ocean where sunlight can never reach, hydrothermal vents pour out boiling water suffused with hydrogen sulphide gas. Specialised bacteria use the heat to convert this mixture into the nutrients they need.

Parasites

Plants and animals that infect other living components of the ecosystem and survive on them are regarded as parasites. Various types of fungi, bacteria and a few flowering plants are parasitic. Several protozoans, insects and nematodes are also parasitic.

Detritus feeders

- Detritus feeders acquire the nutrients they need from partially decomposed organic matter like plant litter, dead bodies of plants and animals, and animal waste products.
- Some examples of detritus feeders include various species of beetles, various species of ants, earthworms, and termites

Decomposers

- These are also called transformers as they transform organic compounds into inorganic or simple compounds.
- Saprophytic fungi and bacteria belong to this category.
- They act upon the dead bodies of plants and animals and decompose them to their elemental stage.
- These, in turn, can be used by producers for their existence and photosynthetic activity.
- The decomposers occupy a central place in the ecosystem as they indirectly support the producers.

Difference Between Detritivores and Decomposers

- A decomposer is a general term while detritivores are one of the classifications of decomposers.
- Decomposers break down the dead organisms through decomposition while the detritivores consume the decaying organisms.
- Most decomposers are in the forms of bacteria or fungus whereas the detritivores come in different forms, namely; worms, millipedes, woodlice, dung flies, and slugs in the terrestrial aspect

Scavenger (is an example of a consumer)

Scavenging is a feeding behaviour in which an animal feeds on either dead animal or dead plant matter. Scavengers are animals with scavenging habits. Scavengers do not spend energy to kill their prey, but they sense the smell of food on which they can feed. Vultures, Burying beetle, Raccoons, Jackals, and Hyenas are some prime examples for animal scavengers. Termites and earthworms are good examples of plant scavengers.

Scavengers role is vital for the ecosystem as they contribute to the decomposition, while decomposers and detritus feeders are responsible for completing the process.

TYPES OF ECOSYSTEMS

Ecosystems are classified as follows:

(i) **Natural Ecosystems:** A ***natural ecosystem*** is the result of interactions between organisms and the environment. Other features of a natural ecosystem are- A natural ecosystem has a diverse

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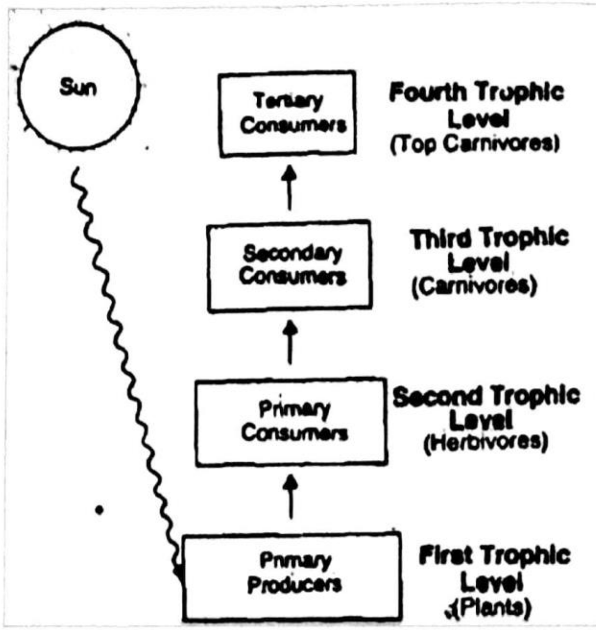
amount of species and plants, Natural ecosystems are self-sustaining, it contains more natural factors and organisms, it is dependent on solar radiation e.g. forests, grasslands, oceans, lakes, rivers and deserts. It provides food, fuel, fodder and medicines. It is dependent on solar radiation and energy subsidies (alternative sources) such as wind, rain and tides. e.g tropical rain forests, tidal estuaries and coral reefs.

(ii) **Man Made/Artificial Ecosystems:** Dependent on solar energy-e.g. Agricultural fields and aquaculture ponds. Dependent on fossil fuel e.g. urban and industrial ecosystems.

TROPHIC LEVEL

Trophic levels are the feeding position in a food chain such as primary producers, herbivore, primary carnivore, etc. At the first trophic level, primary producers (plants, algae, and some bacteria) use solar energy to produce organic plant material through photosynthesis. Herbivores—animals that feed solely on plants—make up the second trophic level. Predators that eat herbivores comprise the third trophic level; if larger predators are present, they represent still higher trophic levels. Organisms that feed at several trophic levels (for example, a hawk that eats snake) are classified at the highest of the trophic levels at which they feed. Decomposers, which include bacteria, fungi, moulds, worms, and insects, break down wastes and dead organisms and return nutrients to the soil.



The trophic level interaction involves the following three concepts –

1. Food Chain
2. Food Web
3. Ecological Pyramids

How many trophic levels can an ecosystem support?

The answer depends on several factors, including the amount of energy entering the ecosystem, energy loss between trophic levels, and the form, structure, and physiology of organisms at each level.

At higher trophic levels, predators generally are physically larger and are able to utilize a fraction of the energy that was produced at the level beneath them, so they have to forage over increasingly large areas to meet their caloric needs. Because of these energy losses, most terrestrial ecosystems have no more than five trophic levels, and marine ecosystems generally have no more than seven. This difference between terrestrial and marine ecosystems is likely due to differences in the fundamental characteristics of land and marine primary organisms.

FUNCTIONS OF ECOSYSTEM

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

- Energy flow through the food chain
- Nutrient cycling (biogeochemical cycles)
- Ecological succession or ecosystem development
- Homeostasis (or cybernetic) or feedback control mechanisms

In an ecosystem, there are three functional components - inorganic constituents, organism and energy

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FUNCTION – ENERGY FLOW THROUGH ECOSYSTEM

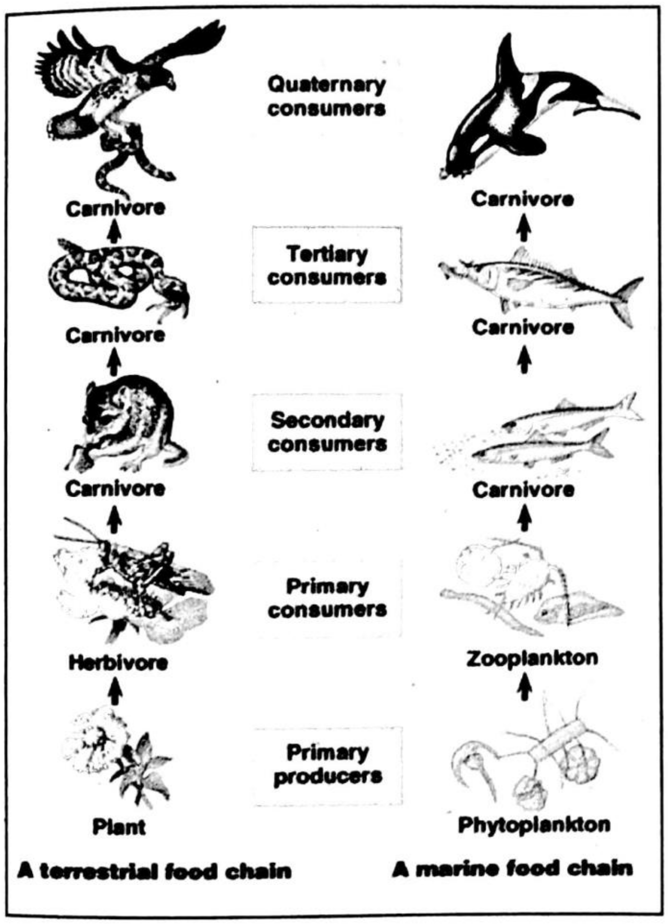
Food chains and energy flow are the functional properties of ecosystems which make them dynamic. The biotic and abiotic components of an ecosystem are linked through them.

Energy Flow

Ecosystems maintain themselves by cycling energy and nutrients obtained from external sources. On average, about 10 percent of net energy production at one trophic level is passed on to the next level.

How?

(1) Processes that reduce the energy transferred between trophic levels include respiration, growth and reproduction, defecation, and non-predatory death (organisms that die but are not eaten by consumers).



(2) The low rate of energy transfer between trophic levels makes decomposers generally more important than producers in terms of energy flow. Decomposers process large amounts of organic materials and return nutrients to the ecosystem in inorganic forms, which are then taken up again by primary producers. Energy is not recycled during decomposition, but rather is released, mostly as heat.

Primary Productivity

- An ecosystem's Gross Primary Productivity (GPP) is the rate of the total amount of organic matter that it produces through photosynthesis.
- Net Primary Productivity (NPP) rate describes the amount of energy that remains available for plant growth after subtracting the fraction that plants use for respiration.
- Productivity in land ecosystems generally rises with temperature up to about 30°C, after which it declines, and is positively correlated with moisture. On land, primary productivity thus is highest in warm, wet zones in the tropics where tropical forest biomes are located. In contrast, desert scrub ecosystems have the lowest productivity because their climates are extremely hot and dry.
- In the oceans, light and nutrients are important controlling factors for productivity. As light penetrates only into the uppermost level of the oceans, photosynthesis occurs in surface and near-surface waters. Marine primary productivity is high near coastlines and other areas where upwelling brings nutrients to the surface, promoting plankton blooms. Among aquatic ecosystems, algal beds and coral reefs have the highest net primary production.

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ECOLOGICAL BALANCE

Ecological balance is a term used to describe the dynamic equilibrium between living organisms such as human being, plants, and animals as well as their environment. Photosynthesis that takes place in the ecosystem contributes to building a good environment that stabilises the coexistence of all organisms. Harmonious relationships reflect a healthy and desirable ecological balance. Human being plays a key role to maintain ecological balance because they have the highest thinking capacity as compared to other living organisms. Sufficient food availability to all living organisms and their stability reflect the existence of ecological balance. Therefore, this balance is very important because it ensures survival, existence and stability of the environment.

Survival of all organisms is actualised due to ecological balance. Favourable ecosystem ensures that each organism thrives and multiply as expected. Ecological balance is also important because it leads to the continued existence of the organisms. For example, human activities such as farming and resources exploitation are checked to prevent excessive destruction of the forests. Deforestation leads to drought. Drought reduces food production resulting in insufficient food. Insufficient food leads to starvation and later death occurs, hence reducing the existence of some species.

Besides, ecological enhances a stable environment that is free from ecological imbalances. This calls for collective efforts to ensure a stable environment is created. Human activities influence environmental stability. Tree planting and reduced deforestation rate prevent undesirable climate change. Control of excessive wild animals' inhabitant maintains desired population growth. Therefore, a human can contribute positively to create and maintain ecological balance.

FOOD CHAIN

The simplest way to describe the flux of energy through ecosystems is as a food chain in which energy passes from one trophic level to the next, without factoring in more complex relationships between individual species. Some very simple ecosystems may consist of a food chain with only a few trophic levels.

> The idea to apply the food chains to ecology and to analyse its consequences was first proposed by Charles Elton.

A food chain is a sequence of who eats whom in a biological community (an ecosystem) to obtain nutrition. It is a sequence of organisms that feed on one another.

A food chain starts with the primary energy source, usually the sun. The next link in the chain is an organism that makes its own food from the primary energy source. For example, photosynthetic plants that make their own food from sunlight by photosynthesis and chemosynthetic bacteria that make their food energy from chemicals in hydrothermal vents. These are called autotrophs or primary producers. Next, come organisms that eat the autotrophs; these organisms are called herbivores or primary consumers. For example, a grasshopper that eats grass. The next link in the chain is animals that eat herbivores, called secondary consumers. For example, a frog or rat that eat grasshoppers. In turn, these animals are eaten by larger predators, called tertiary consumers. For example, a snake that eats rats. Tertiary consumers are eaten by quaternary consumers. For example a hawk that eats snakes. The arrows in a food chain show the flow of energy, from the sun or hydrothermal vent to a top predator. As the energy flows from organism to organism, energy is lost at each step.

