ENVIRONMENT

ECOLOGY AND ECOSYSTEM

Forum IAS

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ECOLOGY AND ECOSYSTEM

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ECOLOGY AND ECOSYSTEM

Man is an important part of the biotic component of the environment. Ecological approach to the study of **man-environment relationships** is based on the **basic principle of ecology** which is the study of **mutual interactions between organisms and physical environment** on the one hand and **interactions among the organism** on the other hand in a given ecosystem.

Ecological school considers man to be most skilled and intelligent, as the leader of all biota and steward of the earth. Therefore, the relationship of man with the natural environment should be **symbiotic and not exploitative or suppressive.** Ecological approach lays emphasis on **wise and restrained use** of natural resources, application of appropriate environmental management programmes, policies and strategies.

The ecological approach lays emphasis on **rational exploitation of resources and optimum utilization through recycling of resources.** Therefore, humans as sentient species have the obligation to ensure **sustainable development** where all the organisms are treated equally and live in harmony.

1. ECOLOGY

1.1 Meaning of Ecology:

Ecology, in a very simple term, is a **science** that studies the **interdependent, mutually reactive and interconnected relationships** between the organisms and their physical environment on the one hand and maong the organisms on the other hand. The term **'ecology'** was first coined and used by the German biologist **Ernst Haeckel**.

Darwin's concept of the 'evolution of species' through natural selection involving interactions between biological species and habitat was the **key stone of the formulation of the idea of ecology.** The definition of ecology led to the development of **two approaches** to the study of ecology and its division into two branches:

1. **Autecology**: Ecological relations of individual species in a given ecosystem are studied.
2. **Synecology**: Study of plant communities in relation to their habitats of a given ecosystem.

1.2 Sub-division of Ecology:

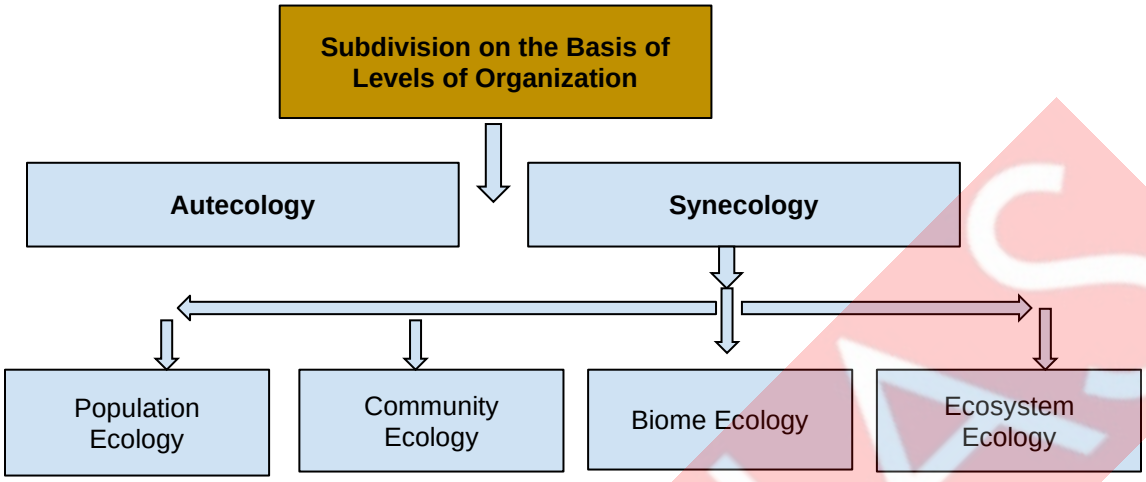
Sub-division based on taxonomic affinities:

- Plant Ecology
- Animal Ecology

Sub-division based on Habitat:

- Forest Ecology
- Grassland Ecology
- Freshwater Ecology
- Estuarine Ecology,
- Marine Ecology, etc.

Sub-division based on Basis of Levels of organization:



The *levels of organization* of biodiversity include ecosystems, species and genes.

- **ecosystem: An** ecosystem **is a dynamic complex** of plant, animal and microorganism **communities and non-living (abiotic) elements, all interacting** as a functional unit. **An ecosystem's character changes as community** members and physical contexts change, sometimes crossing a threshold of tolerance within the system that results in its inability to return to its previous form.
- **Species** are a complete, self-generating, unique ensemble of genetic variation, capable of interbreeding and producing fertile offspring. They (and their subspecies and populations) are generally considered to be the only self-replicating units of genetic diversity that can function independently.
- **Genes** are the working units of heredity; each gene is a segment of the DNA molecule that encodes a single enzyme or structural protein unit. Genetic diversity is the foundation of all biodiversity. Genetic variation permits populations to adapt to changing environments and continue to participate in life's processes.

1.3 Ecological Concepts and Principles:

There are certain basic principles that governs the various aspects of functioning of organisms.

- **Ecosystem is the basic fundamental unit** of ecological study because it comprises both biotic and abiotic components.
- At the largest scale, the whole biosphere becomes an ecosystem.
- Natural hazards adversely affect the biological communities.
- All living organisms and physical environment are mutually reactive.
- 'Nothing actually disappears when we throw it away' because all the materials are rearranged and cycled and recycled through a series of cyclic paths in the natural environment.
- Ecosystem functions through the input of energy mainly solar radiation. **R.L. Lindeman** has formulated principles about the relationship between trophic levels within a natural ecosystem.
    - **Principle 1:** As the distance between the organisms of a given trophic level and the initial source of energy (trophic level one) increases, the probability of the organisms to depend exclusively on the preceding trophic level for energy decreases.

- **Principle 2:** The relative loss of energy due to respiration is progressively greater to higher trophic levels because the species at higher trophic levels are relatively larger in size and have to move and work for getting food and therefore more energy is lost due to respiration.
- **Principle 3:** Species at progressively higher trophic levels appear to be progressively more efficient in using their available food supply.
- **Principle 4:** Organisms at higher trophic levels are 'generalists' in their feeding habit and they are most efficient in using their available food supply.
- **Principle 5:** Food chains tend to be reasonably short. Because loss of energy is progressively higher for higher trophic levels and species at higher levels tends to be less discrete.

- The chemical (inorganic) and organic substances are circulated among the various components of the biosphere through a series of closed system of cycles collectively known as 'biogeochemical cycles.
- The ecosystem productivity (referred to as the rate of growth of organic matter per unit time by autotrophs at trophic level one) depends on two factors:
  1. **Light:** The availability of the amount of solar radiation to the primary producers at trophic level one.
  2. **Photosynthesisability:** The efficiency of plants to convert solar energy into chemical energy.
- The 'normal' or 'uneventful' ecosystem attains its stability through 'homeostatic mechanisms' There is inbuilt self- regulating mechanism in a natural ecosystem through which any change caused by external factors in the ecosystem is counterbalanced by the responses of the ecosystem to the change in such a way that ultimately ecosystem or ecological stability is achieved.

- The ecological concept of diversity/stability has been illustrated in the following manner:
  1. **Impact on food webs:** Increase in the diversity of food webs promote ecosystem stability because the increased food web diversity increases the resilience of the system to outside invasions of exotic organisms and reduced the fluctuations in the population within a given ecosystem. (C.S. Elton)

     More complex food web is more stable: The ecosystem stability increases with increase of number of links in the food web because a large number of interacting feeding links provides alternative channels of energy flow and thus is generates a wide variety of adjustment of the population to environmental changes and stresses within the ecosystem. (P.H. MacArthur)

     Role of succession: High species diversity of a mature ecosystem representing a 'climax community' is related to more stability of natural ecosystem because as the community succession operates, 'homeostasis' increases due to more protection available to the member of the community against external environmental change. (E.P. Odum)

- Evolution of species epitomizes the inherently dynamic nature of ecosystem.
- The concept and principle of succession are very important in ecology as there is successional development of species mainly vegetation communities.
- Man, being an active agent of environmental change, modifies the ecosystem through the exploitation of natural resources.

- The ultimate goal of ecological study is to preserve ecological resources by maintaining the ecological diversity and ecosystem stability.

Figure: ecological concepts and principles.

1.4 Ecological Succession:

F.E. Clement postulated the concept of Vegetation/Ecological succession which is the process of change in the species structure of an ecological community over time.

- "It is the process of change in the species structure of an ecological community over time. This can done in a decades (for example, after a wildfire), or millions of years after a mass extinction."
- Ecological succession is the phenomenon or process by which an community (animals/plants) undergoes more or less orderly and predictable changes following a disturbance or the initial colonization of a new habitat.

The development of vegetation community in any ecosystem or habitat is affected and controlled by:

1. Climate
2. Edaphic factors
3. Biotic factors
4. Physiographic factors
5. Fire factors

Phases of biotic succession:

Phases	
Nudation	Creation of bare area devoid of vegetation. Ex. Newly emerged volcanic island
Migration	Arrival of seeds in to the new bare area.
Ecesis	Seeds are germinated.
Reaction:	Competition between plants and physical environment.
Stabilization	Equilibrium condition of populations of plant species.

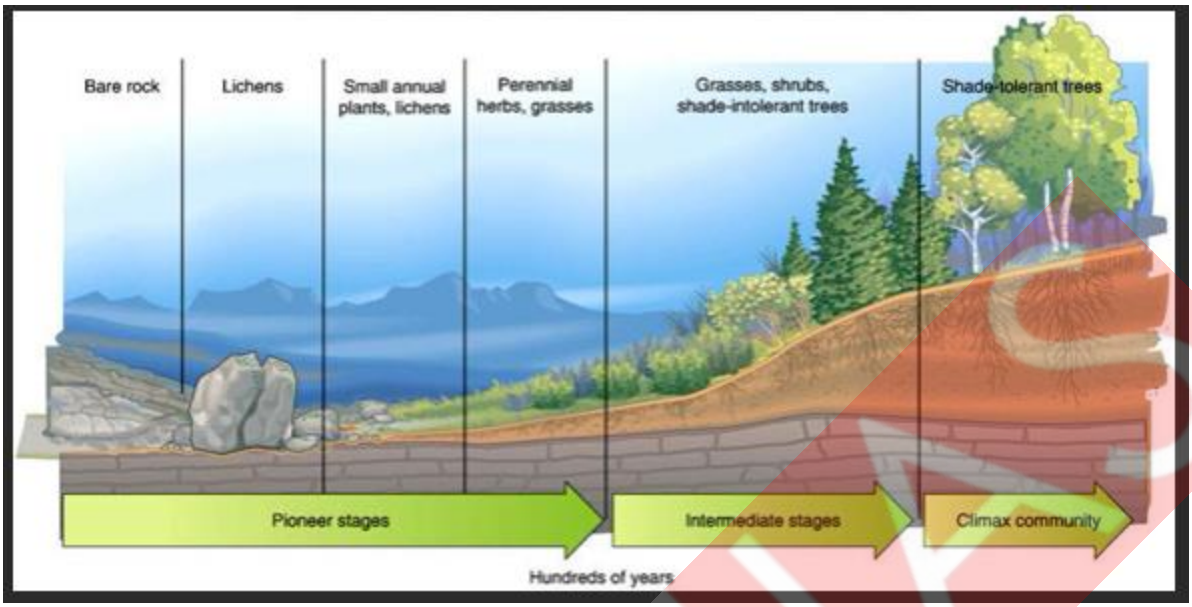


Figure: Stages in Ecological Succession

Characteristics of Ecological Succession:

1. It results from modification of the physical environment of the community. Ex. Development of pioneer species like algae and lichens on bare surface like Krakatoa Island, etc.
2. It is an orderly process of community development.
3. The time required for development of climax vegetation in secondary succession is much less than primary succession.
4. Nutrient variation determines the settlement of new community.
5. Deflected climax due to arresting factors like jhuming cultivation results in plagioclimax.
6. Ecological succession is disrupted in communities like Savanna, Chaparral, etc. by fire.
7. At climax vegetation:
    - Ecosystem is stable and self-perpetuating
    - Biomass increases to maximum
    - Net community production decreases
    - Food chain becomes highly complex changing to food web.

Types of Ecological Succession:

Clements has divided succession in two types:

1. **Primary Succession:** Primary succession refers to developmental sequence of vegetation in those bare areas where there were no vegetation and animals earlier. Ex. Newly emerged sea floor, island of Krakatoa, etc.
2. **Secondary Succession:** Secondary succession refers to the developmental sequences of vegetation in those areas which had vegetation earlier but now have been rendered nude due to destruction by:
    - Natural processes: Lava flow, forest fires, catastrophic floods, etc.
    - Anthropogenic processes: Jhuming cultivation, overgrazing, etc.

Primary Succession	❖ Thesuccessionstartsfromanareawheretherewasnopreviousliving matter. ❖ Pioneercommunity-lichensproduceslichenacids.Theselichenacids wither the rock to form the sand. After the soil formation, the lichens are immediately replaced by the mosses.
Secondary Succession	❖ Succession starts from a previously built-up substratum (already existing livingmatter). ❖ Abrupt changes like fire, snowfall, biotic interventions, cause the disappearance of the existing community. ❖ The area becomes devoid of any living matter due factors like fire or flood. Such areas will be rapidly acquired by new populations, and thus establish a new ecosystem. ❖ Thisprocessisarapidprocessthantheprimarysuccession
Autogenic Succession	❖ After the succession has begun, the communities itself modify its own environment and thus causing its own replacement. ❖ E.g.-collapse of an aquatic ecosystem due to algal bloom
Allogenic Succession	❖ As the succession progresses, the organic matter and energy flow in the ecosystem increase
Heterotrophic Succession	❖ This succession is characterized by an early dominance of heterotrophs such as fungi, bacteria, actinomycetes or animals. ❖ Heterotrophic succession usually starts from a nutrient rich organic environment ❖ As the succession progresses, the organic matter and energy flow in the ecosystem decrease
Hydrarch succession	❖ An ecological succession began from an area where water is abundantly present (such as lake or big pond) is called hydrosere or hydrarch succession. ❖ Pioneer community : phytoplankton. ❖ Climax community: grassland or a forest.
Xerarch succession.	❖ It is an ecological succession starting from an area where water content is very less such as a rock surface. ❖ Pioneer community - lichens
Micro succession	❖ Microsere or is the succession of microorganisms such as bacteria and fungi in a micro habitat ❖ This is also called as Serule.

