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Class : BSc(H) Mathematics first year
Study material (wednesday: 6th May 2020 EVS Class) Time: 10:40am to 12:40 pm

UNIT 3: **Ecosystems**

CONCEPT OF AN ECOSYSTEM

An 'Ecosystem' is a region with a specific and recognizable landscape form such as forest, grassland, desert, wetland or coastal area. The nature of the ecosystem is based on its geographical features such as hills, mountains, plains, rivers, lakes, coastal areas or islands. It is also controlled by climatic conditions such as the amount of sunlight, the temperature and the rainfall in the region. The geographical, climatic and soil characteristics form its non-living (abiotic) component. These features create conditions that support a community of plants and animals that evolution has produced to live in these specific conditions. The living part of the ecosystem is referred to as its biotic component.

Ecosystems are divided into terrestrial or land based ecosystems, and aquatic ecosystems in water. These form the two major habitat conditions for the Earth's living organisms.

All the living organisms in an area live in communities of plants and animals. They interact with their non-living environment, and with each other at different points in time for a large number of reasons. Life can exist only in a small proportion of the earth's land, water and its atmosphere. At a global level the thin skin of the earth on the land, the sea and the air, forms the biosphere.

At a sub-global level, this is divided into bio geographical realms, eg. Eurasia called the palaeartic 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.

At a national or state level, this forms bio geographic regions. There are several distinctive geographical regions in India- the Himalayas, the Gangetic Plains, the Highlands of Central India, the Western and Eastern Ghats, the semi-arid desert in the West, the Deccan Plateau, the Coastal Belts, and the Andaman and Nicobar Islands. These geographically distinctive areas have plants and animals that have been adapted to live in each of these regions.

At an even more local level, each area has several structurally and functionally identifiable ecosystems such as different types of forests, grasslands, river catchments, mangrove swamps in deltas, seashores, islands, etc. to give only a few examples. Here too each of these forms a habitat for specific plants and animals.

Ecosystems have been formed on land and in the sea by evolution that has created species to live together in a specific region. Thus ecosystems have both non-living and living components that are typical to an area giving it its own special characteristics that are easily observed.

Definition: The living community of plants and animals in any area together with the non-living components of the environment such as soil, air and water, constitute the ecosystem.

Some ecosystems are fairly robust and are less affected by a certain level of human disturbance. Others are highly fragile and are quickly destroyed by human activities. Mountain ecosystems are extremely fragile as degradation of forest cover leads to severe erosion of soil and changes in river courses. Island ecosystems are easily affected by any form of human activity which can lead to the rapid extinction of several of their unique species of plants and animals. Evergreen forests and coral reefs are also examples of species rich fragile ecosystems which must be protected against a variety of human activities that lead to their degradation. River and wetland ecosystems can be seriously affected by pollution and changes in surrounding land use.

Understanding ecosystems

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. Each ecosystem has a set of common features that can be observed in the field:

- ‘What does the ecosystem look like?’

One should be able to describe specific features of the different ecosystems in one's own surroundings. Field observations must be made in both urban and natural surroundings.

- What is its structure?

Is it a forest, a grassland, a water body, an agricultural area, a grazing area, an urban area, an industrial area, etc.?

What you should see are its different characteristics. A forest has layers from the ground to the canopy. A pond has different types of vegetation from the periphery to its center. The vegetation on a mountain changes from its base to its summit.

- What is the composition of its plant and animal species?

List the well-known plants and animals you can see. Document their abundance and numbers in nature: very common, common, uncommon, rare. Wild mammals will not be seen in large numbers, cattle would be common. Some birds are common – which are the most common species? Insect species are very common and most abundant. In fact there are so many that they cannot be easily counted.

- ‘How does the ecosystem work?’

The ecosystem functions through several biogeochemical cycles and energy transfer mechanisms. Observe and document the components of the ecosystem which consists of its non-living or abiotic features such as air, water, climate and soil. Its biotic components, the various plants and animals. Both these aspects of the ecosystem interact with each other through several functional aspects to form Nature's ecosystems. Plants, herbivores and carnivores can be seen to form food chains. All these chains are joined together to form a ‘web of life’ on which man depends. Each of these use energy that comes from the sun and powers the ecosystem.

Ecosystem degradation

Ecosystems are the basis of life itself! The natural ecosystems in the wilderness provide a variety of products and are regions in which a number of vital ecological processes are present, without which human civilization would not be able to exist. Ecosystems are

however frequently disrupted by human actions which lead to the extinction of species of plants and animals that can live only in the different natural ecosystems. Some species if eliminated seriously affect the ecosystem.