FOOD WEB

Trophic levels in an ecosystem are not linear; rather they are interconnected and make a food web. All of the interconnected and overlapping food chains in an ecosystem make up a food web.

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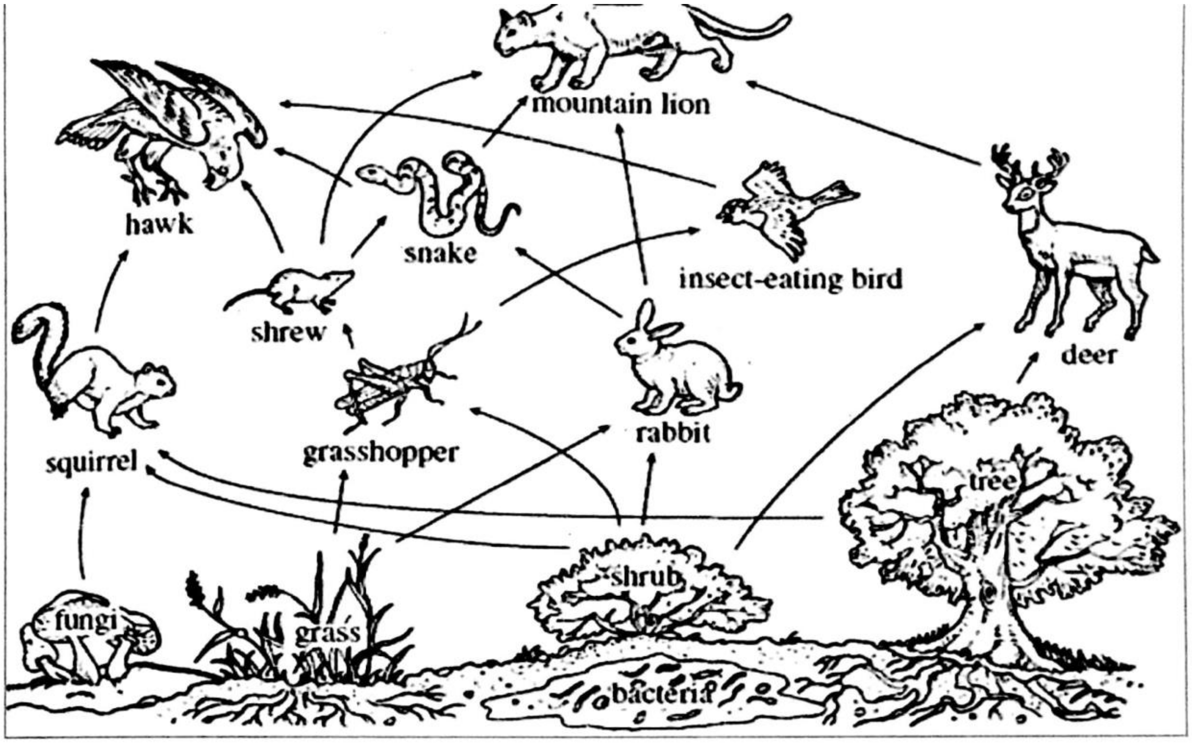

Difference between Grazing food chain and Detritus food chain	
Grazing Food Chain	**Detritus Food Chain**
➢ The Chain begins with green plants (producers) at first trophic level	➢ The Chain begins with detrivores (decomposers) at first trophic level
➢ Energy comes from the sun	➢ Energy comes from the remains of dead organic matters
➢ It consists of all macroscopic organisms	➢ It consists of sub-soil organisms
➢ The food chain is longer in size	➢ The food chain is smaller in size
➢ Plant> Grass hopper> Rat> Snake> Hawk	➢ Dead Bodies> Bacteria> Molluscs> Fish

Each living thing in an ecosystem is part of multiple food chains. Normally, food webs consist of a number of food chains meshed together.

Food web is an important ecological concept. It implies the transfer of food energy from its source in plants through herbivores to carnivores. Food web offers an important tool for investigating the ecological interactions that define energy flows and predator-prey relationship. Most feed webs are complex and involve many species with both strong and weak interactions among them.

In an ecosystem, the amount of energy decreases at each subsequent trophic level. This is due to two reasons:

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

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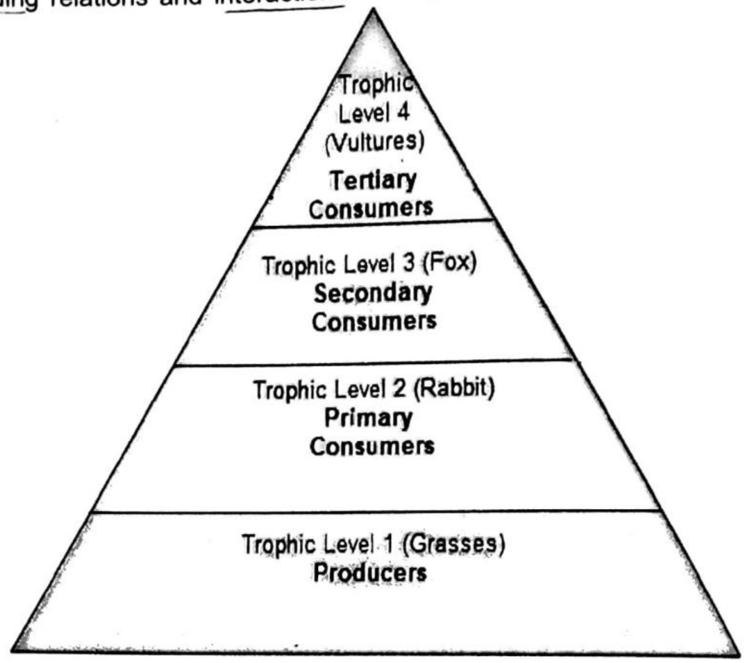
Significance Of Studying Food Chains

- It helps in understanding the feeding relations and interactions among different organisms of an ecosystem.
- It explains the flow of energy and circulation of materials in ecosystems.
- It helps in understanding the concept of biomagnification in ecosystems.



TROPHIC STRUCTURE

It is defined as the arrangement of biotic components of an ecosystem.

For eg if the food chain is Grasses → Rabbit → Fox → Vulture then the trophic structure would be as shown in the diagram.

ECOLOGICAL EFFICIENCY

The ratio between the amount of energy acquired from the lower trophic level and the amount of energy transferred to higher trophic level is called ecological efficiency. Ecological efficiency (also called Lindman's efficiency)

- Lindman in 1942 defined these ecological efficiencies for the 1st time and proposed 10% rule. e.g. if autotrophs produce 100 cal, herbivores will be able to store 10 cal. and carnivores 1 cal.

ECOLOGICAL PYRAMIDS

Charles Elton developed the concept of the ecological pyramid. These pyramids are also known as Eltonian pyramids.

Ecological pyramids illustrate how ecologically important factors, such as energy, biomass, and population size, vary between trophic levels in an ecosystem. Traditionally, they place the primary producers (photosynthetic organisms such as plants) at the bottom and the highest trophic levels at the top of the diagram. The size of the portion of such diagram associated with each trophic level illustrates the amount of energy, biomass, or number of individuals found in each trophic level.

The ecological pyramids may be of following three kinds

- **Pyramid of energy**, showing the rate of energy flow and/or productivity at successive trophic levels
- **Pyramid of numbers**, showing the number of individual organisms at each level
- **Pyramid of biomass**, showing the total dry weight and another suitable measure of the total amount of living matter

Pyramid of Energy

The energy pyramid shows how the amount of energy entering each level varies across trophic levels. An energy pyramid's shape shows how the amount of useful energy that enters each level — chemical energy in the form of food — decreases as it is used by the organisms in that level.

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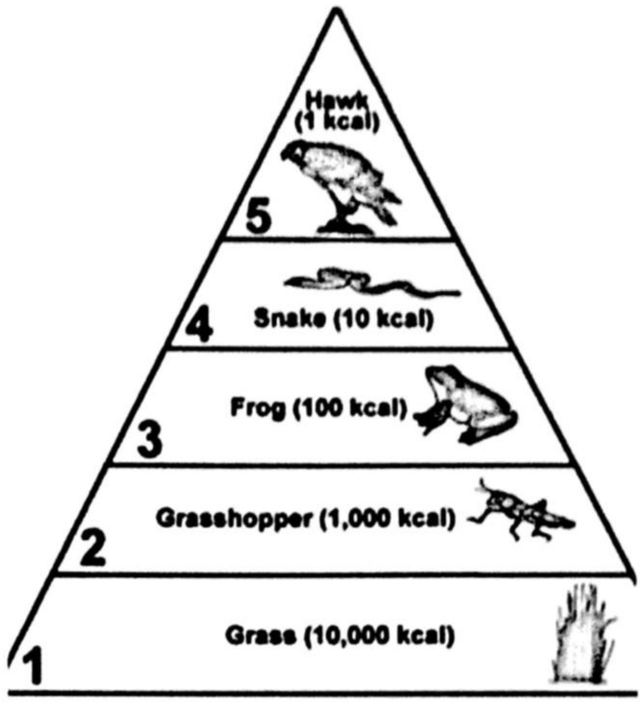
Scientists have calculated that an average of 90% of the energy entering each step of the food chain is "lost". The consumers at the top of a food pyramid, as a group, thus have much less energy available to support them than those closer to the bottom. That's why their numbers are relatively few in most communities. Eventually, the amount of useful energy left can't support another level. That's why energy flow is depicted in the shape of a pyramid.

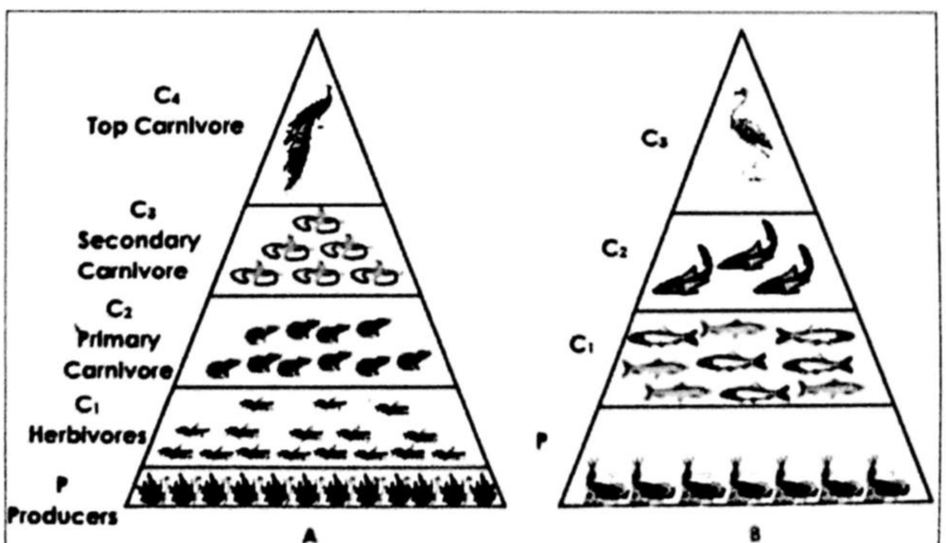


To sum up –

- The energy pyramid always upright and erect.
- It shows the rate of energy flows at different trophic levels.
- It shows that energy is maximum at the producer level and minimum at the carnivores' level.
- At every successive trophic level, there is a loss of energy in the form of heat, respiration etc.