Climax Vegetation:

The vegetation community developed at the last stage of biotic succession is called climax vegetation which is indicative of a mature ecosystem wherein the dominant vegetation is in equilibrium with the environment.

At climax:

- Ecosystem is stable and self-perpetuating.
- Biomass increases to maximum.
- Net community production decreases.

- Food chain becomes highly complex changing to food web.

Plagioclimax Vegetation:

A Plagioclimax community is an area or habitat in which the influences of the humans have prevented the ecosystem from developing further.

- The ecosystem may have been stopped from reaching its full climatic climax or deflected towards a different climax by activities (arresting factors) such as: jhuming cultivation, large scale afforestation, overgrazing, etc. In each case, human activity has led to a community which is not the climax community expected in such an area.
- It is of two types:
    a. **Arrested succession:** The natural succession would continue, if the arresting factors are removed. Ex. If cultivation is stopped in Gangetic plains and Great Plains of USA, normal sere of vegetation succession will start.
    b. **Deflected succession:** Even if the interferences are removed, succession to the original climax community is no longer possible. Ex. Shola forest (Nilgiris), Sahara Desert, Thar Desert, etc.

Fire climax community:

Some landscape never reach a stable climax in the traditional sense because they are characterized by and adapted to periodic fire disruption. Ex. Savanna, chaparral of California, etc.

- **Characteristics of the plants:**
    a. **Fast re-seeding:** They reseed quickly after fires. Thus, fast growth of ecosystem
    b. **Least competition**: Many plants require fire to eliminate competition
    c. To prepare seed-beds for **germination** or to open cones or thick seed coats.

Climax Theories:

Two school of thoughts developed:

One who believed climax

1. **Monoclimax theory:** Clement stated that regional climate is the dominant control factor of climax vegetation.
2. **Polyclimax theory:** Tansley believed in mosaic of climaxes due to fire, topography, climate, drainage, etc. According to this theory, plant community is not always in equilibrium with the climate of that habitat.

One who does not believed climax:

1. Whittaker argued that communities are constantly adjusting in response to the physical environment and therefore no absolute climax.
2. Gleason saw community history to be very unpredictable. He argued that species are individualistic and each getting established according to its ability to colonize and reproduce in an area.

It is perhaps more accurate to say that the rate of succession is so slow in a climax community that, from the perspective of a single human life time, it appears to be unchanging.

1.5 Ecological Niche:

- The term ecological niche was developed by Charles Elton.

- Ecological niche may be defined as 'the functional role and position (micro-habitat) of species in its ecosystem, including what resources it uses, how and when it uses the resources, and how it interacts with other species.
- The ecosystem stability depends upon the diversity of niche. The greater the niche diversity, the more is ecosystem stability because of larger number of pathways for the flow of energy and less fluctuation of species population.
- Sometimes it becomes difficult for two species to inhabit the same niche. In such cases the 'Law of Competitive Exclusion' works.
- In such difficult situations, one species may adopt a few alternative paths i.e.
    - Either one species may migrate to new niche
    - May become extinct
    - May change physiological behaviour for the competition of same resources.
- The process of minimization of competition for resources is called 'Resource Partition' which can allow several species to utilize different parts of the same resource and coexist within a single habitat.
- Dominant species occupy extensive and broader ecological niche in comparison to less dominant species.

Types of niche:

Many species perform different functions in the same habitat:

1. Habitat niche – where it lives,
2. Food niche – what it eats or decomposes & what species it competes with,
3. Reproductive niche – how and when it reproduces,
4. Physical & chemical niche – temperature, land shape, land slope, humidity & another requirement.

The competitive exclusion principle: Two species cannot occupy the same ecological niche in a habitat if they are competing for the same resources. If one species is successful, it reduces the competition. If neither evolves to reduce competition, then the species that can more efficiently exploit the resource will win out, and the other species will eventually become extinct.

2. ECOSYSTEM

An ecosystem is **a community of living organisms in conjunction with the nonliving components** of their environment, **interacting as a system**. Its components are linked together through nutrient cycles and energy flows.

2.1 Components of an Ecosystem:

There are three major components of ecosystems:

1. Energy component
2. Abiotic or physical component
3. Biotic component

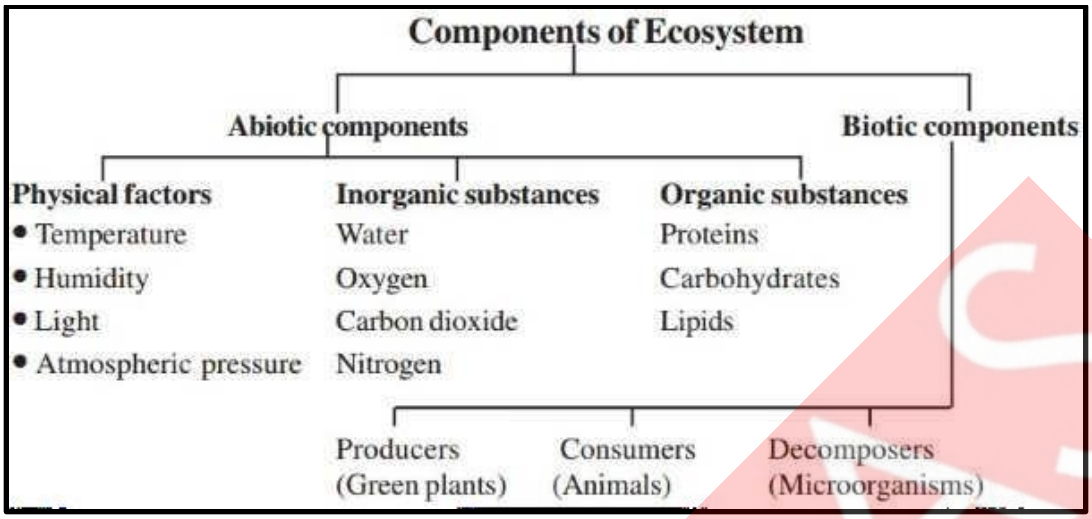


Figure: component of ecosystem

Biotic Components

Producers	• Plants are the 'producers' in the ecosystem as they manufacture their food by using energy from the sun. • In the forest these form communities of plant life. • In the sea these include tiny algal forms to large seaweed.

Consumers	• The herbivorous animals are **primary consumers** as they live on the producers.
	  ○ In a forest, these are the insects, amphibia, reptiles, birds and mammals.
	  ○ In the semiarid areas, there are species such as the chinkara or Indian gazelle.
	  ○ In the sea, there are small fish that live on algae and other plants.
	• At a higher trophic level, there are carnivorous animals, or **secondary consumers**, which live on herbivorous animals.
	  ○ In our forests, the carnivorous animals are tigers, leopards, jackals, foxes and small wild cats.
	  ○ In the sea, carnivorous fish live on other fish and marine animals.

Decomposers	• Decomposers or detritivores are a group of organisms consisting of small animals like worms, insects, bacteria and fungi, which break down dead organic material into smaller particles and finally into simpler substances that are used by plants as nutrition. • Decomposition thus is a vital function in nature, as without this, all the nutrients would be tied up in dead matter and no new life could be produced.

2.2 Classification of Ecosystems:

- Ecosystems are divided into terrestrial or land-based ecosystems, and aquatic ecosystems in water.
- At a sub-global level, this is divided into biogeographical realms.

- Examples:
  - Eurasia called the Palaearctic realm;
  - South and South-East Asia (of which India forms a major part) is the Oriental realm;
  - North America is the Nearctic realm;
  - South America forms the Neotropical realm;
  - Africa the Ethiopian realm; and
  - Australia the Australian realm.
- **Natural ecosystems** include the forests, grasslands, deserts, and aquatic ecosystems such as ponds, rivers, lakes, and the sea.
- **Man modified ecosystems** include agricultural land and urban or industrial land use patterns.

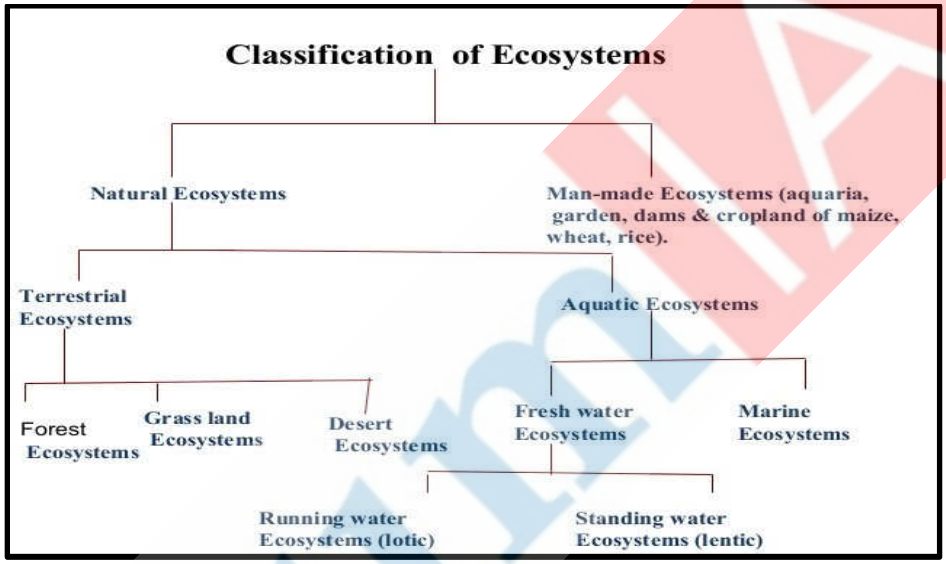


Figure: classification of ecosystem.

2.3 Functioning of Ecosystems:

- The functioning of an ecosystem depends upon the the pattern of energy flow as the living components of an ecosystem depend on energy flow which also helps in the distribution and circulation of organic and inorganic matter within the ecosystem.
- While the energy flow follows unidirectional path the circulation of matter follows cyclic paths.
- The energy pattern and flow are governed by first and second law of thermodynamics.
  - **Law 1:** In any system of constant mass, energy is neither created nor destroyed but it can be transformed from one type to another type.
  - **Law 2:** When work is done, energy is dissipated and the work is done when one form of energy is transformed into another form.

Energy Flow:

- Solar energy is the basic input of energy entering the ecosystem.
- Only a small proportion of radiant energy is used by plants to make food through the process of photosynthesis. The green plants convert solar energy into food/chemical energy.

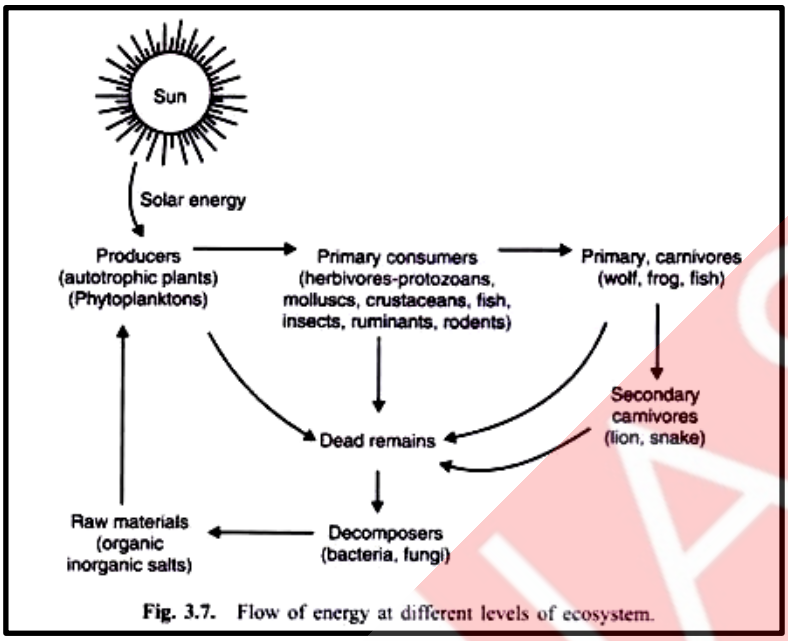


Fig. 3.7. Flow of energy at different levels of ecosystem.

- The chemical energy stored at trophic level one becomes the source of energy to the herbivorous animals at trophic level two of the food chain.
- Some portion of energy is lost from trophic level one through respiration and some portion is transferred to plant eating animals at trophic level two.
- A substantial portion of chemical energy is released by carnivores at trophic level three through respiration because more energy is required for the work to be done by carnivores at trophic level three.
- Some portion of potential chemical energy is transferred from trophic level three to trophic level four or top trophic level represented by omnivores. Some energy is released by omnivores through respiration.
- The remaining energy in the plants and animals is transferred to decomposers when they become dead.

Matter Flow:

- The circulation of elements or matter nutrients (organic and inorganic both) is made possible through energy flow.
- The organic and inorganic substances are moved reversibly in the biosphere, atmosphere, hydrosphere and lithosphere through various closed system of cycles in such a way that the total mass of these substances almost remains the same.
- The materials or nutrients involved within the circulation within an ecosystem are grouped into three categories:
    - **Micro-elements:** oxygen, carbon and hydrogen.
    - **Minor elements:** Nitrogen, phosphorous, potassium, calcium, magnesium and sulphur.
    - **Trace elements:** Iron, zinc, manganese and cobalt.
- Nutrients driven by energy flow pass into various components of biotic communities through the process known as 'biogeochemical cycles'.