These are called 'keystone' species. Extinction occurs due to changes in land use. Forests are deforested for timber, wetlands are drained to create more agricultural land and semi arid grasslands that are used as pastures are changed into irrigated fields. Pollution from industry and waste from urban settings can also lead to extinction of several species. The reason for the depletion of natural resources is twofold – our rapidly exploding population that needs to sustain itself on resources, and the growth of affluent societies, which consume and waste a very large proportion of resources and energy. Increasing extraction of resources is at the cost of natural ecosystems, leading to a derangement of their important functions. Each of us in our daily lives use a variety of resources. If tracked back to their source, one finds that the resources were originally obtained from nature and natural ecosystems. Our insensitivity to using resources carefully has produced societies that nature can no longer sustain. If one thinks before wasting resources such as water, reusing and recycling paper, using less plastics that are non-degradable, culminatively this can have positive implications on the integrity of our natural resource base and conserve the resources that nature provides.

Ecosystems and man: Every region of our earth has different ecosystems based on its climatic conditions and geographical feature. There are terrestrial ecosystems on land and aquatic ecosystems in water.

Resource utilisation

Most traditional societies used their environment sustainably. Though inequality in resource utilization has existed in every society, the number of individuals that used a large proportion of resources was extremely limited. In recent times the proportion of 'rich' people in affluent societies, grew rapidly. Inequality thus became a serious problem. Whereas in the past many resources such as timber and fuel wood from the forest were extracted sustainably, this pattern has drastically changed during the last century. The economically better off sections began to use greater amounts of forest products, while those people who lived in the forest became increasingly poor. Similarly the building of large irrigation projects led to wealth in those areas that had canals, while those who had to remain dependent on a constant supply of water from the river itself, found it difficult to survive.

The key to this issue is the need for an 'equitable' distribution of all types of natural resources. A more even sharing of resources within the community can reduce these pressures on the natural ecosystems.

STRUCTURE AND FUNCTIONS OF AN ECOSYSTEM

Structural aspects

Components that make up the structural aspects of an ecosystem include:

- 1) Inorganic aspects – C, N, CO₂, H₂O.
- 2) Organic compounds – Protein, Carbohydrates, Lipids – link abiotic to biotic aspects.
- 3) Climatic regimes – Temperature, Moisture, Light & Topography.
- 4) Producers – Plants.
- 5) Macro consumers – Phagotrophs – Large animals.
- 6) Micro consumers – Saprotrophs, absorbers – fungi.

Functional aspects

- 1) Energy cycles.
- 2) Food chains.
- 3) Diversity-interlinkages between organisms.
- 4) Nutrient cycles-biogeochemical cycles.
- 5) Evolution.

The non-living components of an ecosystem are the amount of water, the various inorganic substances and organic compounds, and climatic conditions such as rainfall and temperature, which depend on geographical conditions and location which is also related to the amount of sunlight. The living organisms in an ecosystem are inseparable from their habitat.

The living component of plant life ranges from extremely small bacteria, which live in air, water and soil, algae which live in fresh and salt water, to the terrestrial plants which range from grasses and herbs that grow after the monsoon every year, to the giant long-lived trees of the forest. The plants convert energy from sunlight into organic matter for their growth. They thus function as producers in the ecosystem. The living component of the animal world ranges from microscopic animals, to small insects and the larger animals such as fish, amphibia, reptiles, birds and mammals. Man is just one of the 1.8 million species of plants and animals that inhabit the earth.

PRODUCERS, CONSUMERS AND DECOMPOSERS

Every living organism is in some way dependent on other organisms. Plants are food for herbivorous animals which are in turn food for carnivorous animals. Thus there are different trophic levels in the ecosystem. Some organisms such as fungi live only on dead material and inorganic matter



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.

The herbivorous animals are primary consumers as they live on the producers. In a forest, these are the insects, amphibia, reptiles, birds and mammals. The herbivorous animals include for example hare, deer and elephants that live on plant life. They graze on grass or feed on the foliage from trees. In grasslands, there are herbivores such as the blackbuck that feed on grass. In the semiarid areas, there are species such as the chinkara or Indian gazelle. In the sea, there

When human activities alter the balance in these ecosystems, the “perturbation” leads to the disappearance of these uncommon species. When this happens to an endemic species that is not widely distributed, it becomes extinct for all time.