Pyramid of Numbers

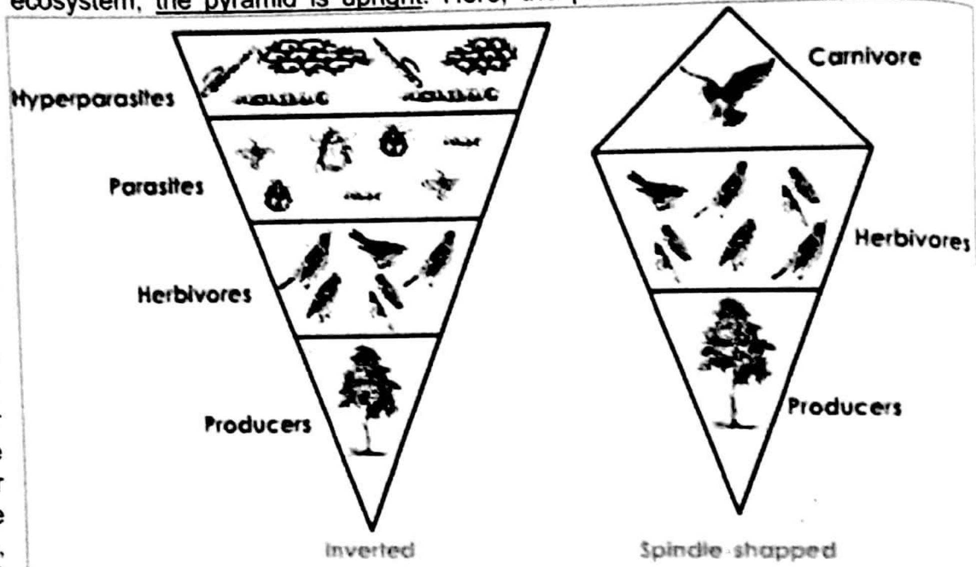
Pyramids of numbers show the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number.



Upright Pyramids of Numbers. (A) In a Grass Land (B) In a Pond

In grassland, the producers who are mainly grasses are always maximum in number. This number then shows a decrease towards apex, as the primary consumers (herbivores) like rabbits, mice etc. are lesser in number than the grasses; the secondary consumers, snakes and lizards are lesser in number than the rabbits and mice. Finally, the top (tertiary) consumer's hawks or other birds are least in number. Thus, the pyramid becomes upright.

Similarly, in a pond ecosystem, the pyramid is upright. Here, the producers, which are mainly the Phytoplankton (ex. Algae etc.), are maximum in number. The herbivores, which are smaller fish are lesser in number than producers and the secondary consumers (carnivores), such as small fish eating each other, water beetles etc. are lesser in number than the herbivores. Finally, the top (tertiary) consumers, the bigger fish are least in number.



Pyramid of Numbers

However, in a parasitic food chain, the pyramids are always inverted. This is due to the fact that a single plant may support the growth of many herbivores and each herbivore, in turn, may provide nutrition to several parasites which support many hyper parasites. Thus, from the producer towards consumers, there is a reverse position, i.e. the number of organisms gradually shows an increase making the pyramid inverted in shape.

The Trophic Transfer of Toxins

Trophic transfer is the major mechanism for contaminant accumulation in organisms higher up in the food web. Toxins ingested by single-celled organisms are subsequently transferred to larger and larger organisms, compounding the amount of toxin at each level. This can be elaborated as follows:

> Bioaccumulation is the gradual build up of a chemical in a living organism.

1. **Bioaccumulation/Bioconcentration** – Bioaccumulation is the accumulation of contaminants by species in concentrations that are higher than that of the surrounding environment. This occurs either because the chemical is taken up faster than it can be used or because the chemical cannot be broken down for use by the organism (that is, the chemical cannot be metabolized). This can occur through a number of different routes, such as breathing, eating (ingesting), drinking (usually water), or through skin contact.

   Bioaccumulation need not be a concern if the accumulated compound is not harmful. Compounds that are harmful to health, such as Polychlorinated Biphenyl (PCBs), Dioxins, DDT, mercury etc. however, can accumulate in living tissues. For example, Minamata disease is a neurological syndrome caused by severe mercury poisoning on consumption of fishes from water polluted by Mercury.

2. **Bio concentration** can also take place when there is the direct uptake of a substance by a living organism from the medium (e.g., water) via skin, gills, or lungs and the subsequent concentration of that substance within the organism's tissues to a level that exceeds ambient environmental concentrations.

3. **Biomagnification** – Biomagnification refers to the tendency of pollutants to concentrate as they move from one trophic level to the next. Biomagnification is also called Bioamplification. It is an increase in concentration of a pollutant from one link in a food chain to another.

   - For Biomagnification to occur, the pollutant must be long-lived, mobile, soluble in fats, biologically active. If a pollutant is short-lived, it will be broken down before it can become dangerous. If it is not mobile, it will stay in one place and is unlikely to be taken up by organisms. If the pollutant is soluble in water it will be excreted by the organism. Pollutants that dissolve in fats, however, may be retained for a long time.
   - If a pollutant is not active biologically, it may bio-magnify.

HOMEOSTASIS IN ECOSYSTEM

Ecosystems are capable of maintaining their state of equilibrium. They can regulate their own species structure and functional processes. This capacity of ecosystem of self-regulation is known as homeostasis. In ecology, the term applies to the tendency for a biological systems to resist changes. For example, in a pond ecosystem if the population of zooplankton increased, they would

Large number of phytoplankton
↓
Increase population of zooplankton due to excess food available
↓
Reduction in phytoplankton
↓
Population of zooplanktons decrease due to starvation
↓
Population of phytoplankton starts increasing due to less consumption

Fig: *Homeostasis in ecosystem*

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consume large number of the phytoplankton and as a result soon zooplankton would be short supply of food for them. As the number zooplankton is reduced because of starvation, phytoplankton population start increasing. After some time, the population size of zooplankton also increases and this process continues at all the trophic levels of the food chain.

In a homeostatic system, negative feedback mechanism (a mechanism which tries to bring the system back to the state of normalcy) is responsible for maintaining stability in a ecosystem. However, homeostatic capacity of ecosystems is not unlimited as well as not everything in an ecosystem is always well regulated. Humans are the greatest source of disturbance to ecosystems.

Factors Which Can Disturb Ecosystem Stability:

1. Natural Environment Changes: Fires, heavy storms, natural climatic changes can bring about changes in the population of plants.
2. A Decline in Biodiversity
3. Human Environmental changes: Human activities can bring about loss in habitat by release of pollutants in the ecosystem, introduction of non-native species.
4. Habitat Fragmentation: Involves clearing patches for urban development and agriculture.
5. Invasive Species: An invasive species in a plant or animal that is not native to a specific location and has a tendency to spread, which is believed to cause damage to the environment, human economy and health.

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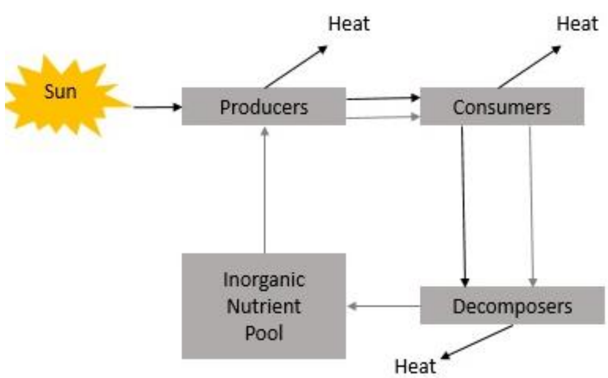
Energy Flow in an Ecosystem

The cycle of energy is based on the flow of energy through different trophic levels in an ecosystem. Our ecosystem is maintained by the cycling energy and nutrients obtained from different external sources. At the first trophic level, primary producers use solar energy to produce organic material through photosynthesis.



The herbivores at the second trophic level, use the plants as food which gives them energy. A large part of this energy is used up for the metabolic functions of these animals such as breathing, digesting food, supporting growth of tissues, maintaining blood circulation and body temperature.

The carnivores at the next trophic level, feed on the herbivores and derive energy for their sustenance and growth. If large predators are present, they represent still higher trophic level and they feed on carnivores to get energy. Thus, the different plants and animal species are linked to one another through food chains.

Decomposers which include bacteria, fungi, molds, worms, and insects break down wastes and dead organisms, and return the nutrients to the soil, which is then taken up by the producers. Energy is not recycled during decomposition, but it is released.

Every ecosystem has several interrelated mechanisms that affect human life. These are the water cycle, the carbon cycle, the oxygen cycle, the nitrogen cycle and the energy cycle. While every ecosystem is controlled by these cycles, in each ecosystem its abiotic and biotic features are distinct from each other.

Biogeochemical Cycles

All elements in the earth are recycled time and again. The major elements such as oxygen, carbon, nitrogen, phosphorous, and sulphur are essential ingredients that make up organisms. Biogeochemical cycles refer to the flow of such chemical elements and compounds between organisms and the physical environment. Chemicals taken in by organisms are passed through the food chain and come back to the soil, air, and water through mechanisms such as respiration, excretion, and decomposition.

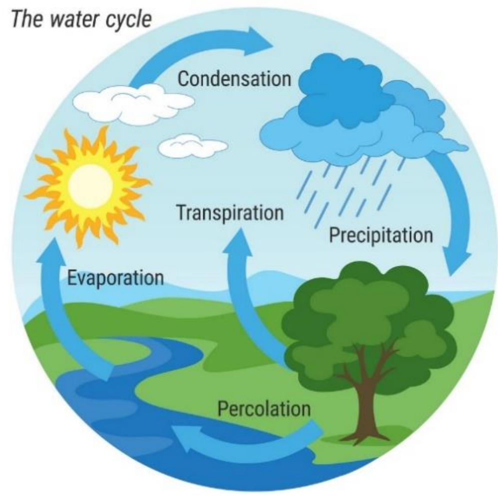
As an element moves through this cycle, it often forms compounds with other elements as a result of metabolic processes in living tissues and of natural reactions in the atmosphere, hydrosphere, or lithosphere.

Such cyclic exchange of material between the living organisms and their non-living environment is called Biogeochemical Cycle.