2.4 Ecosystem Productivity:

The productivity of ecosystem refers to the rate of growth of energy or organic matter per unit time by autotrophs at trophic level one through the process of photosynthesis with the help of solar energy. Ecosystem Productivity depends upon:

- The availability of the amount of solar radiation to the primary producers at trophic level one.
- The efficiency of plants to convert solar energy into chemical energy.

Primary Production:

- The production of organic matter or energy by autotrophs.
- Primary production is measured in two ways:
- Net Primary Production: It excludes the amount of energy which is lost through respiration by the autographs.It represents the usable amount of energy at trophic level one, which is available to higher trophic levels.
- The ecosystem productivity whether gross or net is measured in gram/m2day or year

Secondary Production:

- Secondary production is the rate of generation of heterotrophic biomass, driven by the transfer of organic matter between trophic levels.

Biomass:

- It refers to the quantity or weight of living materials per unit area and is represented in terms of dry weight.

2.5 Difference between Ecology, Environment and Ecosystem:

- **Ecology** = the study of the ecosystems and the environment.
- **Environment** = a group of ecosystems.
- **Ecosystem** = a functional unit of environment (mostly biosphere).
- **Habitat** = Area where an organism lives.
- **Biosphere** = The region on earth that supports life.

3. FOOD CHAIN, FOOD WEB AND ECOLOGICAL PYRAMIDS

3.1 Food Chain:

- The **transfer of energy from the source in plants through a series of organisms by eating and being eaten** constitutes **food chains**.
- At each transfer, **a large proportion of energy is lost in the form of heat**.
- At each linkage in the chain, a major part of the energy from the food is lost for daily activities.
- Each chain usually has **only four to five such links**. However, **a single species may be linked to a large number of species**.
- **Why food chain:** The most obvious aspect of nature is that **energy must pass from one living organism to another**.
    - When herbivorous animals feed on plants, energy is transferred from plants to animals.

- **Detritus' food chain:** In an ecosystem, some of the animals feed on other living organisms, while some **feed on dead organic matter**. The latter form the **'detritus' food chain**.

3.2 Food Web:

- These food chains are not isolated sequences, but are interconnected with each other. This interlocking pattern is known as the food web.
- Impact of human interference: If the linkages in the chains that make up the web of life are disrupted due to human activities that lead to the loss or extinction of species, the web breaks down.

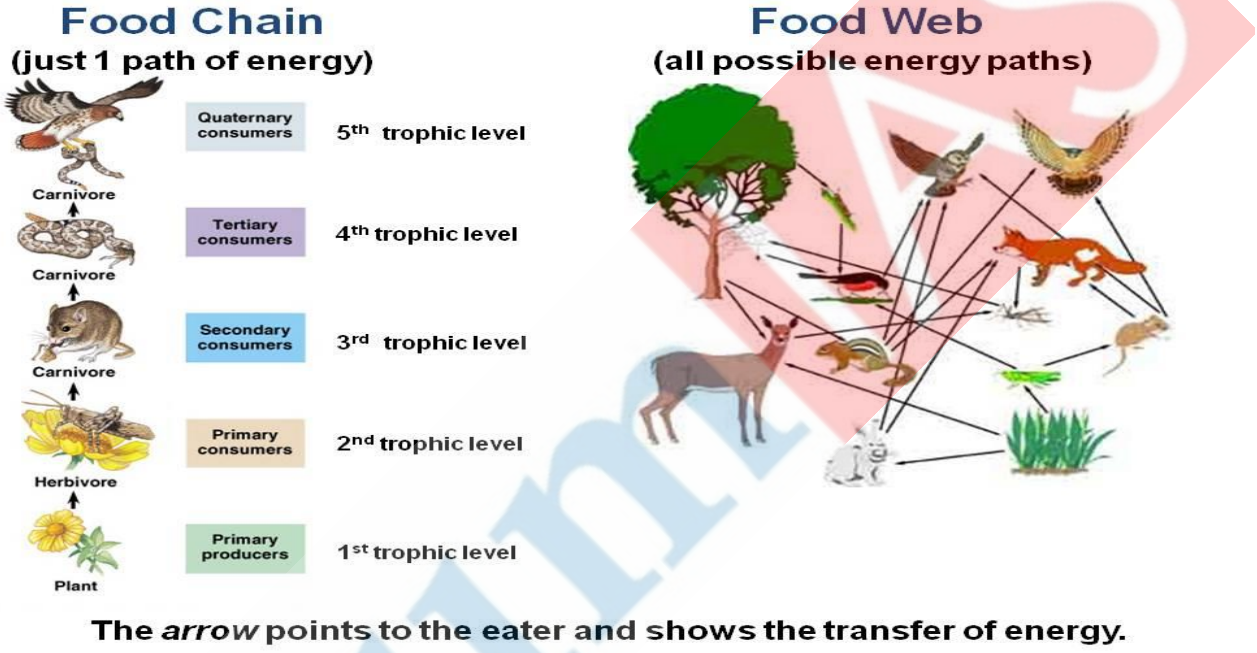


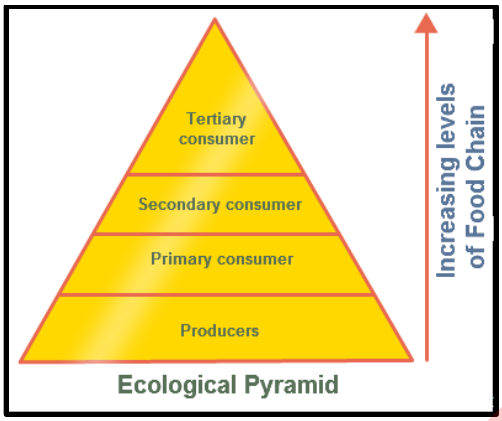
Figure: schematic representation of food web and food chain.

3.3 Ecological Pyramids:

- It is a **graphic representation of the relationship between organisms at various trophic levels** in a food chain.
- depicts the **number of organisms, biomass and productivity** at each trophic level.
- Basis of an ecological pyramid is = biomass, energy, and number.
- Concept of ecological pyramids = first introduced by Charles Elton, the pioneer British Ecologist.

Features:

- The **bottom of an ecological pyramid is the broadest** and is **occupied by the Producers**, which form the **first trophic level**.
- In a food chain, the producers are consumed by the primary consumers. In an ecological pyramid, the **next level is occupied by the primary consumers**.
- The next level of the pyramid is occupied by the **secondary consumers** and the last, by the **tertiary consumers**.



Types of Ecological Pyramids:

There are 3 types of ecological pyramids:

1. Pyramid of energy
2. Pyramid of numbers
3. Pyramid of biomass

3.3.1 Pyramid of Number:

- It graphically **represents the population (total number of individuals) present at each trophic level**.
- This type of pyramid **can have two different forms** depending on the number of organisms: **upright and inverted.**
    - In an **upright pyramid of number**, the number of organisms generally decreases from the bottom to top. This generally occurs in grassland and pond ecosystems where the **plants** (usually the grasses) occupy the base of the pyramid. The succeeding levels of the pyramid include the consumers.
    - An **inverted pyramid of number** is just the opposite of the former. It is usually observed in tree ecosystems with the trees as the producers and the insects as consumers.
- Issues: Among the three types of ecological pyramids, the **pyramid of number is the least accurate** because **it does not take account the exact number of population** and therefore **cannot completely define the trophic structure in that ecosystem**.

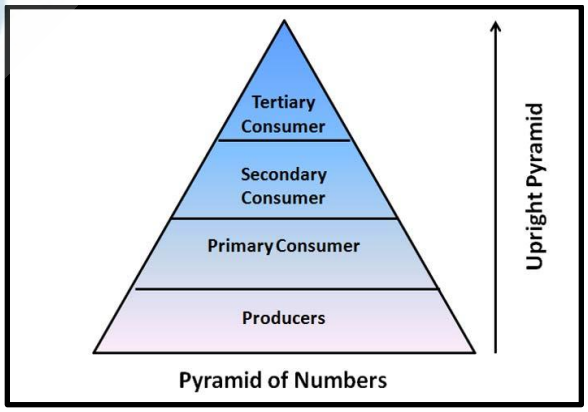


Figure: pyramid of number

3.3.2 Pyramid of Biomass:

- **Biomass** = it refers to the food available for the succeeding trophic level
    - the amount of biomass per unit area product of the living material present in an organism and the total number of organism's present) in a specific trophic level.
- A pyramid of biomass is **a depiction of the amount of food available and how much energy is being passed on at each trophic level**.
- Like the pyramid of numbers, the **pyramid of biomass can either have two forms: upright and inverted**.
- Examples:
    - terrestrial ecosystems = characterized by an upright pyramid of biomass having a larger base (primary producers) with the smaller trophic levels (consumers) located at the top.
    - Aquatic ecosystems = inverted structure of the pyramid; because the phytoplankton producers (with generally smaller biomass) are located at the base while the consumers having larger biomass are located at the top of the pyramid.

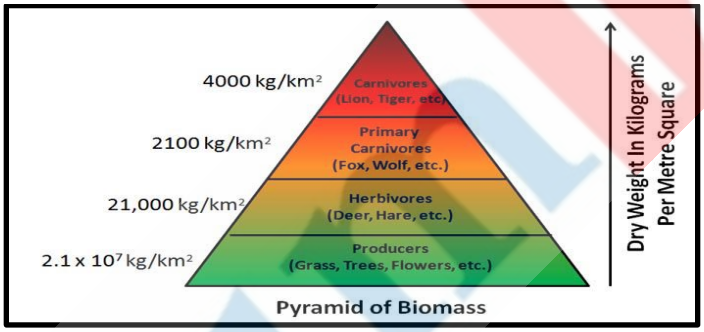


Figure: pyramid of number

3.3.3. Pyramid of Energy (PoE):

- It shows the **overall energy in the ecosystem** and **how much energy is required by organisms as it flows up the higher trophic levels**.
- The pattern of the energy flow in PoE is **based on the principles of thermodynamics** (energy is neither be created nor destroyed; only transformed into another form.)
- PoE shows that **energy is transferred from lower trophic levels with more amount of energy (producers) to higher ones (consumers) and converted in the biomass**.
    - Therefore, it can be concluded that **organisms found at the highest trophic levels of shorter food chains bear a greater amount of energy than the ones found in longer ones.**
- Unlike the first two ecological pyramids, the pyramid of energy is **always illustrated in an upright position**, with the **largest energy carriers at the base**.
- **Significance of PoE:** The idea of PoE is very crucial in the idea of **biological magnification** (tendency of toxic substances to increase in amount as we go up the trophic levels)

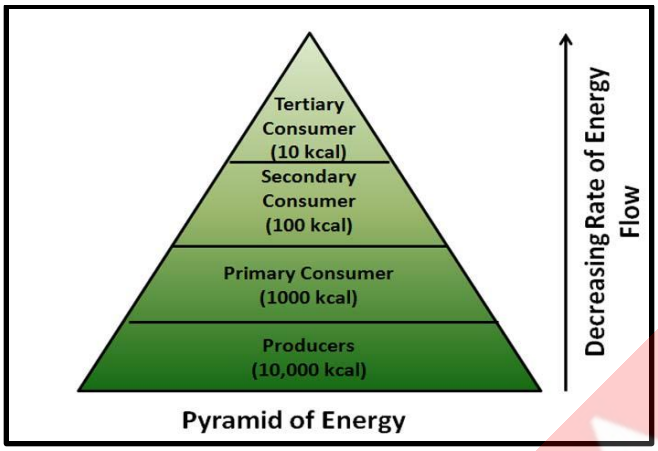


Figure: pyramid of energy

3.3.4 Limitations of Ecological Pyramids:

- These types of pyramids **only are applicable in simple food chains (and not food webs)**, which do not necessarily occur naturally.
- They also **do not consider the possible presence of the same species at different trophic** levels.
- None of the three ecological pyramids provide any idea related to variations in seasons and climates.
- **Other organisms like microorganisms and fungi are not given specific role in the pyramids despite their vital roles in ecosystems**.

4. BIOGEOCHEMICAL CYCLES

- **There is circulation of chemical nutrients like oxygen, carbon, nitrogen, phosphorus, calcium and water, etc. through the physical and biological world**; between atmosphere, hydrosphere, lithosphere and biosphere. These cycles are known as **biogeochemical cycles**.
- These cycles are **natural pathways of circulation of essential elements of life**.
- For the survival of the major ecosystem, it is essential that **all chemical elements make up the living cells must be recycled**.
- As effect of these elements being recycled, in some cycles the elements get accumulated for a long period of time and form reservoirs like ocean or lake.
- Biogeochemical cycles are classed as **in which the reservoirs are** the air or the oceans via evaporation.

Important biogeochemical cycles includes:

- The Carbon cycle,
- The Nitrogen cycle,
- The Oxygen cycle,
- The Phosphorus cycle,
- The Sulfur cycle,
- The Water cycle,
- The Nutrient cycle and

- The Rock cycle.