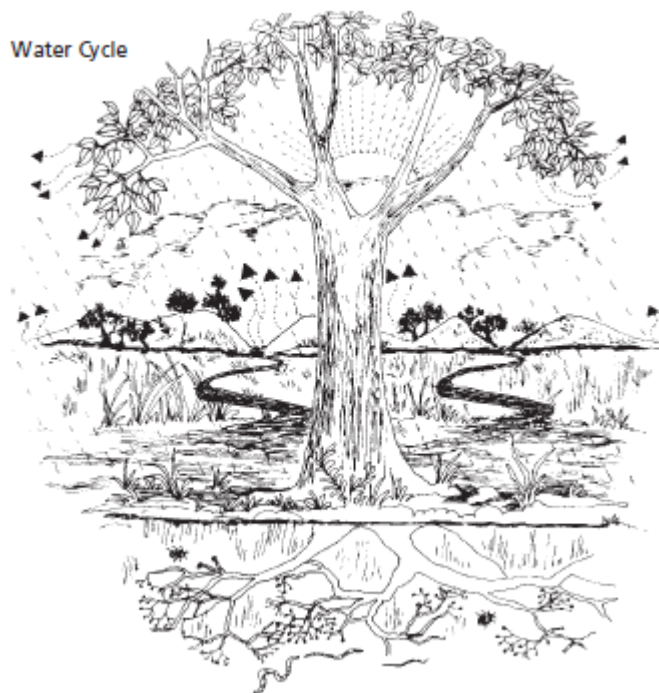
ENERGY FLOW IN THE ECOSYSTEM

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

All the functions of the ecosystem are in some way related to the growth and regeneration of its plant and animal species. These linked processes can be depicted as the various cycles. These processes depend on energy from sunlight. During photosynthesis carbon dioxide is taken up by plants and oxygen is released. Animals depend on this oxygen for their respiration. The water cycle depends on the rainfall, which is necessary for plants and animals to live. The energy cycle recycles nutrients into the soil on which plant life grows. Our own lives are closely linked to the proper functioning of these cycles of life. If human activities go on altering them, humanity cannot survive on our earth.

The Water Cycle

When it rains, the water runs along the ground and flows into rivers or falls directly into the sea. A part of the rainwater that falls on land percolates into the ground. This is stored underground throughout the rest of the year. Water is drawn up from the ground by plants along with the nutrients from the soil. The water is transpired from the leaves as water vapour and returned

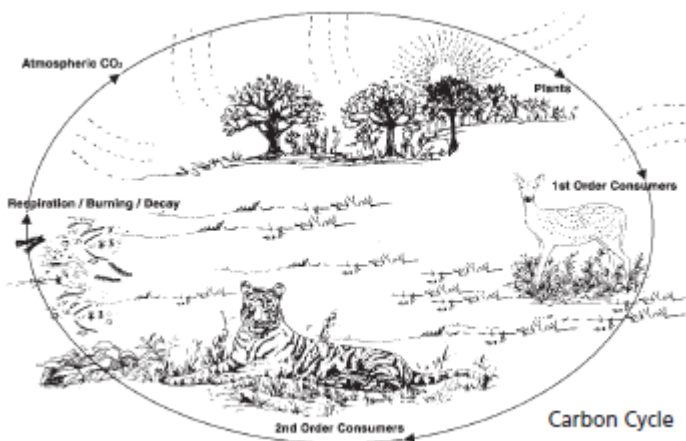


to the atmosphere. As it is lighter than air, water vapour rises and forms clouds. Winds blow the clouds for long distances and when the clouds rise higher, the vapour condenses and changes into droplets, which fall on the land as rain. Though this is an endless cycle on which

life depends, man's activities are making drastic changes in the atmosphere through pollution which is altering rainfall patterns. This is leading to prolonged drought periods extending over years in countries such as Africa, while causing floods in countries such as the US. El Nino storms due to these effects have devastated many places in the last few years.