Following are some important biogeochemical cycles −

- Carbon Cycle
- Nitrogen Cycle
- Water Cycle
- Oxygen Cycle
- Phosphorus Cycle
- Sulphur Cycle

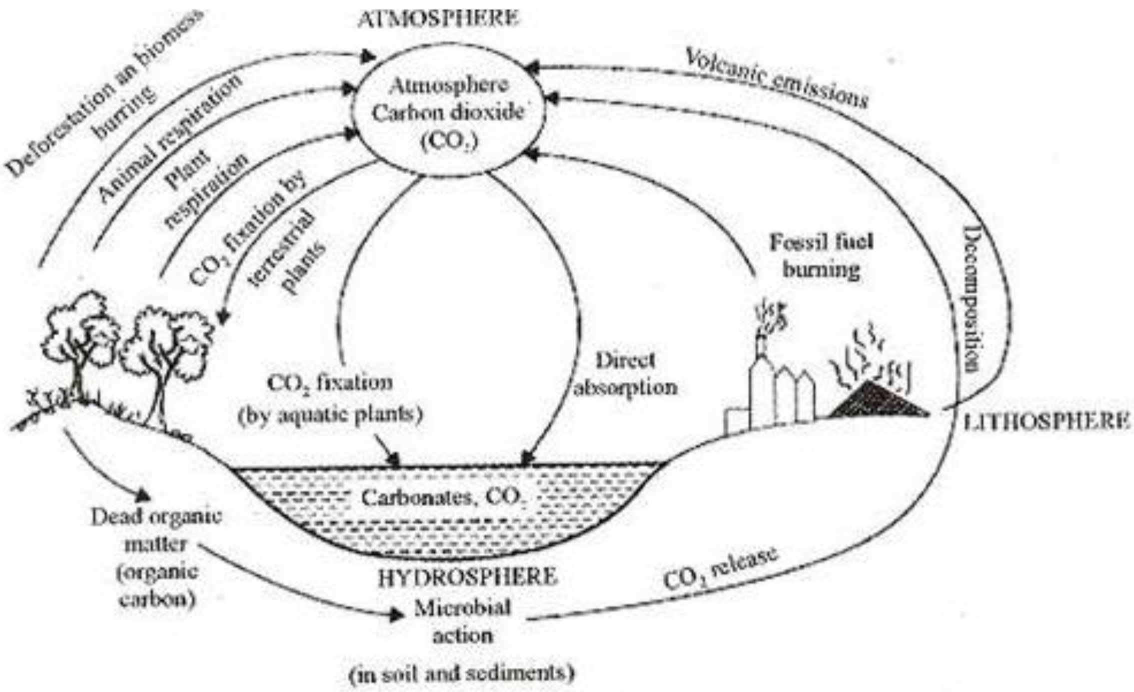
The Hydrological Cycle:



The water cycle describes how water moves through the Earth's crust, atmosphere and oceans. Heat from the Sun causes liquid water to evaporate from rivers, lakes and oceans and it becomes a gas called water vapour. As the gas rises, it cools and condenses to create clouds. Water returns to the ground as solid hail and snow or liquid rain and sinks into the earth. Below the ground it forms aquifers where water is held between grains in rock layers, sands and gravels. Where aquifers intersect or cut the surface of the ground the liquid water flows out to form lakes, rivers and oceans. When it rains, the water runs along the ground and flows into rivers or falls directly into the sea. A part of the rainwater that falls on land percolates into the ground. This is stored underground throughout the rest of the year. Water is drawn up from the ground by plants along with the nutrients from the soil. The water is transpired from the leaves as water vapour and returned to the atmosphere. As it is lighter than air, water vapour rises and forms clouds. Winds blow the clouds for long distances and when the clouds rise higher, the vapour condenses and changes into droplets, which fall on the land as rain. Though this is an endless cycle on which life depends, man's activities are making drastic changes in the atmosphere through pollution which is altering rainfall patterns. This is leading to prolonged drought periods extending over years in countries such as Africa, while causing floods in countries such as the US. El Nino storms due to these effects have devastated many places in the last few years.

The Carbon Cycle

Carbon cycle is the process where carbon compounds are interchanged among the biosphere, geosphere, pedosphere, hydrosphere, and atmosphere of the earth.



It is one of the most important cycles of the earth and allows for carbon to be recycled and reused throughout the biosphere and all of its organisms.

Without the proper functioning of the carbon cycle, every aspect of life could be changed dramatically. Plants, animals, and soil interact to make up the basic cycles of nature. In the carbon cycle, plants absorb carbon dioxide from the atmosphere and use it, combined with water they get from the soil, to make the substances they need for growth. The process of photosynthesis incorporates the carbon atoms from carbon dioxide into sugars.

Animals, such as the rabbit eat the plants and use the carbon to build their own tissues. Other animals, such as the fox, eat the rabbit and then use the carbon for their own needs. These animals return carbon dioxide into the air when they breathe, and when they die, since the carbon is returned to the soil during decomposition. The carbon atoms in soil may then be used in a new plant or small microorganisms. The following major reservoirs of carbon interconnected by pathways of exchange

i. The atmosphere.

ii. The terrestrial biosphere, which is usually defined to include fresh water systems and non-living organic material, such as soil carbon.

iii. The oceans, including dissolved inorganic carbon and living and non-living marine biota.

iv. The sediments including fossil fuels

v. The Earth's interior, carbon from the Earth's mantle and crust is released to the atmosphere and hydrosphere by volcanoes and geothermal systems.

The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest active pool of carbon near the surface of the Earth, but the deep ocean part of this pool does not rapidly exchange with the atmosphere in the absence of an external influence, such as an uncontrolled deep-water oil well leak.

Carbon is released into the atmosphere in several ways:

i. Through the respiration performed by plants and animals. This is an exothermic reaction and it involves the breaking down of glucose (or other organic molecules) into carbon dioxide and water.

ii. Through the decay of animal and plant matter. Fungi and bacteria break down the carbon compounds in dead animals and plants and convert the carbon to carbon dioxide if oxygen is present, or methane if not.

iii. Through combustion of organic material which oxidizes the carbon it contains, producing carbon dioxide (and other things, like water vapour). Burning fossil fuels such as coal, petroleum products releases carbon dioxide. Burning agro fuels also releases carbon dioxide

iv. Volcanic eruptions and metamorphism release gases into the atmosphere. Volcanic gases are primarily water vapour, carbon dioxide and sulphur dioxide.

v. Carbon is transferred within the biosphere as heterotrophs feed on other organisms or their parts (e.g., fruits). This includes the uptake of dead organic material (detritus) by fungi and bacteria for fermentation or decay.

vi. Most carbon leaves the biosphere through respiration. When oxygen is present, aerobic respiration occurs, which releases carbon dioxide into the surrounding air or water, following the reaction $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$. Otherwise, anaerobic respiration occurs and releases methane into the surrounding environment, which eventually makes its way into the atmosphere or hydrosphere (e.g., as marsh gas or flatulence).

Circulation of carbon dioxide:

i. Plants absorbs the carbon dioxide from the atmosphere.

ii. During the process of photosynthesis, plants incorporates the carbon atoms from carbon dioxide into sugars.

iii. Animals, such as the rabbit eat the plants and use the carbon to build their own tissues, chain the carbon content

iv. Through the food chain, carbon is transferred into foxes, lions etc.

v. The animals return carbon dioxide into the air when they breathe, and when they die, since the carbon is returned to the soil during decomposition

In Case of Ocean:

In regions of oceanic upwelling, carbon is released to the atmosphere. Conversely, regions of down welling transfer carbon (CO_2) from the atmosphere to the ocean. When CO_2 enters the ocean, it participates in a series of reactions which are locally in equilibrium:

i. Conversion of CO_2 (atmospheric) to CO_2 (dissolved).

iii. Conversion of carbonic acid (H_2CO_3) to bicarbonate ion.

iv. Conversion of bicarbonate ion to carbonate ion.

In the oceans, dissolved carbonate can combine with dissolved calcium to precipitate solid calcium carbonate, $CaCO_3$, mostly as the shells of microscopic organisms. When these organisms die, their shells sink and accumulate on the ocean floor. Over time these carbonate sediments form limestone which is the largest reservoir of carbon in the carbon cycle. The dissolved calcium in the oceans comes from the chemical weathering of calcium-silicate rocks, during which carbonic and other acids in groundwater react with calcium-bearing minerals liberating calcium ions to solution and leaving behind a residue of newly formed aluminium-rich clay minerals and insoluble minerals such as quartz.

The flux or absorption of carbon dioxide into the world's oceans is influenced by the presence of widespread viruses within ocean water that infect many species of bacteria. The resulting bacterial deaths spawn a sequence of events that lead to greatly enlarged respiration of carbon dioxide, enhancing the role of the oceans as a carbon sink.

The Nitrogen Cycle:

The nitrogen cycle is the set of biogeochemical processes by which nitrogen undergoes chemical reactions, changes form, and moves through difference reservoirs on earth, including living organisms.

Nitrogen is required for all organisms to live and grow because it is the essential component of DNA, RNA, and protein. However, most organisms cannot use atmospheric nitrogen, the largest reservoir. The five processes in the nitrogen cycle

i. Nitrogen fixation

ii. Nitrogen uptake

iii. Nitrogen mineralization

iv. Nitrification

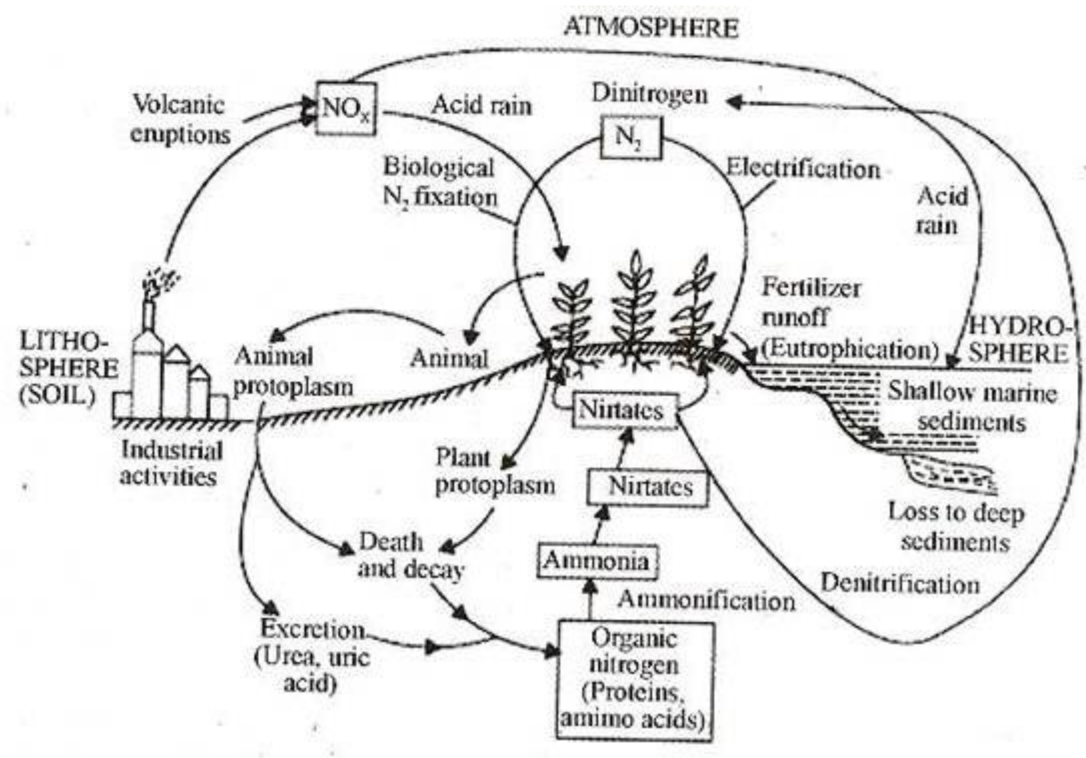
v. De-nitrification

Humans influence the global nitrogen cycle primarily through the use of nitrogen-based fertilizers.

I. Nitrogen fixation: N_2 -> NH_4^+

Nitrogen fixation is the process wherein N_2 is converted to ammonium, essential because it is the only way that organisms can attain nitrogen directly from the atmosphere. Certain bacteria, for example those among the genus Rhizobium, are the only organisms that fix nitrogen through metabolic processes.

Nitrogen fixing bacteria often form symbiotic relationships with host plants. This symbiosis is well-known to occur in the legume family of plants (e.g. beans, peas, and clover). In this relationship, nitrogen fixing bacteria inhabit legume root nodules and receive carbohydrates and a favourable environment from their host plant in exchange for some of the nitrogen they fix. There are also nitrogen fixing bacteria that exist without plant hosts, known as free-living nitrogen fixers. In aquatic environments, blue-green algae (really a bacteria called cyanobacteria) is an important free-living nitrogen fixer.



II. Nitrogen uptake: NH_4^+ -> Organic N

The ammonia produced by nitrogen fixing bacteria is usually quickly incorporated into protein and other organic nitrogen compounds, either by a host plant, the bacteria itself, or another soil organism.

III. Nitrogen mineralization: Organic N ->NH_4^+

After nitrogen is incorporated into organic matter, it is often converted back into inorganic nitrogen by a process called nitrogen mineralization, otherwise known as decay. When organisms die, decomposers (such as bacteria and fungi) consume the organic matter and lead to the process of decomposition.