Gaseous Cycle:

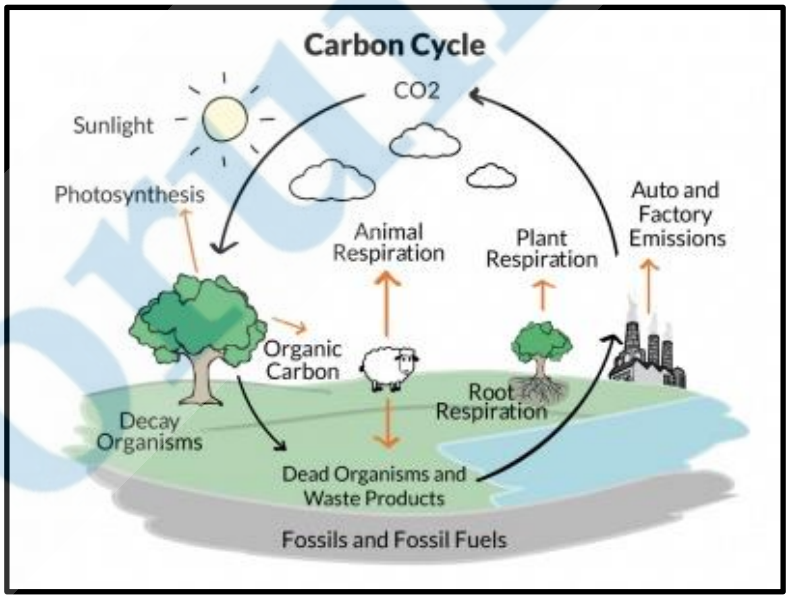
- It includes that of nitrogen, oxygen, carbon and water.
- They move rapidly and adjust more readily to the changes in the biosphere because of the large atmospheric reservoir.
- For example, accumulations of CO2 are scattered by winds or are absorbed by plants.

Sedimentary Cycle:

- Sedimentary cycle **varies from one another, varies from one element to the other, each cycle consists of a solution and a rock or sediment phase**.
- Weathering of rocks releases minerals in the form of salts which dissolve in water and can pass through a series of organisms and can reach deep sea where they settle out of circulation indefinitely.
- Other salts settle as deposit as sediment and rock in shallow seas.

Carbon Cycle:

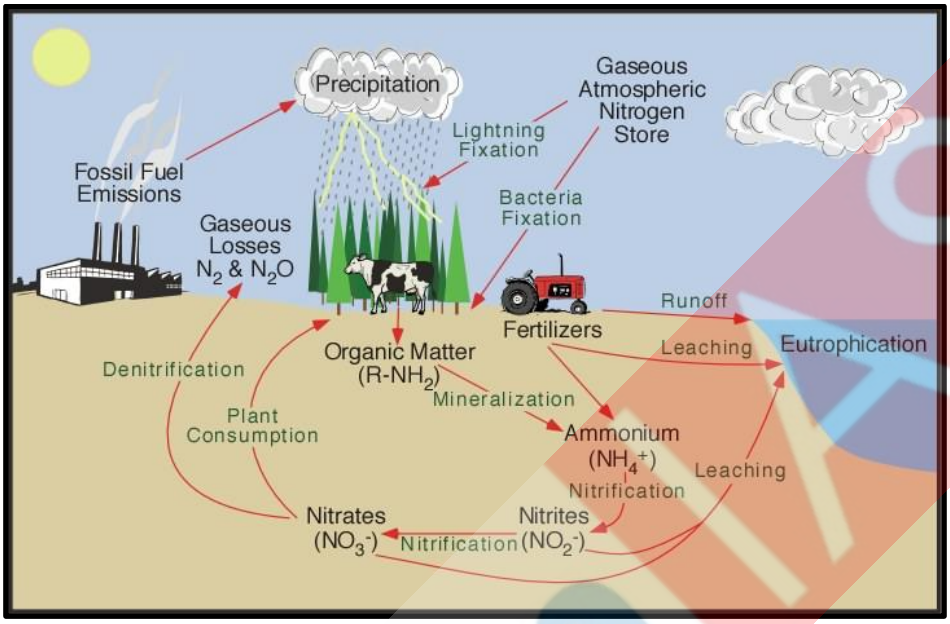
- It is a cycle where there is **exchange of carbon among all the spheres of the ecosystem**.
- It is the **balance of exchange of carbon between carbon reservoirs or between specific spheres; carbon is exchanged among the biosphere, hydrosphere, atmosphere, pedosphere and geosphere** as a result of physical, biological, chemical, and geological processes.



Nitrogen Cycle:

- It is the **transformation between its various chemical forms in both biological and physical processes**.
- Important processes of this cycle is **nitrogen fixation, ammonification, nitrification and denitrification**.

- Atmospheric nitrogen being the largest reservoir of nitrogen is available in limited amounts for biological use.

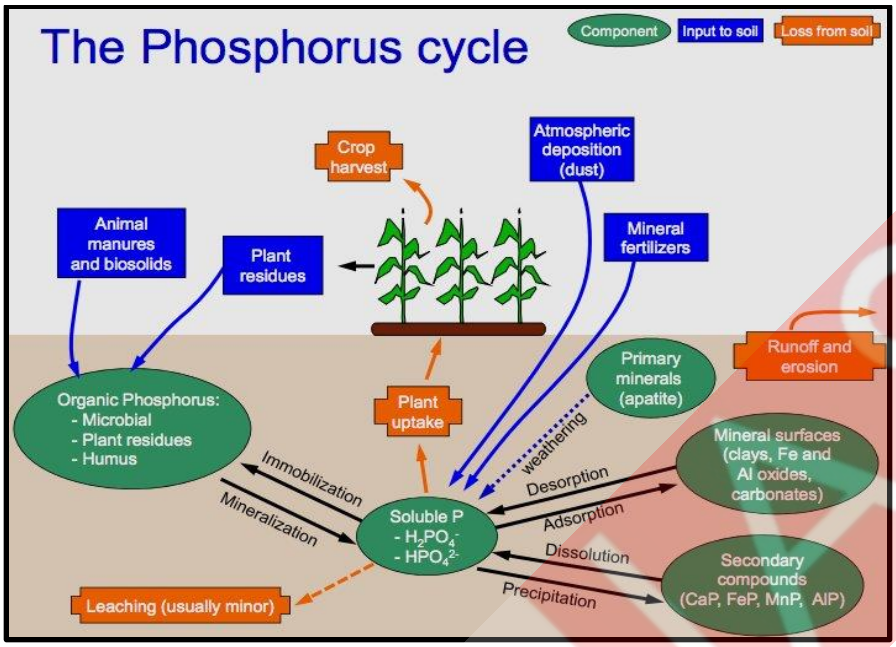


Oxygen Cycle:

- It describes the **movement of oxygen within the atmosphere, biosphere and the lithosphere**.
- Failures of occurence of oxygen cycle in the hydrosphere => Creation of hypoxic zones.
- Photosynthesis = main factor for the oxygen cycle

Phosphorus Cycle:

- It is the **movement of phosphorus through the lithosphere, hydrosphere and biosphere**.
- In this cycle, the atmosphere does not play a significant role as **phosphorus and phosphorus-based compounds are usually solids at the typical range of temperatures of Earth**.
- Phosphorus has gradually become less available to plants as it is slowly lost in runoff.
- Phosphorus is essential for plant growth and microbial biomass.
- Microorganisms of the soil act as sink and source of phosphorus available in the biogeochemical cycle.

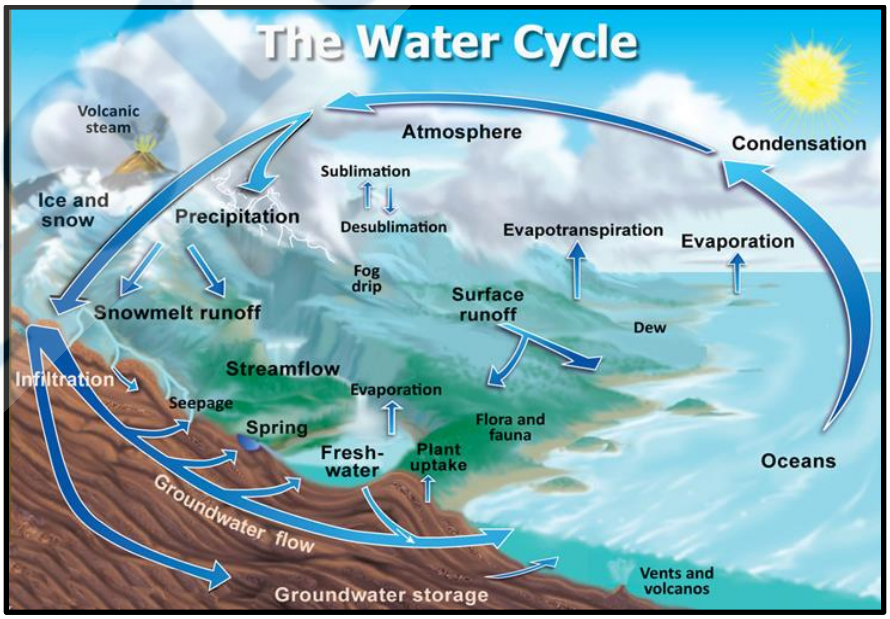


Sulphur Cycle:

- It is the group of processes through which **sulphur moves to and from the mineral, waterways and the living systems**.
- sulphur is constituent of many proteins and cofactors.

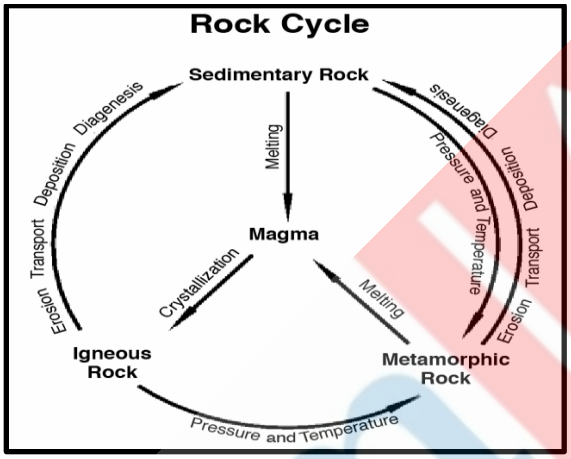
Water Cycle:

- It **describes the continuous movement of water on, above, and below the surface of the Earth**.
- Water moves from one reservoir to another by physical processes of **evaporation, condensation, precipitation, infiltration, runoff and substrate flow**.
- Through these processes water undergoes **different phases like liquid, solid and gas**.



Rock Cycle:

- It **describes the dynamic transitions through geologic time among three main rock types sedimentary, metamorphic and igneous**.
- In this cycle, **each type of rocks is altered or destroyed when it is forced out of equilibrium conditions**.
- Due to the forces of the rock cycle, tectonic plates, and water cycle; the rocks do not remain in equilibrium and are forced to change in their new environments.



Nutrient Cycle:

- The nutrient cycle is the movement and exchange of organic and inorganic matter back into the production of living matter.
- This process is regulated by food web pathways and decomposes matter into mineral nutrients.

5. ECOSYSTEM SERVICES

Economic services are the many benefits which society derives from **nature.** They include fresh water; fertile soil; wild plant resources such as foods, fibres, medicinal plants and the wild relatives of crops; wild pollinators and the natural enemies of crop pests; carbon sequestration from the atmosphere; and the important spiritual, aesthetic and recreational values of nature.

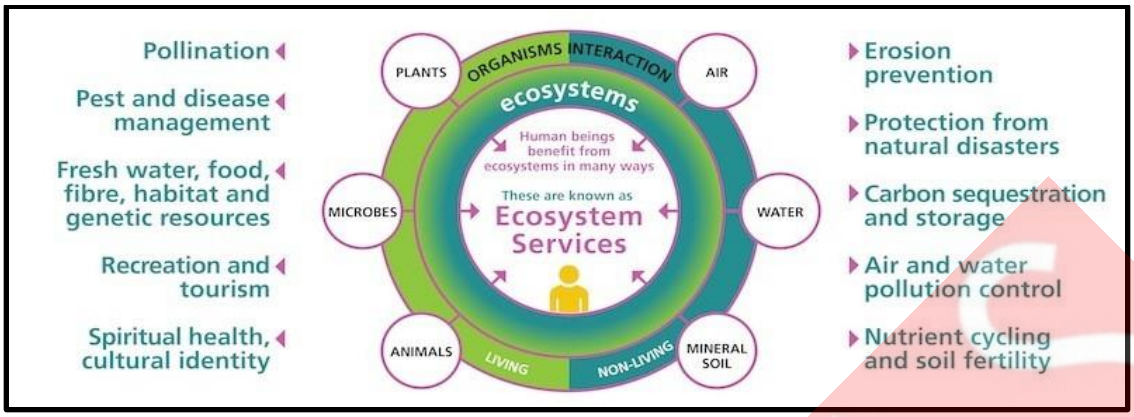
According to TEEB, ecosystem services can be categorized in four main types:

(i) **Provisioning services** are the products obtained from ecosystems such as food, fresh water, wood, fiber, genetic resources and medicines.

(ii) **Regulating services** are defined as the benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control.

(iii) **Habitat services** highlight the importance of ecosystems to provide habitat for migratory species and to maintain the viability of gene-pools.

(iv) **Cultural services** include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreation and aesthetic values.