During this process, a significant amount of the nitrogen contained within the dead organism is converted to ammonium. Once in the form of ammonium, nitrogen is available for use by plants or for further transformation into nitrate (NO_3^-) through the process called nitrification.

IV. Nitrification: NH_4^+ -> NO_3^-

Some of the ammonium produced by decomposition is converted to nitrate via a process called nitrification. The bacteria that carry out this reaction gain energy from it. Nitrification requires the presence of oxygen, so nitrification can happen only in oxygen-rich environments like circulating or flowing waters and the very surface layers of soils and sediments. The process of nitrification has some important consequences.

Ammonium ions are positively charged and therefore stick (are sorbed) to negatively charged clay particles and soil organic matter. The positive charge prevents ammonium nitrogen from being washed out of the soil (or leached) by rainfall.

In contrast, the negatively charged nitrate ion is not held by soil particles and so can be washed down the soil profile, leading to decreased soil fertility and nitrate enrichment of downstream surface and groundwater's.

V. De-nitrification: NO_3^- -> N_2+ N_2O

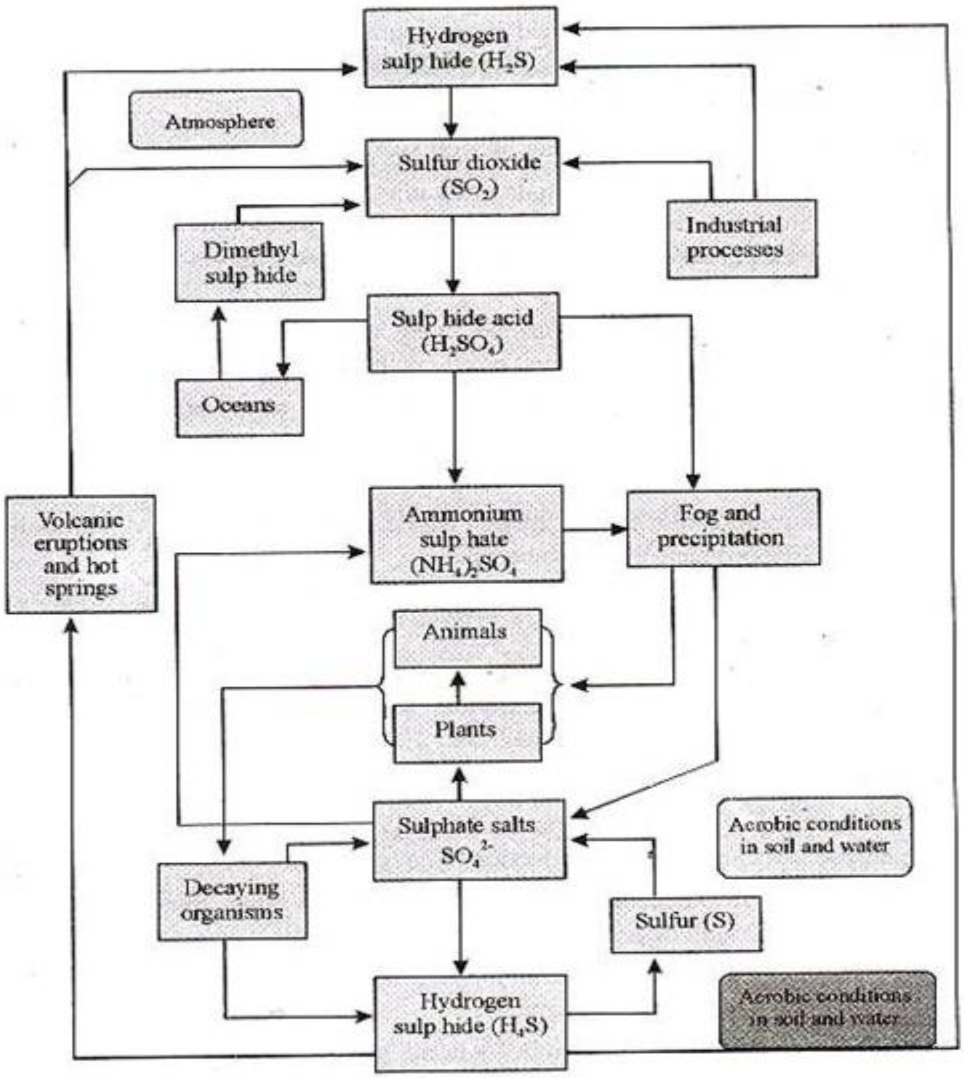
Through de-nitrification, oxidized forms of nitrogen such as nitrate and nitrite (NO_2) are converted to di-nitrogen (N_2) and, to a lesser extent, nitrous oxide gas. De-nitrification is an anaerobic process that is carried out by denitrifying bacteria, which convert nitrate to nitrogen in the following sequence:

NO_3^- -> NO_2^- -> NO ->N_2O ->N_2

Nitric oxide and nitrous oxide are both environmentally important gases. Nitric oxide (NO) contributes to smog, and nitrous oxide (N_2O) is an important greenhouse gas, thereby contributing to global climate change.

The Sulphur Cycle:

Sulphur is one of the components that make up proteins and vitamins. Proteins consist of amino acids that contain sulphur atoms. Sulphur is important for the functioning of proteins and enzymes in plants, and in animals that depend upon plants for sulphur. It enters the atmosphere through both natural and human sources. Natural recourses can be for instance volcanic eruptions, bacterial processes, evaporation from water, or decaying organisms. When sulphur enters the atmosphere through human activity, this is mainly a consequence of industrial processes where sulphur dioxide (SO_2) and hydrogen sulphide (H_2S) gases are emitted on a wide scale. When sulphur dioxide enters the atmosphere it will react with oxygen to produce sulphur trioxide gas (SO_3), or with other chemicals in the atmosphere, to produce sulphur salts. Sulphur dioxide may also react with water to produce sulphuric acid (H_2SO_4). Sulphuric acid may also be produced from demethyl-sulphide, which is emitted to the atmosphere by plankton species.



All these particles will settle back onto earth, or react with rain and fall back onto earth as acid deposition. The particles will then be absorbed by plants again and are released back into the atmosphere, so that the sulphur cycle will start over again.

i. Fossil fuels like coal and petroleum are extremely important energy resources which are getting exhausted.

ii. Hydrocarbon fuel based resources create pollution levels and greenhouse gases. Their management is related to improved technology and finding alternative energy sources taking this into account.

iii. An overall prudent and sustainable uses of resources both at an individual and collective level can benefit a wide cross section of society as well meet the future generations.

The Phosphorus Cycle

The **phosphorus cycle** is the biogeochemical **cycle** that describes the movement of **phosphorus** through the lithosphere, hydrosphere, and biosphere.

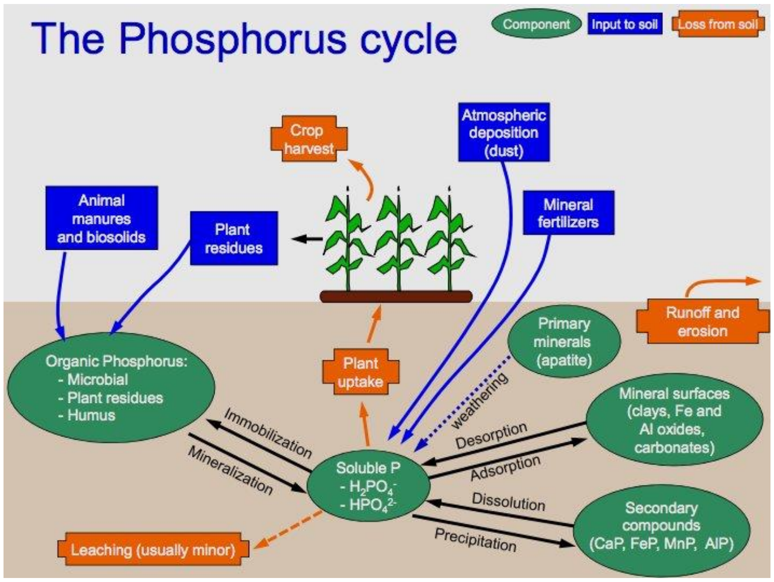
Phosphorus Cycle Steps

The phosphorus cycle is a slow process, which involves five key steps, as shown in the diagram below and described as follows:

Weathering: Since the main source of phosphorus is found in rocks, the first step of the phosphorus cycle involves the extraction of phosphorus from the rocks by weathering. Weather events, such as rain and other sources of erosion, result in phosphorus being washed into the soil.

Absorption by Plants and Animals: Once in the soil, plants, fungi, and microorganisms are able to absorb phosphorus and grow. In addition, phosphorus can also be washed into the local water systems. Plants can also directly absorb phosphorus from the water and grow. In addition to plants, animals also obtain phosphorus from drinking water and eating plants.

Return to the Environment via Decomposition: When plants and animals die, decomposition results in the return of phosphorus back to the environment via the water or soil. Plants and animals in these environments can then use this phosphorus, and step 2 of the cycle is repeated.



Human Impact on the Phosphorus Cycle: Humans have had a significant impact on the phosphorus cycle due to a variety of human activities, such as the use of fertilizer, the distribution of food products, and artificial eutrophication. Fertilizers containing phosphorus add to the phosphorus levels in the soil and are particularly detrimental when such products are washed into local aquatic ecosystems. When phosphorus is added to waters at a rate typically achieved by natural processes, it is referred to as natural eutrophication. A natural supply of phosphorus over time provides nutrients to the water and serves to increase the productivity of that particular ecosystem. However, when foods are shipped from farms to cities, the substantial levels of Phosphorus that is drained into the water systems is called artificial or anthropogenic eutrophication. When levels of phosphorus are too high, the overabundance of plant nutrients serves to drive the excessive growth of algae. However, these algae die or form algae blooms, which are toxic to the plants and animals in the ecosystem. Thus, human activities serve to harm aquatic ecosystems, whenever excess amounts of phosphorus are leached into the water.

Introduction, types, characteristic features, structure and function of some ecosystems

Ecosystem is the highest level of ecological integration which is energy-based and this functional unit is capable of energy transformation, accumulation and circulation.

Types of ecosystem

- Terrestrial ecosystems e.g. forests, grassland
- Aquatic ecosystems

(a) Forest ecosystem

A forest ecosystem is a natural woodland unit consisting of all plants, animals and micro-organisms (Biotic components) in that area functioning together with all of the non-living physical (abiotic) factors of the environment. Forests contain a wide assortment of trees, plants, mammals, reptiles, amphibians, invertibrates and micro-organisms. Forests occupy approximately one-third of Earth's land.