5.1 Ecosystem goods and services:

Direct Values: These are resources that people depend upon directly and are easy to quantify in economic terms. a. **Consumptive Use Value** – Non-market value of fruit, fodder, firewood, etc. that are used by people who collect them from their surrounds. b. **Productive Use Value** - Commercial value of timber, fish, medicinal plants, etc. that people collect for sale.	**Indirect Values:** These are uses that do not have easy ways to quantify them in terms of a clearly definable price. a. **Non-consumptive use value** - scientific research, bird-watching, ecotourism, etc. b. **Option value** - maintaining options for the future, so that by preserving them one could reap economic benefits in the future. c. **Existence value** - ethical and emotional aspects of the existence of wildlife and nature

Examples of ecosystem services:

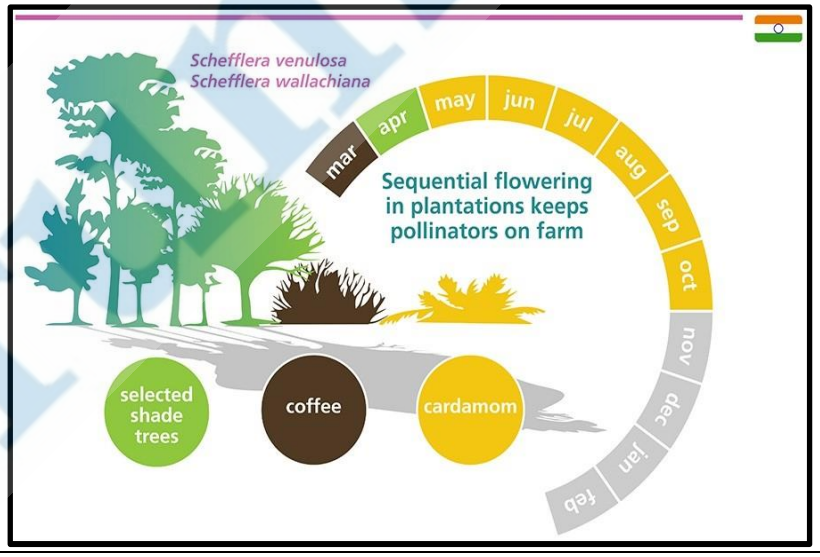
- **Climate regulation** - ecosystems play a vital role in climate regulation. Peat soils contain the largest single store of carbon and in boreal and cool temperate zones. However, the climate regulating function of peatlands depends on land use and intensification (such as drainage and conversion to agriculture)
- and is likely to have profound impacts on the soil capacity to store carbon and on carbon emissions (great quantities of carbon are being emitted from drained peatlands).
- **Water purification**. Both vegetation and soil organisms have profound impacts on water movements: vegetation is a major factor in controlling floods, water flows and quality; vegetation cover in upstream watersheds can affect quantity, quality and variability of water supply; soil micro-organisms are important in water purification; and soil invertebrates influence soil structure, decreasing surface runoff. Forests, wetlands and protected areas with dedicated management actions often provide clean water at a much lower cost than man-made substitutes like water treatment plants.
- **Pests and diseases** are regulated in ecosystems through the actions of predators and parasites as well as by the defence mechanisms of their prey. One example of these regulating services is provided by insectivorous birds in farms that use most of their land for agriculture.
- **Soil biodiversity** supports a range of provisioning services such as food, fiber and fuel provision and is fundamental to soil fertility, being a highly important ecosystem service in India. In addition, a diverse soil community will help prevent loss of crops due to soil-borne pest diseases.
- **Cultural services** provided by ecosystems are also very important to citizens. Evidence can be found in the scale of membership of conservation organizations. E.g. Chipko movement.

5.2 Case Study: Decline in Pollinators:

Context: Across India's agrarian plains, plantations and orchards, millions of birds, bats and insects toil to pollinate crops. However, many of these thousands of species may be in dangerous decline.

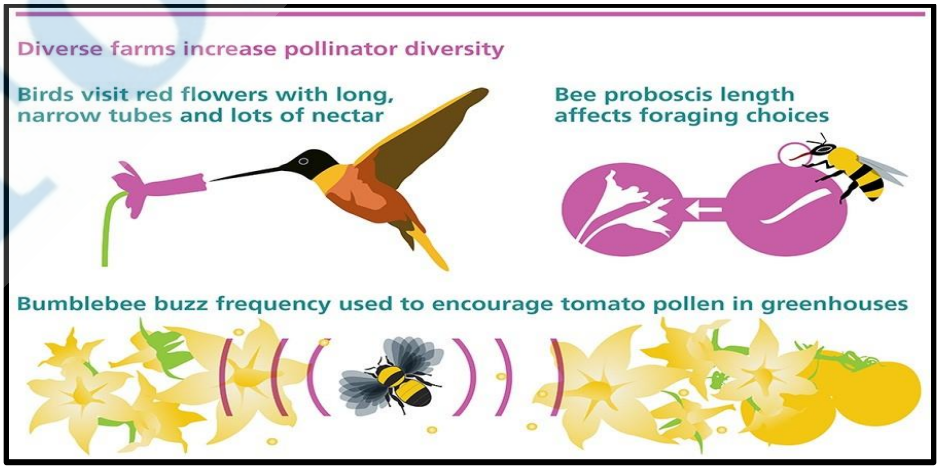
Pollination	• It is the vital process in **flowering plant reproduction** • It involves the **transfer of pollen grains from the anther (or male part) to the *stigma* (or female part) of the same, or another plant of the same species**. • The **fertilised egg cells grow into seeds** which are then spread in the many fruits and vegetables that are eaten. • This **transfer of pollen can be done by the wind, birds, bats, mammals and insects.** Most important of them are the honey bees that pollinate on a huge commercial scale.
Significance of Pollination:	• Pollination is important for the food crops i.e. food security. • It's also vital for the foraging crops, such as field beans and clover, used to feed the livestock. • It **maintains the genetic diversity** of the flowering plants.
Significance of	In 2015, the Intergovernmental Science-Policy Platform on Biodiversity

Pollination for India	and Ecosystem Services (IPBES) found that **pollinators lead to huge agricultural economic gains**. • **Economic gain:** The report estimated pollinator contribution in India to be **$0.831-1.5 billion** annually for just six vegetable crops. • **Crop dependency:** This is an underestimation considering that nearly 70% of tropical crop species are dependent on pollinators for optimal yields. • **Role of Wild pollinators:** The **wild pollinators now are declining**, and their loss will imperil human food supply. Most of our staple food crops (wheat, rice, sorghum, barley and maize etc.) do not require animals for their pollination. However, **wild pollinators play a very important role in the production of crops such as some pulses, sunflower seeds, cardamom, coffee, cashew nuts, oranges, mangoes and apples**. • **Crop yield decreasing**: In the Himalayas, **apple yields in recent years have decreased**. The decreases have been attributed to reduction in the number of bees, but the exact causes of low yields are not known. In North India, **lowering yields of mustard cultivation** may be caused by disappearing pollinators.
Reason behind decline of Pollinators:	**Anthropogenic Activities:** The decline of moths, bees, butterflies, hoverflies and other pollinators is undeniably linked to **A.** **Human activity:** a. **monoculture:** Large tracts of natural habitats have been cleared for monoculture cultivation b. **use of chemicals:** The use of pesticides and fertilisers is pushing out nature's little helpers. Native Indian bees, when exposed to multiple pesticides, suffer from memory and olfactory impairment, lower response rates, and oxidative stress which damages cells. **Case studies:** ■ Between 1964 and 2008, there was a 40-60% growth in relative yields of pollinator-dependent crops, while pollinator-independent crops such as cereals and potatoes saw a corresponding 140% rise in yields. ■ In Kashmir, researchers have pinned lowering yields of apple trees on the declining frequency of bee visits. In north India, lowering yields of mustard cultivation may be caused by disappearing pollinators. • Researchers at the University of Virginia have discovered that **air pollution from automobiles and power plants has been inhibiting the ability of pollinators such as bees and butterflies to find the fragrances**

	of flowers. **B. Natural causes:** • Rapid transfer of parasites and diseases of pollinator species around the world • Changes in seasonal behaviour due to global warming: In 2014, the Intergovernmental Panel on Climate Change reported that **bees, butterflies, and other pollinators faced increased risk of extinction because of global warming due to alterations in the seasonal behaviour of species.** Climate change was causing bees to emerge at different times in the year when flowering plants were not available.
Initiatives taken in India to control decline on Pollinators	• **Shape providing tree**: Selected shade trees were planted on coffee and cardamom farms. The temperature control that these trees provide in April help to keep pollinators on-farm between flowering of coffee in March and the flowering of cardamom, which starts in May. • **I-LTEO**: The Ministry of Environment, Forests and Climate Change has recently **launched a programme to establish a network of Indian Long-Term Ecological Observatories (I-LTEO) to monitor the country's ecosystems**. The I- LTEO network **offers tremendous opportunities to monitor wild pollinators** 
International Initiatives to control decline on Pollinators	• **Pollinator Health Task Force: The** U.S. has established a **Pollinator Health Task Force (PHTS)** and a national strategy that **focuses on increasing the monarch butterfly population and planting native species and flowers** in more than 28,000 sq. km to attract pollinators. • **National Pollinator Strategy**: developed by 23 U.K. • **Coalition of the Willing on Pollinators:** After the IPBES report, almost 20 countries have joined this coalition. • **Pollinators' Initiative by EU.** This can provide pointers to India,

	particularly as a **policy of direct payment support to farmers** to provide buffer strips for pollinators for nectar- and pollen-rich plants.

What needs to be done:	• The IPBES report makes a number of recommendations to restore the integrity of pollinators:
	  ○ improvements in the science of pollination,
	  ○ strong regulations underlying pesticide use, and
	  ○ restoration and protection of habitats for wild pollinators.
	• Promote organic farming
	• Landscape management
	  ○ Adoption of The EU Pollinators' Initiative: a policy of **direct payment support to farmers to provide buffer strips for pollinators for nectar- and pollen-rich plants**.
	  ○ India has millions of hectares of reserve forests, some of which have been converted to pulpwood plantations.
	• There is an urgent need for **monitoring wild pollinators**, and for **strengthening the governance of natural assets**.
	• **Pollinators in urban areas can service and enhance food production in peri-urban areas. Wild biodiversity, including pollinators, must become a significant component of future 'smart cities'**.
	• The IPBES assessment serves notice to government agencies that they must **rethink conventional sectoral approaches and narrow disciplinary perspectives**.
	• Pollinators have different tastes, physiologies, and are active at different times of the year. Birds typically visit red flowers with long, narrow tubes and lots of nectar, while bee proboscis length affects the type of foraging, they can do. Accounting for these differences by **diversifying crops** not only lead to increased agricultural yields: birds can act as natural pest control; bees produce honey; and the buzz frequency of bumblebees actually encourages tomato pollination.



- In general, for the country as a whole, **we have a very poor knowledge of the pollination systems of our animal pollinated crops, and how best we can manage the pollinators for optimal yields.** How are our wild and managed pollinators responding to ongoing loss and fragmentation of natural habitats? What are the effects of widespread pesticide use? Is climate change implicated in the spread of new diseases among honeybee colonies? We need ample research on these.

6. FOREST ECOSYSTEM

Forests are **formed by a community of plants** which is predominantly structurally defined by its trees, shrubs, climbers and ground cover. The forest ecosystem has two parts:

- The **non-living or abiotic aspects of the forest**: The type of forest depends upon the abiotic conditions at the site. Forests on mountains and hills differ from those along river valleys. Vegetation is specific to the amount of rainfall, the local temperature which varies according to latitude and altitude and the type of soil.
- The **living or the biotic aspects of the forest**: The plants and animals form communities that are specific to each forest type. The biotic component includes both the large (macrophytes) and the microscopic plants and animals.
    1. Plants include the trees, shrubs, climbers, grasses, and herbs in the forest. These include species that flower (angiosperms), and non-flowering species (gymnosperms) such as ferns, bryophytes, fungi and algae.
    2. The animals include species of mammals, birds, reptiles, amphibians, fish, insects and other invertebrates and a variety of microscopic animals.

6.1 Forest types in India:

- Forests in India can be broadly divided into **Coniferous forests** and **Broadleaved forests**.
- They can also be classified according to the nature of their tree species – **evergreen, deciduous, xerophytic or thorn trees, mangroves**, etc.
- They can also be classified according to the most abundant species of trees such as **Sal or Teak forests**.

Coniferous forests grow in the Himalayan mountain region, where the temperatures are low.
These forests have tall stately trees with **needle like leaves** and **downward sloping branches** so that the snow can slip off the branches. They have **cones instead of seeds** and are called **gymnosperms**.
Broadleaved forests have several types, such as evergreen forests, deciduous forests, thorn forests, and mangrove forests. Broadleaved forests have **large leaves of various shapes**.

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.

6.2 What more need to be done for Conservation of forest ecosystems:

- **Controlled Deforestation:** While deforestation cannot be avoided completely, we must look to control it.
    - Young and immature trees should not be felled as far as possible.
    - avoid large-scale commercial deforestation
    - Adapting practices such as **clear-cutting or selective cutting**
- **Protect against Forest Fires:** Precautions must be taken.
    - Some of the fire suppression techniques are to **develop three-metre-wide five lanes around the periphery of the fire**, back fires, **arrangement of water spray, fire retardant chemicals** should be sprayed from back tank and if possible by helicopters.
    - **clearing out dry leaves and trees**
    - There must be a trained staff of firefighters to control the fire.
- **Reforestation and Afforestation:** any forested land which has been destroyed by fire or mining activities should be reforested. In rugged terrain **aerial seeding** is the method of choice.
    - Besides all this, fresh afforestation programmes should be started. **New plantations will not only increase the forest cover but also help in making up the eco-balance**.
    - For afforestation, **selection of trees should be done according to local geographical conditions**
- **Better Farming Practices:** Control Slash and burn farming, overgrazing by cattle, shifting agriculture
- 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.
- **Check over Forest Clearance for Agricultural and Flabitation Purposes:**

- Most of the present-day agricultural land was once forested and then cleared for the use of agriculture. But now it has reached the stage where further clearance will be dangerous for the entire ecosystem.
- For the conservation of forest, this should be checked and an **alternative system should be suggested** to them.
- Similarly, for the development of villages, towns and cities, forest lands have been cleared and this process continues to this day causing loss of forest cover. This also should be checked and **green belts around cities should be developed**.

- **Protect from forest disease:** There are several forest diseases resulting from parasitic fungi, rusts, mistletoes, viruses and nematodes which cause the destruction of trees. The forests should be protected either by use of chemical spray, antibiotics or by development of disease resistant strains of trees.

7. GRASSLAND ECOSYSTEM

Characteristics of ecosystem

Grasslands are highly dynamic ecosystems that include **vegetation that is mainly dominated by grass or grass-like plants**.