Forests have been divided into four types

1. ***Equitorial Rain Forests***
2. ***Tropical Deciduous Forests***
3. ***Temperate Forests***
4. ***Boreal Forests (Taiga)***

Equatorial Rain Forests:

Found in and around eqator regions, characterized by ample heat and heavy rainfall throughout year. E.g. Congo Basin, cameroon highlands, rain forests of the Amazon

- ✓ *Trees are very tall*
- ✓ *Vegetation very dense so that a little light reaches the floor*
- ✓ *Evergreen and not deciduous*
- ✓ *Branches are hung with epiphytes*
- ✓ *Uniformity of temperature throughout the year around 28 degrees. No winter*
- ✓ *Well distributed annual rainfall of 150-250 cm*
- ✓ *A distinct layered arrangement with thick canopy at the top of all the trees and plants struggle for sunlight*

Tropical Deciduous Forests

- ✓ *Found in areas characterized by distinct dry and heavy wet seasons*
- ✓ *These forests are the mixture of grasses and tress*
- ✓ *Summer heat very intense in these forests which burns the dry grasses and kills the seeds of weeds*
- ✓ *Trees are normally deciduous because of the marked dry period, during which they shed their leaves to withstand the drought*
- ✓ *Provide valuable timber and prized for their valuable hardwood eg. Tak, seal, acasia etc.*

Temperate Forests

- ✓ *Found in areas with a milder and shorter winter season. This occupies the eastern half of the United states and a large portion of Europe.*
- ✓ *Shed their leaves in autumn*
- ✓ *Canopy is moderately dense and allows light to penetrate, resulting in well-developed and richly diversified understory vegetation and stratification of animals.*
- ✓ *Average temperature is 15 degrees*

Boreal Forests

- *Occurring between 50 ºC 60 ºC North latitudes. Found in broad belt of Eurasia and North America*
- *Seasons are divided into short, moist and moderately warm summers and long cold dry winters. Boreal forests are dominated by conifers.*
- *Little rainfall.*
- *Pecipitation comes in the form of fog and snow.*

Forest types in India

According to the nature of tree species

Evergreen	Deciduous	Thorny	Mangroove
✓ Grow in high rainfall area e.g Western Ghats, North eastern areas, Andeman Nicobar Islands. ✓ Mansoon rich areas ✓ Donot shed their leaves ✓ Continuous Canopy i.e trees overlap each other ✓ Very little light penetrates to reach the base.	✓ Grow in moderate rainfall areas ✓ Shed their leaves in winter and regain leaves in April ✓ Light penetrates to reach the base	✓ Grow in semi-arid regions of India ✓ Trees sparsely distributed with grassy areas in-between the trees ✓ Mostly Xerophytes grow there ✓ Needle or waxy leaves to reduce the rate of transpiration	✓ Grow along the coast or river deltas ✓ Adapted to grow in a mix of saline and fresh water ✓ Possess breathing roots or respiratory roots

Forest communities:

Forest type	Plants Examples	Common Animal Examples	Rare Animal Examples
Himalayan Coniferous	Pine, deodar	Wild goats and sheep, Himalayan black bear.	Snow leopard, Hangul, Himalayan brown bear, Musk deer, Himalayan Wolf.
Himalayan Broadleaved	Maple, oak		
Evergreen North-east, Western Ghats, Andaman & Nicobar	Jamun, Ficus, Dipterocarpus	Tiger, Leopard, Sambar, Malabar whistling thrush, Malabar Pied hornbill, tree frogs.	Pigmy Hog, Rhino, Liontailed macaque
Deciduous – Dry	Teak, Ain, Terminalia	Tiger, Chital, Barking deer, Babblers, Flycatchers, Hornbills.	
Moist	Sal		
Thorn and scrub, Semiarid forests	Babul, Ber, Neem	Blackbuck, Chinkara, Fourhorned antelope, Partridge, Monitor lizard.	Wolf, Bustard, Florican, Bustards,
Mangrove Delta Forests	Avicenia	Crocodile, shorebirds – sandpipers, plovers, fish, crustacea.	Water monitor lizard.

Forest Utilization

Natural forests provide local people with a variety of products if the forest is used carefully. Over-exploitation for fuel wood or timber, and conversion to monoculture plantations for timber or other products, impoverishes local people as the economic benefit goes to people who live elsewhere. The entire resource base on which local people have traditionally survived for generations, is rapidly destroyed. Eventually the forest is completely degraded. Natural forest ecosystems play an important role in controlling local climate and water regimes. It is well-known that under the canopy of a natural forest, it is cooler than outside the forest. During the monsoon, the forest retains moisture and slowly releases it through perennial streams during the rest of the year. Plantations fail to perform this function adequately. The loss of forest cover in the catchments of a river thus leads to irreversible changes such as excessive soil erosion, large run-off of surface water during monsoons leading to flash floods, and a shortage of water once the monsoons are over.

Direct uses of forest products

Fruits – mango, jamun, awla

Roots – Dioscoria

Medicine – Gloriosa, Foxglove

Fuelwood – many species of trees and shrubs

Small timber for building huts and houses

Wood for farm implements

Bamboo and cane for baskets

Grass for grazing and stall feeding livestock

Indirect uses of forest products

Building material for construction and furniture for the urban sector

Medicinal products collected and processed into drugs

Gums and resins processed into a variety of products

Raw material for industrial products and chemicals

Paper from bamboo and softwoods

Threats to Forest Ecosystem

1. Overutilization on account of fuelwood and timber
2. Developmental activities like rapid population growth, industrialization and urbanization,
3. mining
4. building dams

How can forest ecosystems be conserved?

We can conserve forests only if we use its resources carefully. This can be done by using alternate sources of energy instead of fuelwood. There is a need to grow more trees than are cut down from forests every year for timber. Afforestation needs to be done continuously from which fuelwood and timber can be judiciously used. The natural forests with all their diverse species must be protected as National Parks and Wildlife Sanctuaries where all the plants and animals can be preserved.

(B) Grassland Ecosystem

Grassland Ecosystem is an area where the vegetation is dominated by grasses and other herbaceous (non-woody) plants. It is also called transitional landscape because grassland ecosystems are dominated by the grass with few or no trees in the area where there is not enough for a forest and too much of a forest.

The components of the Grassland Ecosystem are discussed below:

1. Abiotic Components: These are non-living thing components consist of carbon, hydrogen, sulphur, nitrogen and phosphorous etc.

2. Biotic Components: These are living components and its sub-components are discussed below-

(I) Producers**:** The primary producers of food are the grasses such as Aristida, Cynodon, Digitaria, Desmodium, Setaria etc. If herbs and shrubs are present, they also contribute to the primary production of food.

(II) Consumers: The consumers in a grassland ecosystem are of three levels.

(a) Primary consumers: These feed directly from the grasses (grazing) and include herbivores such as Cows, Buffaloes, Goats, Rabbits, Mouse etc. and also insects, termites, centipede, millipedes etc.

(b) Secondary consumers: These consumers are the carnivorous animals such as snakes, lizard, jackal, foxes, frogs etc. which feed on the primary consumers.

(c) Tertiary consumers: Hawk, Eagles and vultures constitute the tertiary consumer in the grassland ecosystem which preys upon the secondary and primary consumer.

(III) Decomposers: The organic matter of the grassland is decomposed by the microbes like actinomycetes, fungi (Mucor, Aspergillus, Rhizopus, Penincillium, and Cladosporium), aerobic and anaerobic soil bacteria etc. They release the minerals back into the soil thus making the soil fertile.

Functions of the Grassland Ecosystem

The primary function of an ecosystem is productivity. The producers fix the solar energy and produce the complex organic matter with the help of minerals. It provides forage for livestock, protection and conservation of soil and water resources, furnishing a habitat for wildlife, both flora and fauna and (contribution to the attractiveness of the landscape. The functional aspects of the Grassland can be studied by two means:

1. Food Chain in an ecosystem: There is an important feature of the ecosystem that one level of an organism serves as food for another level of the organism. A series is formed which is known as Food Chain. In an ecosystem, the food chain does not follow the linear pattern, but an organism may feed upon more than one organism in the same food chain or upon organisms of different food chains. Thus interconnected food chain system is formed known as a food web.

2. Nutrient cycle in an ecosystem: For any ecosystem to be successful, it is important that the constituent materials move in a cyclic manner. The producers (green plant) takes up the mineral elements from the soil and air, convert them into organic form and after passing through the different trophic levels, are again returned to the soil and air.

Economic importance of Grassland Ecosystem

Grass lands biomes are important to maintain the crop of many domesticated and wild herbivores such as horse, mule, ass, cow, pig, sheep, goat, buffalo, camel, deer, zebra etc. which provides food, milk, wool and transportation to man. Hence, we can say that the Grassland Ecosystem is a mixture of grass, clover and other leguminous species, dicotyledonous, herbs and shrubs which contribute to a high degree of the preservation.

Grassland Types in India:

Grasslands form a variety of ecosystems that are located in different climatic conditions ranging from near desert conditions, to patches of shola grasslands that occur on hillslopes alongside the extremely moist evergreen forests in South India. In the Himalayan mountains there are the high cold Himalayan pastures. There are tracts of tall elephant grass in the low-lying Terai belt south of the Himalayan foothills. There are semi-arid grasslands in Western India, parts of Central India, and in the Deccan Plateau. The Himalayan pasture belt extends upto the snowline. The grasslands at a lower level form patches along with coniferous or broadleaved forests. Himalayan wildlife requires both the forest and the grassland ecosystem as important parts of their habitat. The animals migrate up into the high altitude grasslands in summer and move down into the forest in winter when the snow covers the grassland. These Himalayan pastures have a large variety of grasses and herbs. Himalayan hill slopes are covered with thousands of colourful flowering plants. There are also a large number of medicinal plants.

The Terai consists of patches of tall grasslands interspersed with a Sal forest ecosystem. The patches of tall elephant grass, which grows to a height of about five meters, are located in the low-lying waterlogged areas. The Sal forest patches cover the elevated regions and the Himalayan foothills. The Terai also includes marshes in low-lying depressions. This ecosystem extends as a belt south of the Himalayan foothills.

The Semi-arid plains of Western India, Central India and the Deccan are covered by grassland tracts with patches of thorn forest. Several mammals such as the wolf, the blackbuck, the chinkara, and birds such as the bustards and floricans are adapted to these arid conditions. The Scrublands of the Deccan Plateau are covered with seasonal grasses and herbs on which its fauna is dependent. It is teaming with insect life on which the insectivorous birds feed.

The Shola grasslands consist of patches on hillslopes along with the Shola forests on the Western Ghats, Nilgiri and Annamalai ranges. This forms a patchwork of grassland on the slopes and forest habitats along the streams and lowlying areas.

How are grasslands used?

Grasslands are the grazing areas of many rural communities. Farmers who keep cattle or goats, as well as shepherds who keep sheep, are highly dependent on grasslands. Domestic animals are grazed in the ‘common’ land of the village. Fodder is collected and stored to feed cattle when there is no grass left for them to graze in summer.

Grass is also used to thatch houses and farm sheds. The thorny bushes and branches of the few trees that are seen in grasslands are used as a major source of fuelwood.

Overgrazing by huge herds of domestic livestock has degraded many grasslands. Grasslands have diverse species of insects that pollinate crops. There are also predators of these insects such as the small mammals like shrews, reptiles like lizards, birds of prey, and amphibia such as frogs and toads. All these carnivorous animals help to control insect pests in adjoining agricultural lands.

What are the threats to grassland ecosystems?

In many areas grasslands have been used for centuries by pastoral communities.

Overutilization and changes in landuse of the ‘common grazing lands’ of rural communities has led to their degradation. The grassland cover in the country in terms of permanent pastures now covers only 3.7 percent of land. A major threat to natural grasslands is the conversion of grasslands into irrigated farmlands. In the Deccan, grasslands have been altered to irrigated farms and are now mainly used to grow sugarcane. After continuous irrigation such land becomes saline and useless in a few years. More recently many of these residual grassland tracts have been converted into industrial areas. This provides short-term economic gains but result in long-term economic and ecological losses. Grasslands have a limited ability to support domestic animals and wildlife. Increasing this pressure by increasing the number of domestic animals reduces the ‘naturalness’ of the grassland ecosystem leading to its degradation. Most grassland ecosystems are highly modified by human activities. Cattle, sheep and goat grazing, and lighting repeated fires affects grasslands adversely. Changing the grasslands to other forms of landuse such as agriculture, tree plantations and industrialization forms a serious threat to this highly productive ecosystem. Thus

some of the grassland patches which are in a less disturbed state and have retained their special plants and animals need to be urgently protected. Degradation of grasslands due to over grazing by cattle, sheep and goats occurs if more than a critical number of domestic animals are present in the grasslands. When animals overgraze the area, the grasses are converted into flat stubs with very little green matter. Degraded grasslands have fewer grass species as the nutritious species are entirely used up by the large number of domestic animals. They are thus unable to regenerate. When fires are lit in the grasslands in summer, the burnt grass gets a fresh flush of small green

How can grassland ecosystems be conserved?

Grasslands should not be overgrazed and areas of the grasslands should be closed for grazing. It is better to collect grass for stall feeding cattle. A part of the grassland in an area must be closed every year so that a rotational grazing pattern is established. Fires must be prevented and rapidly controlled. In hilly areas soil and water management in each micro-catchment helps grasslands to return to a natural highly productive ecosystem.

To protect the most natural undisturbed grassland ecosystems, Sanctuaries and National Parks must be created. Their management should focus on preserving all their unique species of plants and animals. Thus they should not be converted into plantations of trees. The open grassland is the habitat of its specialized fauna. Planting trees in these areas reduces the natural features of this ecosystem resulting in the destruction of this unique habitat for wildlife. Keeping grasslands alive is a National priority.

(C) Desert ecosystem

Desert ecology is the study of interactions between both biotic and abiotic components of desert environments. A desert ecosystem is defined by interactions between organism populations, the climate in which they live, and any other non-living influences on the habitat.

Deserts and semi-arid areas are located in Western India and the Deccan Plateau. The climate in these vast tracts is extremely dry. There are also cold deserts such as in Ladakh, which are located in the high plateaus of the Himalayas. The most typical desert landscape that is seen in Rajasthan is in the Thar Desert. This has sand dunes. There are also areas covered with sparse grasses and a few shrubs, which grow if it rains. In most areas of the Thar the rainfall is scanty and sporadic. In an area it may rain only once every few years. In the adjoining semi-arid tract the vegetation consists of a few shrubs and thorny trees such as kher and babul. The Great and Little Rann of Kutch are highly specialised arid ecosystems. In the summers they are similar to a desert landscape. However as these are low-lying areas near the sea, they get converted to salt marshes during the monsoons. During this period, they attract an enormous number of aquatic birds such as ducks, geese, cranes, storks, etc. The Great Rann is famous,as it is the only known breeding colony of the Greater and Lesser Flamingos in our country.The Little Rann of Kutch is the only home of the wild ass in India. Desert and semi-arid regions have a number of highly specialized insects and reptiles. The rare animals include the Indian wolf, desert cat, desert fox and birds such as the Great Indian Bustard and the Florican. Some of the commoner birds include partridges, quails and sandgrouse.

Areas of scanty vegetation with semi-arid scrubland have been used for camel, cattle and goat grazing in Rajasthan and Gujarat, and for sheep grazing in the Deccan Plateau. Areas that have a little moisture, such as along the watercourses, have been used for growing crops such as jowar, and bajra. The natural grasses and local varieties of crops have adapted to growing at very low moisture levels. These can be used for genetic engineering and developing arid land crops for the future.

What are the threats to desert ecosystems?

Several types of development strategies as well as human population growth have begun to affect the natural ecosystem of the desert and semi arid land. Conversion of these lands through extensive irrigation systems has changed several of the natural characteristics of this region. The canal water evaporates rapidly bringing the salts to the surface. The region becomes highly unproductive as it becomes saline. Pulling excessive groudwater from tube wells lowers the water table creating an even drier environment. Thus human activities destroy the naturalness of this unique ecosystem. The special species that evolved here over millions of years may soon become extinct.

How can desert ecosystems be conserved?

Desert ecosystems are extremely sensitive. Their ecological balance that forms a habitat for their plants and animals is easily disturbed. Desert people have traditionally protected their meagre water resources. The Bishnois in Rajasthan are known to have protected their Khejdi trees and the blackbuck antelope for several generations. The tradition began when the ruler of their region ordered his army to cut down trees for his own use. Several Bishnois were said to have been killed while trying to protect their trees. There is an urgent need to protect residual patches of this ecosystem within National Parks and Wildlife Sanctuaries in desert and semi arid areas. The Indira Gandhi Canal in Rajasthan is destroying this important natural arid ecosystem, as it will convert the region into intensive agriculture. In Kutch, areas of the little Rann, which is the only home of the Wild Ass, will be destroyed by the spread of salt works.

Development Projects alter the desert and arid landscape. There is a sharp reduction in the habitat available for its specialised species bringing them to the verge of extinction.

We need a sustainable form of development that takes the special needs of the desert into account.

(D) Aquatic ecosystems

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

Freshwater ecosystem

• Lotic – Running water e.g. river, stream, spring etc.

• Lentic – Standing water e. g. lake, pond, well swamp etc.

Marine ecosystems e.g. ocean, sea etc.

a. Freshwater Aquatic Ecosystem

They cover only a small portion of earth nearly 0.8 per cent. Freshwater involves lakes, ponds, rivers and streams, wetlands, swamp, bog and temporary pools. Freshwater habitats are classified into lotic and lentic habitats. Water bodies such as lakes, ponds, pools, bogs, and other reservoirs are standing water and known as lentic habitats. Whereas lotic habitats represent flowing water bodies such as rivers, streams.

- ***Lotic Ecosystems***

They mainly refer to the rapidly flowing waters that move in a unidirectional way including the rivers and streams. These environments harbor numerous species of insects such as beetles, mayflies, stoneflies and several species of fishes including trout, eel, minnow, etc. Apart from these aquatic species, these ecosystems also include various mammals such as beavers, river dolphins and otters.

- ***Lentic Ecosystems***

They include all standing water habitats. Lakes and ponds are the main examples of Lentic Ecosystem. The word lentic mainly refers to stationary or relatively still water. These ecosystems are home to algae, crabs, shrimps, amphibians such as frogs and salamanders, for both rooted and floating-leaved plants and reptiles including alligators and other water snakes are also found here.

- Wetlands

Wetlands are marshy areas and are sometimes covered in water which has a wide diversity of plants and animals. Swamps, marshes, bogs, black spruce and water lilies are some examples in the plant species found in the wetlands. The animal life of this ecosystem consists of dragonflies and damselflies, birds such as Green Heron and fishes such as Northern Pike.

b. Marine Aquatic Ecosystem

Marine ecosystem covers the largest surface area of the earth. Two-third of earth is covered by water and they constitute of oceans, seas, intertidal zone, reefs, seabed, estuaries, hydrothermal vents and rock pools. Each life form is unique and native to its habitat. This is because they have adaptations according to their habitat. In the case of aquatic animals, they can't survive outside of water. Exceptional cases are still there which shows another example of adaptations (e.g. mudskippers). The marine ecosystem is more concentrated with salts which make it difficult for freshwater organisms to live in. Also, marine animals cannot survive in freshwater. Their body is adapted to live in saltwater; if they are placed in less salty water, their body will swell (osmosis).

- **Ocean Ecosystems**

Our planet earth is gifted with the five major oceans, namely Pacific, Indian, Arctic, and the Atlantic Ocean. Among all these five oceans, the Pacific and the Atlantic are the largest and deepest ocean. These oceans serve as a home to more than five lakh aquatic species. Few creatures of these ecosystems include shellfish, shark, tube worms, crab small and large ocean fishes, turtles, crustaceans, blue whale, reptiles, marine mammals, seabirds, plankton, corals and other ocean plants.

- **Coastal Systems**

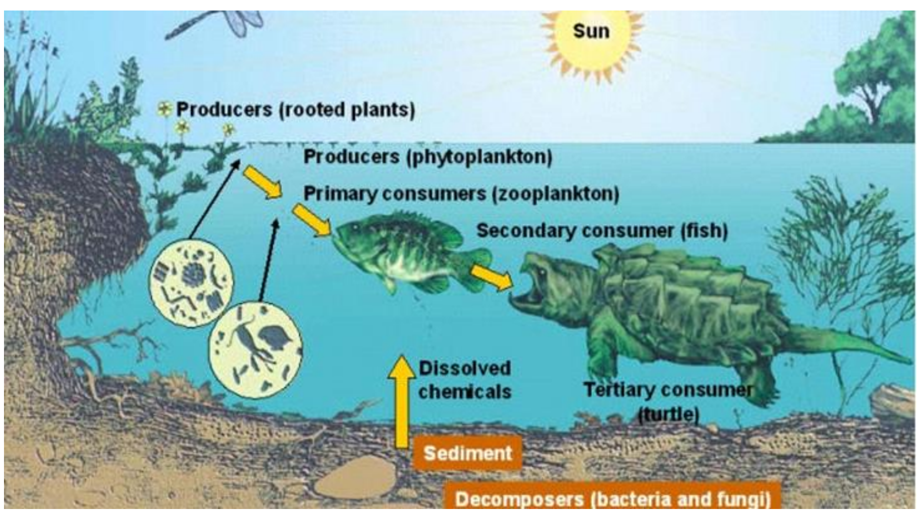
They are the open systems of land and water which are joined together to form the coastal ecosystems. The coastal ecosystems have a different structure, and diversity. A wide variety of species of aquatic plants and algae are found at the bottom of the coastal ecosystem. The fauna is diverse and it mainly consists of crabs, fish, insects, lobsters snails, shrimp, etc.

Plants and animals in an aquatic ecosystem show a wide variety of adaptations which may involve life cycle, physiological, structural and behavioural adaptations. Majority of aquatic animals are streamlined which helps them to reduce friction and thus save energy. Fins and gills are the locomotors and respiratory organs respectively. Special features in freshwater organisms help them to drain excess water from the body. Aquatic plants have different types of roots which help them to survive in water. Some may have submerged roots; some have emergent roots or maybe floating plants like water hyacinths.

Some Examples of Ecosystems

The Pond ecosystem

The pond is the simplest aquatic ecosystem to observe. There are differences in a pond that is temporary and has water only in the monsoon, and a larger tank or lake that is an aquatic ecosystem throughout the year. Most ponds become dry after the rains are over and are covered by terrestrial plants for the rest of the year. When a pond begins to fill during the rains, its life forms such as the algae and microscopic animals, aquatic insects, snails, and worms come out of the floor of the pond where they have remained dormant in the dry phase. Gradually more complex animals such as crabs, frogs and fish return to the pond.



The vegetation in the water consists of floating weeds and rooted vegetation on the periphery which grow on the muddy floor under water and emerge out of the surface of the water. As the pond fills in the monsoon a large number of food chains are formed. Algae is eaten by microscopic animals, which are in turn eaten by small fish on which larger carnivorous fish depend. These are in turn eaten by birds such as kingfishers, herons and birds of prey. Aquatic insects, worms and snails feed on the waste material excreted by animals and the dead or decaying plant and animal matter. They act on the detritus, which is broken down into nutrients which aquatic plants can absorb, thus completing the nutrient cycle in the pond. The temporary ponds begin to dry after the rains and the surrounding grasses and terrestrial plants spread into the moist mud that is exposed. Animals such as frogs, snails and worms remain dormant in the mud, awaiting the next monsoon.

Lake ecosystem

A lake ecosystem functions like a giant permanent pond. A large amount of its plant material is the algae, which derives energy from the sun. This is transferred to the microscopic animals, which feed on the algae. There are fish that are herbivorous and are dependent on algae and aquatic weeds. The small animals such as snails are used as food by small carnivorous fish, which in turn are eaten by larger carnivorous fish. Some specialised fish, such as catfish, feed on the detritus on the muddy bed of the lake.

Energy cycles through the lake ecosystem from the sunlight that penetrates the water surface to the plants. From plants energy is transferred to herbivorous animals and carnivores. Animals excrete waste products, which settle on the bottom of the lake. This is broken down by small animals that live in the mud in the floor of the lake. This acts as the nutrient material that is used by aquatic plants for their growth. During this process plants use Carbon from CO_2 for their growth and in the process release Oxygen. This Oxygen is then used by aquatic animals, which filter water through their respiratory system.