- These can be **in the form of natural and semi-natural pastures, woodlands, scrub and steppe formations** (Intermediate areas between forests and deserts made up of small grasses).
- The UNESCO defines grassland as "land covered with herbaceous plants with less than 10 percent tree and shrub cover" and "wooded grassland as 10-40 percent tree and shrub cover".

Formation of Grasslands	• Grasslands cover areas **where rainfall is usually low** and/or the **soil depth and quality is poor**. • The **low rainfall prevents the growth of a large number of trees and shrubs**, but is **sufficient to support the growth of grass cover during the monsoon**. • Low rainfall can also trigger droughts and fires that prevent the development of dense forests but grasses can survive fires and heat and their stems can grow again from where they have been burnt off.
Seasonal events in Grassland Ecosystem	• Many of the grasses and other small herbs become dry and the part above the ground dies during the summer months. • In the next monsoon the grass cover grows back from the rootstock and the seeds of the previous year. This change gives grasslands a highly seasonal appearance with periods of increased growth followed by a dormant phase.
Evolution in Grassland Ecosystem	• A variety of grasses, herbs, and several species of insects, birds and mammals have evolved so that they are adapted to these wide-open grass covered areas. • These animals are **able to live in conditions where food is plentiful after the rains**, so that they can **store this as fat that they use during the dry period** when there is very little to eat. • Man began to use these grasslands as pastures to feed his livestock when he began to domesticate animals and became a pastoralist in ancient times.

Grasslands of the World	• Grasslands **cover about 2/3rd of the landmass of the world** and **makeup about one-fourth of the earth's surface**. Grasslands contain diverse types of grasses numbering to over 10,000 and about 12,000 species of legumes that often grow with grasses. • Grasslands are usually divided into two categories— 1. **Tropical** (grasslands located near the equator such as those in Africa, southern Asia, Australia and northern South America) and 2. **Temperate** (grasslands located between the equator and the poles including those in North America, Europe, southern South America, Africa and Australia). • Some of the typical grasslands found in the world include prairies, savannas, veldts, steppes, llanos, campos, downs, meadows, moors, pamir, pampas, pantanals, patanas, punas, pusztas, and sahel.
Grassland Types in India	• Grasslands **occupy nearly 24 percent of the geographical area in India**. • According to Rawat and Adhikari (2015), the **major types of grasslands in India are** ○ **the alpine moist meadows of the Greater Himalayas**; ○ alpine arid pastures or steppe formations of the trans Himalayas; ○ hillside grasslands in the mid-elevation ranges of the Himalayas; ○ 'Chaurs' of the Himalayan foothills; 'Terai' grasslands on the Gangetic and the Brahmaputra floodplains; ○ 'Phumdis' or floating grasslands of Manipur; ○ 'Banni' and 'Vidis' of Gujarat; savannas of western and peninsular India; ○ plateau and valley grasslands in the Satpuras and Maikal hills; ○ dry grasslands of the Andhra Pradesh and Tamil Nadu plains and ○ 'Shola' grasslands of the Western Ghats.
Significance of Grasslands	• Grasslands provide vital ecosystem services such as **water and climate regulation that support agriculture, biogeochemical cycling, carbon storage, cultural and recreational services**. • Grasslands are **important reservoirs of the crop gene pool** and **many of the crops like wheat, corn, rice and millets that support human survival have originated from grasslands**. • Grasslands also **serve as a critical habitat for a range of plants and animals**. • **Significance for the rural economy?** ○ In India grazing-based livestock husbandry plays an important role in the rural economy. ○ Pasturelands over an area of 12 Mha constitute the main grazing resources that are available. ○ Nearly 30 pastoral communities in hilly or arid/semi-arid regions in the northern and western parts of India, as well as 20 in temperate/hilly regions, depend on grazing-based livestock production.

Threats faced by Grasslands in India	Grassland ecosystems continue to be **one of the most neglected ecosystems in the country** and are **increasingly under threat of being exploited and destroyed for economic gains** or being treated as wastelands. **Anthropogenic causes:** ● Many natural grasslands like wet grasslands of Terai and Shola grasslands of the Western Ghats, dry grasslands of Deccan are **being converted to plantations even in Protected Areas (PAs)**. ● Anthropogenic pressures, **land-filling, overgrazing, habitat destruction or fragmentation, uncontrolled growth of invasive species** and **climate change** are further increasing the threat to grasslands. ● **Overutilization** and **changes in land use of the 'common grazing lands' of rural communities** has lead to their degradation. ● **conversion of grasslands into irrigated farmlands**. ○ **Case study:** 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**. **Natural causes:** ● **Forest Fires:** When fires are lit in the grasslands in summer, the burnt grass gets a fresh flush of small green shoots which the domestic animals graze on. If this is done too frequently the grasslands begin to deteriorate. Finally, grasslands become bare, the soil is solidly compacted by trampling, or is washed away during the monsoon by rain and whipped into dust storms during the hot dry summer. The land is degraded, as there is no grass to hold the soil in place. It becomes a wasteland.
Government Initiatives for Regulation and protection of grasslands	● Although grasslands have an important role to play in the rural economy and biodiversity conservation, it is shocking to know that there is **still no policy in place to protect grasslands**. ● The **Task Force Report on Grasslands and Deserts** in 2006 submitted to the Planning Commission of India aptly describes the precarious situation the grasslands are in. It states, "**Grasslands are not managed by the forest department whose interest lies mainly in trees; not by the agriculture department who are interested in agriculture crops; nor the veterinary department who are concerned with livestock but not the grass on which the livestock is dependent**. The grasslands are the 'common' lands of the community and are the **responsibility of none**. They are the most productive

	ecosystems in the subcontinent but they belong to all, are controlled by none, and they have no godfathers."

What needs to be done to protect Grassland Ecosystem?	• Grassland as critical habitats was first recognised by the **National Forest Commission** in 2003 and **recommended protection of grasslands to protect wildlife and livestock by developing a centrally coordinated and funded scheme**.
	• The need for a policy on grasslands was identified in the **Report of the Task Force on Grasslands and Deserts** submitted in 2006 to the Planning Commission of India. The report had suggested special schemes for the conservation of grasslands and made the following recommendations:
	  ○ Formulate a **National Grazing Policy** to ensure the sustainable use of grasslands and biodiversity conservation.
	  ○ **Modifications in the Environment Impact Assessment (EIA) guidelines** to include grasslands and deserts into ecologically-fragile and environmentally-sensitive areas.
	  ○ Start **Integrated Research and Development Programmes** in the grasslands to understand the impact of climate change and land use practices on grasslands.
	  ○ Include grasslands and desert ecosystems in Protected Area system.
	  ○ Start a separate division or section to look after grasslands issues.
	• Experts feel that a good start would be to update this report and work on its recommendations on an urgent basis.
	• 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 specialised fauna. Planting trees in these areas reduces the natural features of this ecosystem resulting in the destruction of this unique habitat for wildlife.
	• We need to **create an awareness** among people that grasslands are of great value. If we are all concerned about our disappearing grasslands and their wonderful wildlife, the Government will be motivated to protect them.

Location of Grasslands in India:

- Grasslands in India 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.

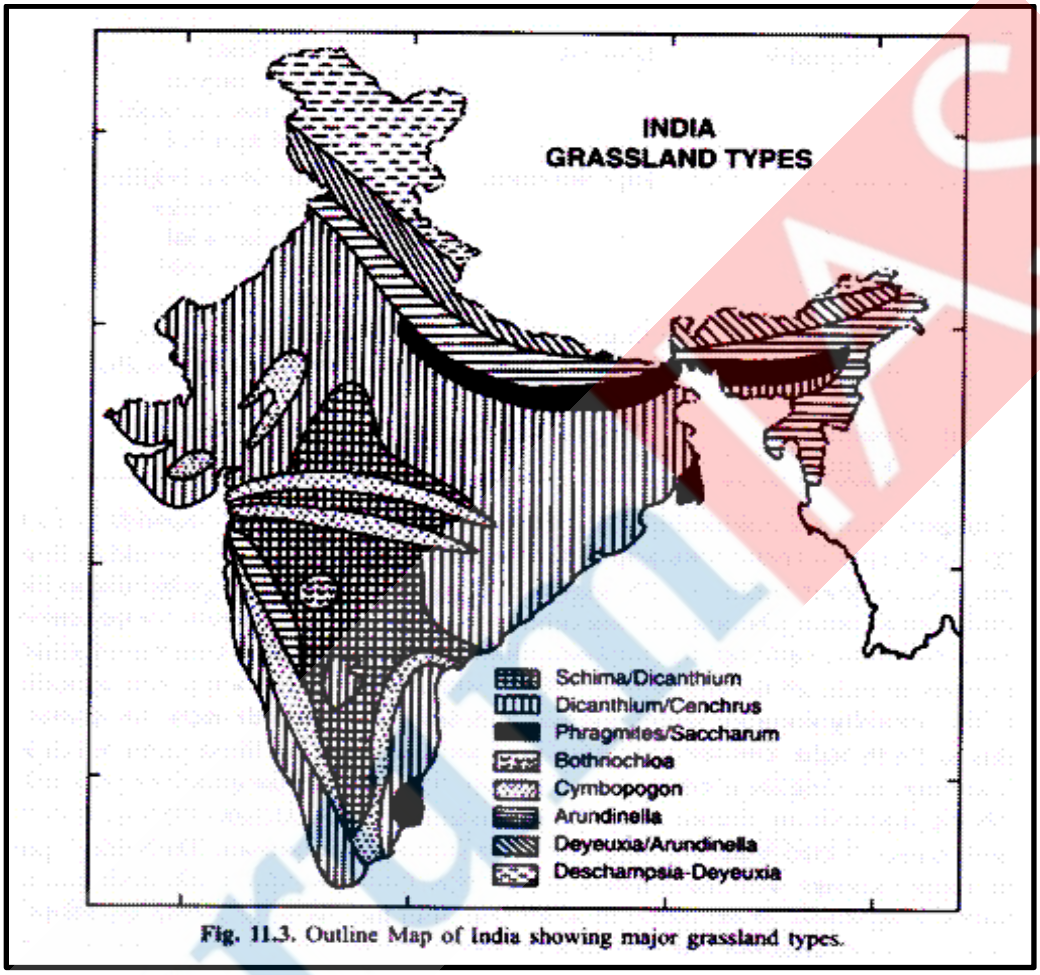


Fig. 11.3. Outline Map of India showing major grassland types.

The grasses are successful invaders and are capable of colonization in various habitats due to their following adaptabilities:

1. They can grow in both hydrophytic and xerophytic habitats
2. Many of the grasses show xeromorphic adaptations
3. Their life span is from annual to perennial
4. Habit varies from trailing to erect
5. Size varies from small to dendroid
6. Meristematic activity both apical and intercalary.
7. Superficial rooting habit
8. High reproductive capacity and capability for both sexual and vegetative reproduction
9. They produce light seeds which are easily and quickly dispersed by wind and animals
10. Grasses can withstand trampling. Grazing and fire
11. Grasses have wide ecological amplitudes

12. Grasses tolerate poor growth conditions
13. They can act as pioneer colonizer in Primary and Secondary successions

8. WETLAND ECOSYSTEM

- A wetland is a place **where the land is covered by water, either salt, fresh or somewhere in between**.
- Wetlands = land area where **soil is saturated with moisture either permanently or seasonally**
- Examples of wetlands: **all lakes and rivers, underground aquifers**, swamps and marshes, wet grasslands, peatland, oases, estuaries, delta at the mouth of a river and tidal flats, **mangroves** and other coastal areas, **coral reefs**, and all **human-made sites such as fish ponds, rice paddies, reservoirs and salt pans**.
- Wetlands are **transition zones between terrestrial and aquatic ecosystems**. Eg.
    - Mangroves,
    - Lake littorals (marginal areas between highest and lowest water level of the lakes)
    - Floodplains (areas lying adjacent to river channels beyond the natural levees and periodically flooded during high discharge in the river) etc.

8.1 Significance/Functions of Wetlands:

- Mitigation effect : they **acts as carbon sinks**.
- **Water Filtration:** Wetlands aid in water filtration by removing excess nutrients, slowing the water allowing particulates to settle out of the water which can then be absorbed into plant roots.
    - Studies have shown that **up to 92% of phosphorus and 95% of nitrogen can be removed from passing water through a wetland**.
    - Wetlands also **let pollutants settle and stick to soil particles**, up to 70% of sediments in runoff.
    - **Some wetland plants have even been found with accumulations of heavy metals** more than 100,000 times that of the surrounding waters' concentration.
    - Wetlands can even **filter out and absorb harmful bacteria from the water. Their complex food chain hosts various microbes and bacteria, which invertebrates feed on. These invertebrates can filter up to 90% of bacteria out of the water this way**.
- **Water Storage:** Wetlands **can store approximately 1-1.5 million gallons of floodwater per acre**.
    - By storing and slowing water, wetlands **allow groundwater to be recharged**.
    - And combining the ability of wetlands to **store and slow down water with their ability to filter out sediments**, wetlands **serve as strong erosion buffers**.
- **Biological Productivity**
    - Through wetlands ability to absorb nutrients, they are able to be **highly biologically productive (able to produce biomass quickly)**.
    - Freshwater wetlands are even comparable to tropical rainforests in plant productivity. Their ability to efficiently create biomass may become important to the **development of alternative energy sources**.

- **Wetland as habitat**
    - Wetlands **support a vast and intricate food web** the wetlands are important wildlife habitats. Many species are dependent upon wetlands.
    - They often **support high concentrations of animals**—including mammals, birds, fish and invertebrates—and **serve as nurseries for many of these species**.

Significance for Human:

- Without wetlands, cities have to spend more money to treat water for their citizens, floods are more devastating to nearby communities, storm surges from hurricanes can penetrate farther inland, animals are displaced or die out, and food supplies are disrupted, along with livelihoods.

8.2 Functions, Related Effects of Functions, Corresponding Societal Values, and Relevant Indicators of Functions for Wetlands

Hydrologic Function	***Effects***	***Societal Value***	***Indicator***
Short-term surface water storage	Reduced downstream flood peaks	Reduced damage from floodwaters	Presence of floodplain along river corridor
Long-term surface water storage	Maintenance of base flows, seasonal flow distribution	Maintenance of fish habitat during dry periods	Topographic relief on floodplain
Maintenance of high-water table	Maintenance of hydrophytic community	Maintenance of biodiversity	Presence of hydrophytes

Biogeochemical Function	***Effects***	***Societal Value***	***Indicator***
Transformation, cycling of elements	Maintenance of nutrient stocks within wetland	Wood production	Tree growth
Retention, removal of dissolved substances	Reduced transport of nutrients downstream	Maintenance of water quality	Nutrient outflow lower than inflow
Accumulation of peat	Retention of nutrients, metals, other substances	Maintenance of water quality	Increase in depth of peat
Accumulation of inorganic sediments	Retention of sediments, some nutrients	Maintenance of water quality	Increase in depth of sediment

Habitat and Food Web Support Function	*Effects*	*Societal Value*	*Indicator*
Maintenance of characteristic plant communities	Food, nesting, cover for animals	Support for furbearers, waterfowl	Mature wetland vegetation
Maintenance of characteristic energy flow	Support for populations of vertebrates	Maintenance of biodiversity	High diversity of vertebrates

8.3 Threats faced by Wetlands:

Anthropogenic causes

a. **Pollutants:** Excessive wastes (Industrial effluents, domestic waste, agricultural runoff etc.) are dumped into wetlands beyond the recycling capacity.
b. **Reservoirs:** Dams alter the natural flow of water and impact on existing ecosystems.
c. **Farming:** Conversion of wetlands for agriculture
d. **Illegal practices: Encroachment** by public and mafia.
e. **Overfishing and fish farming** (Aquaculture).
f. Overgrazing in marshy soils.
g. Removal of sand from beds near seas makes the wetland vulnerable to wave action and tidal bore.

Natural causes:

a. **Climate change:** Increases in temperature are causing polar ice to melt and sea levels to rise. This in turn is leading to
b. **Rising water level:** Shallow wetlands being swamped and some species of mangrove trees being submerged and drowned.
c. **Drought:** wetlands - estuaries, floodplains, and marshes - are being destroyed through drought.
d. erosion and inundation from sea level rise and storms.
e. Estuarine wetlands typically protect the coastline from erosion and flooding, but if sea level increases and development prevent inland migration of wetlands, more wetlands will be converted to open water.

8.4 Government Initiatives to Protect Wetlands:

National Wetland Conservation Programme (NWCP)

- Under the programme 115 wetlands have been identified till now by the Ministry which requires urgent conservation and management initiatives.
- **Aim of the Scheme:** Conservation and wise use of wetlands in the country so as to prevent their further degradation.
- **Objectives of the Scheme**
    - to lay down policy guidelines for conservation and management of wetlands in the country;
    - to undertake intensive conservation measures in priority wetlands;
    - to monitor implementation of the programme; and
    - to prepare an inventory of Indian wetlands.

- **Conservation and management of wetlands is primarily vested with the State/UTs**, who are in physical possession of the area.
- After **identification of wetlands under the Scheme**, the **State/UTs are to submit long-term comprehensive Management Action Plans (MAPs) for a period of 3-5 years**, preferably 5 years, coinciding with the Plan period.
- The State Governments are advised to **define objectives taking into consideration factors responsible for degradation of the wetland**.
- The MAP should also have short-term objectives to cater to immediate problems confronting wetlands and to go in for immediate rectification measures.
- Under the Scheme, Ministry also **sponsor multidisciplinary research projects by academic/ managerial/ research institutions** on various aspects of wetland conservation to supplement execution of MAP in more realistic manner.

Ramsar Convention on Wetland:

- The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is **an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources**.
- There are presently 158 Contracting Parties to the Convention, with 1758 wetland sites, totaling 161 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance.
- Ramsar Convention is **the only global environment treaty dealing with a particular ecosystem**.
- In addition, **many wetlands are international systems lying across the boundaries of two or more countries**, or are part of river basins that include more than one country.
- Major obligations of countries which are party to the Convention are:
    - Designate wetlands for inclusion in the **List of Wetlands of International Importance**.
    - Promote, as far as possible, **the wise use of wetlands in their territory**.
    - Promote **international cooperation** especially with regard to transboundary wetlands, shared water systems, and shared species.
    - Create **wetland reserves**.

Montreux Record:

- Montreux Record under the Convention is **a register of wetland sites on the List of Wetlands of International Importance where changes in ecological character have occurred, are occurring, or are likely to occur as a result of technological developments, pollution or other human interference**.
- It is **maintained as part of the Ramsar List**.
- The Montreux Record is **employed to identify priority sites for positive national and international conservation attention**.
- **Sites may be added to and removed** from the Record **only with the approval of the Contracting Parties in which they lie**.

Wetlands (Conservation and Management) Rules, 2017:

Notified by Ministry of Environment, Forests and Climate Change

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Salient Features:

- Scope: The rules apply to:
  - wetlands categorised as "wetlands of international importance" under the Ramsar Convention.
  - wetlands as notified by the central and state governments and UT administration.
- Fact: There are at least 115 wetlands that are officially identified by the central government and of those 26 are identified as wetlands of international importance under Ramsar Convention which is an international intergovernmental treaty for conservation of wetlands.
- **Definition of wetland** : Wetlands are defined as an area of marsh, fen, peatland or water.
  - It could be natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt.
  - It includes areas of marine water the depth of which at low tide does not exceed six metres.
- **State Wetlands Authority (SWA):** The new rules stipulate **setting up of a State Wetlands Authority in each State and union territories** that will be **headed by the State's environment minister** and **include a range of government officials**.
  - They will also include one expert each in the fields of wetland ecology, hydrology, fisheries, landscape planning and socioeconomics to be nominated by the state government.
  - These authorities will need to
    - **develop a comprehensive list of activities to be regulated and permitted within the notified wetlands and their zone of influence, recommend additional prohibited activities for specific wetlands,**
    - define strategies for conservation and wise use of wetlands, and
    - undertake measures for enhancing awareness within stakeholders and local communities on values and functions of wetlands.
    - Wise use is defined as the principle of sustainable uses that is compatible with conservation.
- It is up to the states to decide which wetlands are to be notified.
- Under the new rules, the **powers have been given to the State governments so that protection and conservation work can be done at the local level**. Central government has mainly retained powers regarding monitoring.

- **National Wetlands Committee (NWC):**
  - The rules stipulates for setting up of NWC, headed by MoEFCC Secretary, **to monitor implementation of these rules and oversee work carried out by States**.
  - NCW will also advise Central Government on appropriate policies and action programmes for conservation and wise use of wetlands, recommend designation of wetlands of international importance under Ramsar Convention, advise on collaboration with international agencies on issues related to wetlands etc.
- **Digital inventory of all wetlands:** It is mandatory for **state authorities to prepare list of all wetlands and list of wetlands** to be notified within six months.
  - Based on it, a comprehensive digital inventory of all wetlands will be created and will be updated every ten years.

- **Restrictions:**
    - The rules **prohibit activities like conversion of wetland for non-wetland uses** including **encroachment of any kind**, **setting up of any industry and expansion of existing industries**, **manufacture or handling or storage or disposal of hazardous substances** and **construction and demolition waste**, solid waste dumping, discharge of untreated wastes and effluents from industries, cities, towns, villages and other human settlements.

Criticism of the Rules: Environmental experts pointed out that

- **Not comprehensive in the context of definitions:** The 2010 Rules included in the definition of wetlands, all inland waters such as lakes, reservoir, tanks, backwaters, lagoon, creeks, estuaries, etc. It also included man-made wetland and the zone of direct influence on wetlands.
    - However, the **2017 Rules are not as comprehensive** as the 2010 rules.
    - It **does not include**
        - **river channels, paddy fields, human-made water bodies/tanks specifically for drinking water purposes, aquaculture, salt production, recreation and irrigation purposes**.
        - wetlands under forest and coastal regulation zones.
- Provisions like "central government may consider proposals from the state government or union territory administration for **omitting any of the (prohibited) activities on the recommendation of the authority**" in the new rules can be misused.
- The **term 'wise use' is subjective and could dilute the earlier restrictions**.
- There is **no timeline specified for phasing out solid waste and untreated waste from being dumped into wetlands**.
- The restrictions on "any other activity likely to have an adverse impact on the ecosystem of the wetland" are not specified clearly in the Rules.
- As per the 2010 version of the rules, there was a Central Wetlands Regulatory Authority (CWRA) which will now be replaced by a national committee.
- Another major objection is about the **process of appeal against the decisions of wetland authorities**. According to the 2010 rules, anyone aggrieved with the CWRA's decisions could have filed an appeal with the National Green Tribunal, but the **new 2017 rules are silent on the appeal process**.
- At the outset, the **identification process by the State Wetland Authority does not distinguish between existing wetlands and especially those past wetlands which have been encroached and can be proved through legal documents**. It also **does not take into account the Jagpal Singh judgment of Justice Katju for restoration of encroached wetlands throughout the country.**

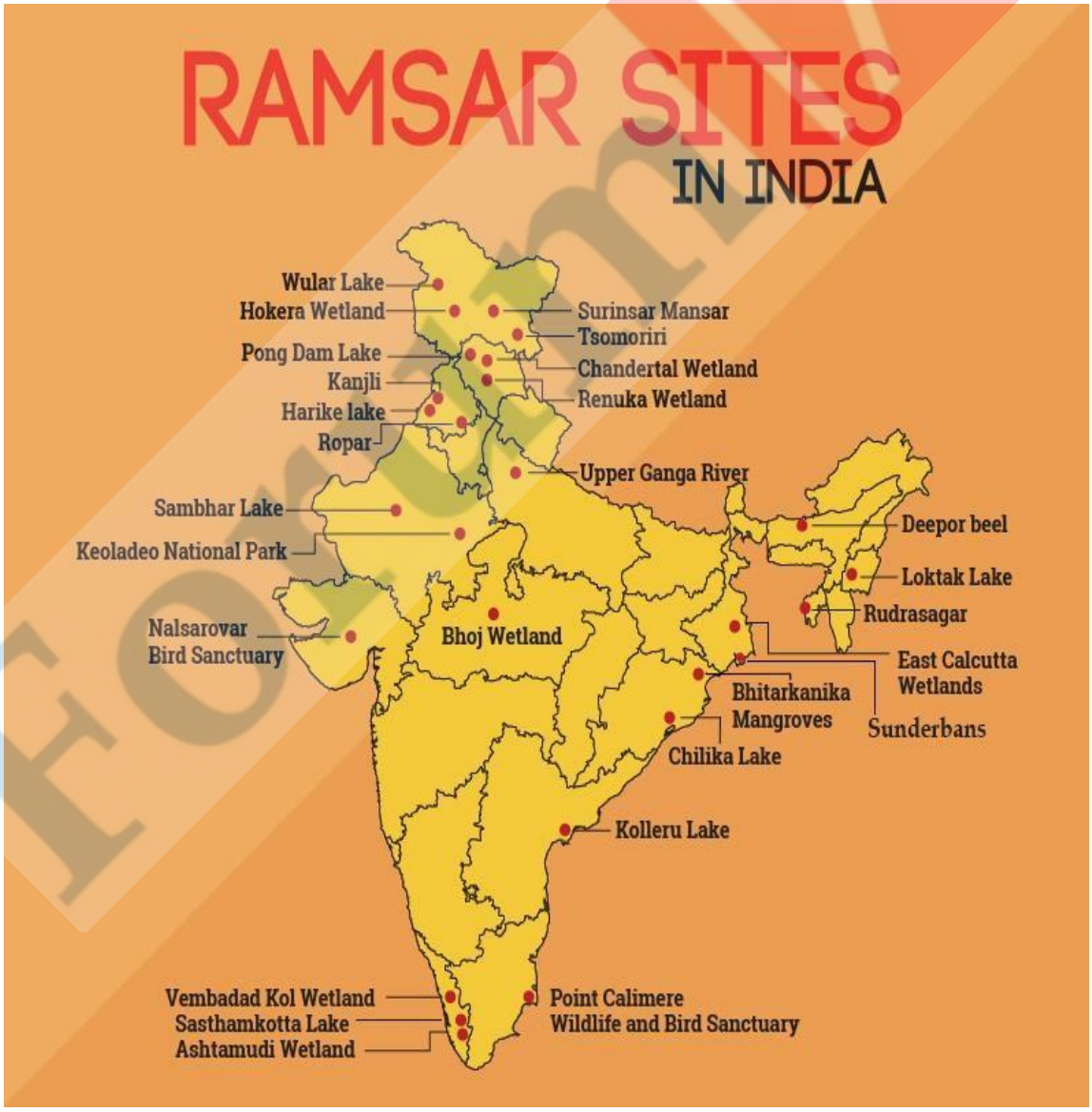
8.5 Wetland Ecosystem and India State of Forest Report (ISFR) 2017

- Forests play a vital role in water conservation and improve the water regime in the area.
- State Forest Departments besides plantation and protection also undertake steps to improve water conservation through different interventions such as building Check dams, vegetation barriers, percolation ponds, contour trenches etc. under various Central & State Government schemes
- As per the latest assessment, water bodies inside forest cover have increased by 2,647 sq. kms during the last decade.