Stream and River ecosystems

Streams and rivers are flowing water ecosystems in which all the living forms are specially adapted to different rates of flow. Some plants and animals such as snails and other burrowing animals can withstand the rapid flow of the hill streams. Other species of plants and animals such as water beetles and skaters can live only in slower moving water. Some species of fish, such as Mahseer, go upstream from rivers to hill streams for breeding. They need crystal clear water to be able to breed. They lay eggs only in clear water so that their young can grow successfully. As deforestation occurs in the hills the water in the streams that once flowed throughout the year become seasonal. This leads to flash floods in the rains and a shortage of water once the streams dry up after the monsoon. The community of flora and fauna of streams and rivers depends on the clarity, flow and oxygen content as well as the nature of their beds. The stream or river can have a sandy, rocky or muddy bed, each type having its own species of plants and animals.

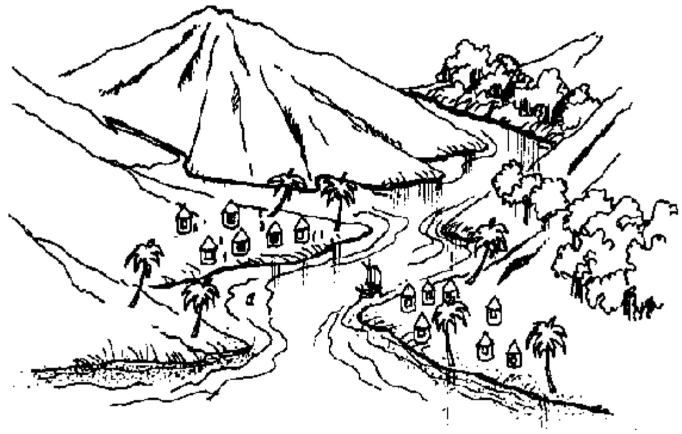
Estuarine ecosystems

Estuaries are where rivers discharge into the sea. They are semi-enclosed bodies of water, connected to the open sea, but where the sea water is diluted by fresh water from the land. Both land and sea affect estuaries, and their influence varies throughout the day and from season to season. These factors pose serious challenges for living organisms, and estuaries have developed unique ecosystems in response.

Salinity

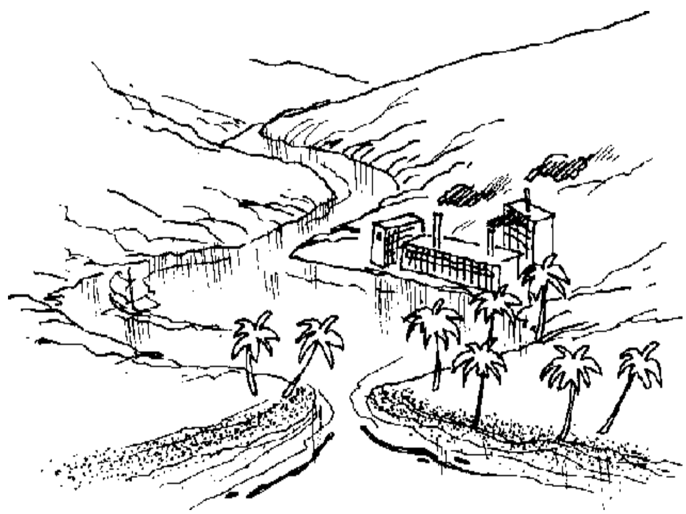
Inflow of fresh water from one side and the open sea at the other gives rise to a gradient of increasing salinity from the interior to the estuary mouth. The salinity also changes with the tides and the season. The Mandovi-Zuari estuary in Goa and Cochin backwaters in Kerala are typical estuaries in which surface salinity ranges from 0.65% at the peak of the monsoon in August to 33.64% in the hot pre-monsoon period in April. Brackish waters are poorer in species diversity than either the sea or fresh water. Seasonal fluctuations in salinity influence the distribution of organisms in the estuary. Continuous rains during the monsson harms marine fauna. When salinity returns to normal after few months, the marine animals re-establish themselves. Estuarine animals either adapt to avoid unfavourable salinities or tolerate a range in salinity by using physiological mechanisms. For instance, to avoid unfavourable salinity, barnacles shut their valves, mussels close their shells, eupogebia burrow into the substrate, and other creatures migrate up and down the estuary. Many estuaries in India were formed when the sea level rose, submerging parts of the coast and drowning river valleys. The Mandovi and Zuari estuaries in Goa were formed in this way.

Estuaries can also be formed when shingle and sand bars form parallel to the coast, enclosing a shallow area and partly blocking a river's exit to the sea. One example of this is the Vellar Estuary in Tamil Nadu.



Estuarine ecosystems

Most estuarine animals have effective osmoregulatory adaptations (methods of controlling the amount of salt in their bodies). Some regulate their salt content higher than the surroundings when the surrounding water has low salinity (this is called hyperosmotic regulation). The shore crab Carcinus, amphipod Gammarus, the crab Sarsama erythrodactyla certain prawns and the bivalve Mercenaria mercenaria all show hypertonicity in blood in diluted sea water.



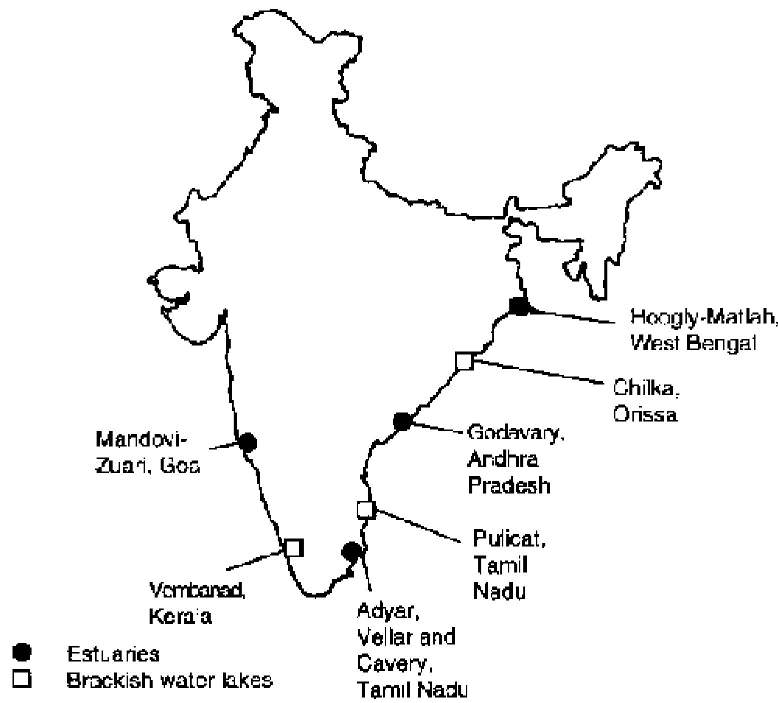
Vellar Estuary in Tamil Nadu

Mytilus edulis and Arenicola marina have no osmoregulatory mechanism. They adjust as their tissues are able to function under low salt content. However, they are unable to survive in salinity below their threshold concentration.

Temperatures vary widely in estuaries owing to the mixing of water of different temperatures and shallowness of the water. In shallow estuaries, the water is much cooler in winter and warmer in summer. These temperature fluctuations affect the species composition and eliminate most animals that cannot withstand wide changes.

Sediments: The sediment type influences the organisms living in the estuary, especially plants and benthic animals. Mudflats are common. The substrate here is composed of soft, loose mud or a mixture of mud and sand. Characteristic vegetation such as eel grass in temperate areas and mangroves in the tropics develops on mudflats, making estuarine ecosystems very productive and at the same time providing special habitat for animals. Mangroves are found in most estuaries along the Indian coast.

Turbidity: Silt suspended in the water in estuaries causes the water to be turbid. The degree of turbidity varies widely throughout the year; it is at a maximum during the rainy season. It also varies from place to place within the estuary. Turbid water prevents light from penetrating even one metre below the water surface. This reduces the level of photosynthesis by phytoplankton in the deeper layers. Shore plants which are not covered by turbid waters are therefore the most important photosynthesisers of organic matter. Salt-marsh plants such as spartina and zoostera and mangrove forest assume great importance as primary producers.



Typical estuarine habitats and brackish water lakes in India

Nutrient flows: The fertility of the estuary depends on the flow of nutrients from the river and on tidal currents. The Mandovi-Zuari rivers are rich in nutrients, especially nitrates and phosphates. Drainage from the land is the major source of nutrient inputs into the estuary. In addition, industrial effluents and city waters also find their way into the estuary. Some estuaries in Gujarat are subject to heavy industrial pollution, making it difficult for fish to survive. The overall productivity of most Indian estuaries is low because of their high turbidity. In Cochin backwaters, the gross primary productivity measure of ranges from 270 to 298 g C/m²/yr, while net production is 124 g C/m²/yr. In Cochin backwaters, only 25% of the total phytoplankton production is estimated to be used by the herbivore population. The unconsumed food sinks to the bottom as detritus. Even though the estuarine phytoplankton production is low, it is well compensated by the productivity of plants such as marsh grass, reeds and mangroves. More than 50% of production is available to estuaries in the form of detritus. Land drainage also supplies abundant detritus.

What are the threats to aquatic ecosystems?

Water pollution occurs from sewage and poorly managed solid waste in urban areas when it enters the aquatic ecosystem of lakes and rivers. Sewage leads to a process called eutrophication, which destroys life in the water as the oxygen content is severely reduced. Fish and crustacea cannot breathe and are killed. A foul odour is produced. Gradually the natural flora and fauna of the aquatic ecosystem is destroyed. In rural areas the excessive use of fertilisers causes an increase in nutrients, which leads to eutrophication. Pesticides used in adjacent fields pollute water and kills off its aquatic animals. Chemical pollution from industry kills a large number of life forms in adjacent aquatic ecosystems. Contamination by heavy metals and other toxic chemicals affects the health of people who live near these areas as they depend on this water.

CASE STUDY

Threats to wetlands in Assam: Almost 40% of all wetlands in Assam are under threat. A survey conducted by the Assam Remote Sensing Application Center (ARSAC), Guwahati, and the Space Research Center, Ahemadabad, has revealed that 1367 out of 3513 wetlands in Assam are under severe threat due to invasion of aquatic weeds and several developmental activities. The wetlands of Assam form the greatest potential source of income for the State in terms of fisheries and tourism. Though the wetlands of Assam have the capacity of producing 5,000 tones of fish per hectare per year, around 20,000 tones of fish have to be imported to meet local demands. This is primarily due to poor wetland management.

How can aquatic ecosystems be conserved?

For sustainable use of an aquatic ecosystem, water pollution must be prevented. It does not make sense to allow water to be polluted and then try to clean it up.

Changing the nature of the aquatic ecosystem from a flowing water ecosystem to a static ecosystem destroys its natural biological diversity. Thus dams across rivers decrease the population of species that require running water, while favouring those that need standing water.

Aquatic ecosystems, especially wetlands, need protection by including them in Sanctuaries or National Parks in the same way in which we protect natural forests. These sanctuaries in aquatic ecosystems protect a variety of forms of life as well as rare fish which are now highly endangered such as the Mahseer. Wetland Sanctuaries and National Parks are of greatest importance as this is one of the most threatened of our ecosystems. As the proportion of the earth's surface that is naturally covered by wetlands is very small compared to forests or grasslands, the wetland ecosystems are very highly threatened.

Recommended Books:

1. Textbook of Environmental studies, Erach Bharucha, UGC.
2. Fundamental concepts in Environmental Studies, D. D. Mishra, S Chand & Co Ltd.

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