- Maharashtra (432 sq. kms), Gujarat (428 sq. kms), Madhya Pradesh (389 sq. kms) are top three states showing increase in water bodies within forest areas. Overall, almost all the states have shown a positive change in water bodies.

8.6 Steps needed to conserve Wetlands:

- **Demarcation of wetlands** using latest technology
- **Eutrophication abatement :** Processing nutrient rich discharge into the water body.
- **Afforestation, weed control**
- **Preventing invasive species:** stop the introduction of exotic invasive species like water hyacinth
- Treatment of **industrial effluents** and **water from farm lands** before discharging into wetlands.
- Proper enforcement of laws and stringent punishments for violators.
- **Preventing unsustainable aquaculture** and cultivation of shellfish.
- Soil conservation measures + Preventing grazing in peripherals of wetlands.
- Involving local population in the conservation of wetlands.



9. MANGROVE ECOSYSTEM

- Mangroves is a **littoral (near the sea shore) forest ecosystem**.
- These are **mostly evergreen forests** that grow in sheltered low-lying coasts, estuaries, mudflats, tidal creeks backwaters (coastal waters held back on land), marshes and lagoons of tropical and subtropical regions.
- Mangroves are located between the land and sea => they represent the best example of ecotone.

9.1 Features of Mangroves:

- Mangroves are shrubs or small salt tolerant trees (also called **halophytes**) capable of growing in marine intertidal environments; coastal saline or brackish water.
    - They **do not rely on salt water** but are **able to tolerate it**.
    - According to the IUCN, there are 70 species of mangroves, of which 11 are threatened with extinction
- They are adapted to the **low oxygen (anoxic)** conditions of waterlogged mud.
- They produces **pneumatophores (blind roots)** to overcome respiratory problem in the anaerobic soil conditions.
    - **Specialized roots enable mangroves to "breath" and anchor in soft sediments:** Mangrove habitats are **usually very low in oxygen beneath the surface**, especially in the sediments where microbes deplete available oxygen during metabolizing processes.
    - In order to deal with this non-hostile environment, specialized forms of roots have emerged which enable the tree to breathe oxygen from the air, even when the roots are submerged in water.
- **Long- distance floating mangroves seeds that already grow on the trees:** All mangrove species **use the water to disperse their seeds but only some are *viviparous*** meaning **their seeds already grow to seedlings *on* the plant** before being released into the water.
    - Advantage: the fully-grown seedling is ready to anchor itself wherever it gets washed up once it's fallen from its mother tree.
    - The already developed plant is capable of photosynthesising and growing straight away instead of being washed back and forth by the incoming tides.

9.2 Growing Areas:

- Mangroves **grow below the high-water level of spring tides**.
- Mangroves occur worldwide in the tropics and subtropics, mainly between latitudes 25° N and 25° S.
    - Mangroves require high solar radiation to filter saline water through their roots.
- Best locations : **where abundant silt is brought down by rivers** or on the backshore of accreting sandy beaches.

9.3 Mangroves in India:

- As per the ISFR 2017 report, the **total area of mangrove cover of India is 4921 km2**, (181 km2 positively changed with respect to 2015 mangrove cover assessment) which **contributes 3.3% to the global mangrove cover**.
- The deltas of the Ganges, Mahanadi, Krishna, Godavari, and Kaveri rivers contain mangrove forests.

- Backwaters in Kerala have high density of mangrove forest on the shores.
- Indian mangroves consist of 46 species (4 of which are natural hybrids) belonging to 22 genera and 14 families, representing about 57% of the world's mangrove species.
- **Mangroves of Sundarbans** : the largest single block of tidal halophytic mangroves of the world.
    - The major species of this dense mangrove forest include Heritiera fomes, Rhizophora spp., Bruguiera spp., Ceriops decandra, Sonneratia spp. and Avicennia spp..
    - Nypa fruticans are found along the creeks.
    - famous for the Royal Bengal Tiger and crocodiles.
    - Issue faced: Mangrove areas here are being cleared for agricultural use.
- **Bhitarkanika mangroves:** form India's second largest forest, located in the state of Odisha.
    - Bhitarkanika is created by the two river deltas of Brahmani and Baitarani river and one of the important Ramsar Wetland in India.
    - It is also the home of saltwater crocodiles and nesting olive ridley sea turtles.
- **Godavari-Krishna mangroves:** lie in the delta of the Godavari and Krishna rivers in the state of Andhra Pradesh. Mangroves ecoregion is under protection for Calimere Wildlife and Pulicat Lake Bird Sanctuary.
- **Pichavaram mangroves:** hosts the second largest mangrove forests in the world
- **Mumbai mangroves:** has mangroves on its coastline along the west coast of India.
    - These mangroves support a rich diversity of life forms, especially molluscs.
- **Baratang Island mangroves:** are located within the Andaman and Nicobar Islands.
    - The mangrove swamps of Baratang Island are situated between Middle and South Andaman Island.

9.4 Functions of Mangroves:

- Mangroves **enhance and trigger the growth of phytoplankton** (due to the provided nutrients) which in turn supports adjacent fish populations.
- They not only **serve as a source for nutrients**, but also **act as a sink for excess nutrients** and thus play an extremely important ecological role in coastal areas.
    - An intact mangrove forest can substantially impact fishing yields and cleared areas are often followed by a collapse and/or sharp decline in catches
- Mangrove forests are also among the **most carbon-rich habitats on earth.**
    - They play a huge role in *carbon sequestration* (i.e. uptake of carbon from the atmosphere) and can **help counteracting climate change**.
    - **Huge amounts of carbon are stored in the sediments and within the roots and trunks systems of the mangrove trees**.
    - They are thus not only able to **absorb (sequester) CO2 from the atmosphere but also store it away forming a so-called carbon sink**.
- Mangroves provide food, fire wood, shelter and sustainable tourism opportunities to local people.
- As transition zones between land and sea **they clean land-driven wastewaters and sewage by filtering the water and burying many kinds of toxic substances like heavy metals, dioxin-like compounds and other pollutants**.
- **Mangrove roots cause the water to slow down and enhance sedimentation**, which **traps colloidal particles in the fine sediments as well**.

- Generally, the water flow through mangroves forests disperses point sources of e.g. industrial waste water and sewage into vast areas and dampens the negative environmental effect.
- **Natural protection from tsunamis and hurricanes:** Mangrove forests **act as a natural protection in case of storms and decrease erosion on coastal areas**.
    - The huge amount of biomass dissipates the energy of incoming waves and may greatly decrease the impact of hurricanes and tsunamis in coastal areas.
- **Mangroves serve as kindergartens for many species:** The provided habitat enables many species to nurse in the shallow and usually clean waters of mangroves and a large amount of species stays here for a certain period of life to grow while being protected from bigger predators and benefiting from high prey availability.
    - A few examples are shrimps, sharks and reef fish as well as other pelagic predators.

9.5 Threats faced by mangrove forests and their habitats:

Anthropogenic Activities:

- **Clearing:** Mangrove forests have often been **cleared to make room for agricultural land, human settlements and infrastructure (such as harbours), and industrial areas**.
    - clearing for tourist developments, shrimp aquaculture, and salt farms
- **Overharvesting:** Mangrove trees are used for firewood, construction wood, wood chip and pulp production, charcoal production, and animal fodder. Harvesting in some parts of the world it is no longer sustainable, threatening the future of the forests.
- **River changes: Dams and irrigation reduce the amount of water reaching mangrove forests, changing the salinity level of water in the forest**.
    - If salinity becomes too high, the mangroves cannot survive.
    - Freshwater diversions can also lead to mangroves drying out.
    - In addition, increased erosion due to land deforestation can massively increase the amount of sediment in rivers. This can overcome the mangrove forest's filtering ability, leading to the forest being smothered.
- **Overfishing:** The ecological balance of food chains and mangrove fish communities can also be altered.
- **Pollution:** Fertilizers, pesticides, and other toxic man-made chemicals carried by river systems from sources upstream can kill animals living in mangrove forests, while oil pollution can smother mangrove roots and suffocate the trees.

Natural causes:

- **Destruction of coral reefs: Coral reefs provide the first barrier against currents and strong waves**.
    - When they are destroyed, the **stronger-than-normal waves and currents reaching the coast can undermine the fine sediment in which the mangroves grow**.
    - This can prevent seedlings from taking root and wash away nutrients essential for mangrove ecosystems.
- **Climate change:** Mangrove forests require stable sea levels for long-term survival. They are therefore extremely sensitive to current rising sea levels caused by global warming and climate change.

9.6 Government Initiatives to Conserve Mangroves:

- **Wetlands (Conservation and Management) Rules, 2017 (already covered under wetland ecosystems)**
- **National Wetland Conservation Programme (NWCP) (already covered under wetland ecosystems)**
- **Ramsar Convention on Wetland (already covered under wetland ecosystems)**
- **Montreux Record (already covered under wetland ecosystems)**
- **World Wetland Day (already covered under wetland ecosystems)**
- **Mangroves for the Future (MFF)**
    - is a unique multi- country, multi sectoral, partner- led initiative
    - have two objectives:
        - To strengthen the environmental sustainability of coastal development.
        - To promote the investment of funds and effort in coastal ecosystem management for sustainable development.
    - MFF is being coordinated by International Union for Conservation of Nature, IUCN covering, initially, six Tsunami affected countries namely India, Indonesia, Maldives, Seychelles, Sri Lanka and Thailand. India has agreed to participate in the IUCN- MFF Initiative.

9.7 Mangrove Ecosystem and India State of Forest Report (ISFR) 2017:

- As per ISFR 2017, **mangrove forests have increased by 181 sq kms**.
- Maharashtra (82 sq kms), Andhra Pradesh (37 sq kms) and Gujarat (33 sq kms) are the top three gainers in terms of mangrove cover.
- 7 out of the 12 mangrove states have shown an increase in mangrove cover and none of them show any negative change.
- Mangrove ecosystems are rich in biodiversity and provide a number of ecological services. They also play a major role in protecting coastal areas from erosion, tidal storms and tsunamis.

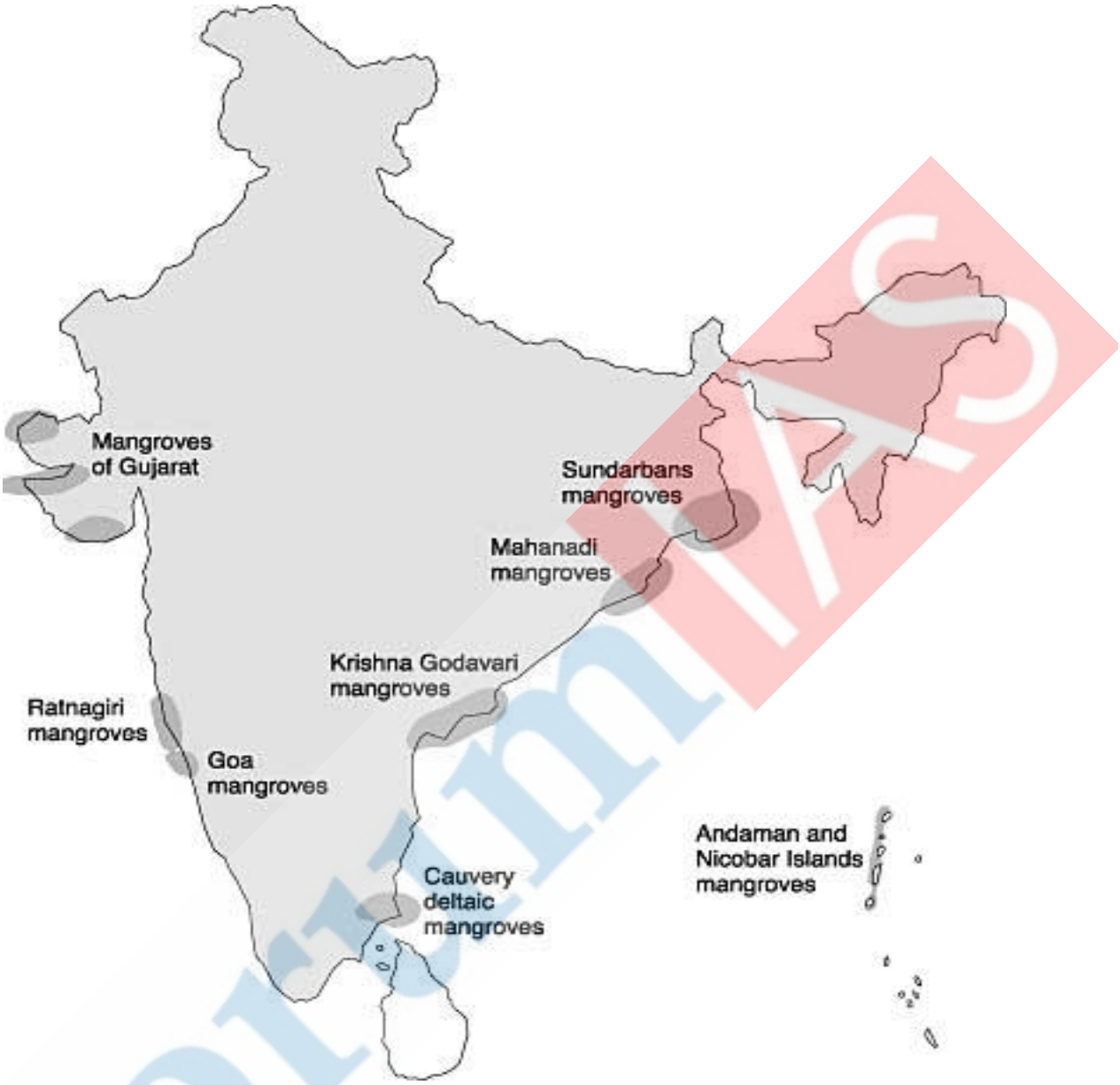


Figure: Mangroves in India