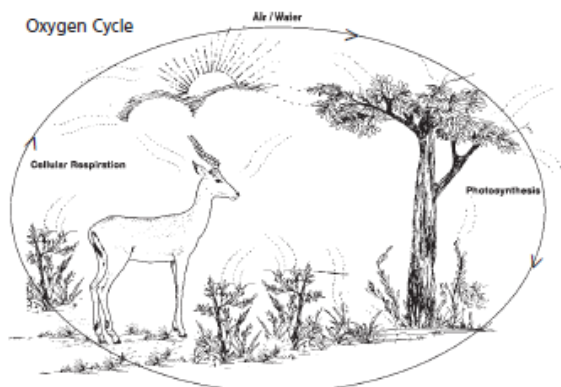
The Carbon cycle

The carbon, which occurs in organic compounds, is included in both the abiotic and biotic parts of the ecosystem. Carbon is a building block of both plant and animal tissues. In the atmosphere, carbon occurs as carbon dioxide (CO₂). In the presence of sunlight, plants take up carbon dioxide from the atmosphere through their leaves. The plants combine carbon dioxide with water, which is absorbed by their roots from the soil. In the presence of sunlight they are able to form carbohydrates that contain carbon. This process is known as photosynthesis. Plants use this complex mechanism for their growth and development. In this process, plants release oxygen into the atmosphere on which animals depend for their respiration. Plants therefore help in regulating and monitoring the percentage of Oxygen and Carbon dioxide in the earth's atmosphere. All of mankind thus depends on



the oxygen generated through this cycle. It also mkeeps the CO₂ at acceptable levels.

Herbivorous animals feed on plant material, which is used by them for energy and for their growth. Both plants and animals release carbon dioxide during respiration. They also return fixed carbon to the soil in the waste they excrete. When plants and animals die they return their carbon to the soil. These processes complete the carbon cycle.

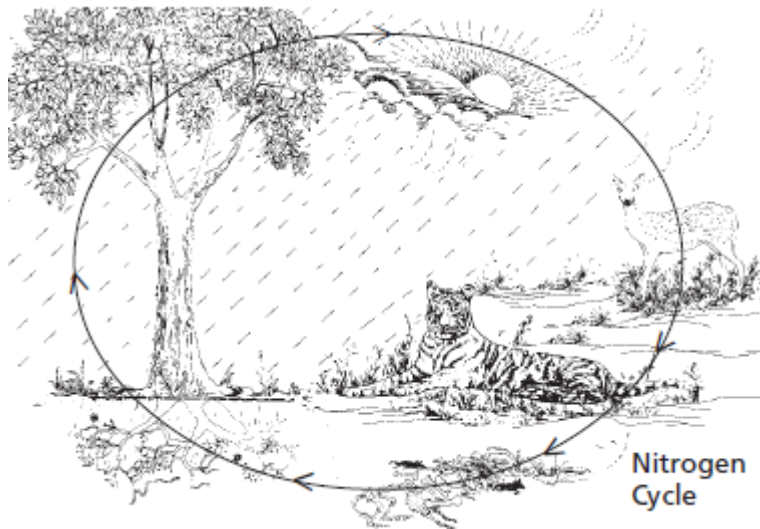


The Oxygen Cycle

Oxygen is taken up by plants and animals from the air during respiration. The plants return oxygen to the atmosphere during photosynthesis. This links the Oxygen Cycle to the Carbon Cycle. Deforestation is likely to gradually reduce the oxygen levels in our atmosphere. Thus plant life plays an important role in our lives which we frequently do not appreciate. This is an important reason to participate in afforestation programs.

The Nitrogen Cycle

Carnivorous animals feed on herbivorous animals that live on plants. When animals defecate, this waste material is broken down by worms and insects mostly beetles and ants. These small 'soil animals' break the waste material into smaller bits on which microscopic bacteria and fungi can act. This material is thus broken down further into nutrients that plants can absorb and use for their growth. Thus nutrients are recycled back from animals to plants. Similarly the bodies of dead animals are also broken down into nutrients that are used by the plants for their growth. Thus the nitrogen cycle on which life is dependent is completed. Nitrogen fixing bacteria and fungi in soil gives this important element to plants, which absorb it as nitrates. The nitrates are a part of the plant's metabolism, which help in forming new plant proteins. This is used by animals that feed on the plants. The nitrogen is then transferred to carnivorous animals when they feed on the herbivores. Thus our own lives are



closely interlinked to soil animals, fungi and even bacteria in the soil. When we think of food webs, we usually think of the large mammals and other large forms of life. But we need to understand that it is the unseen small animals, plants and microscopic forms of life that are of great value for the functioning of the ecosystem.

The Energy Cycle

The energy cycle is based on the flow of energy through the ecosystem. Energy from sunlight is converted by plants themselves into growing new plant material which includes leaves, flowers, fruit, branches, trunks and roots of plants.



Since plants can grow by converting the sun's energy directly into their tissues, they are known as producers in the ecosystem. The plants are used by herbivorous animals as food, which gives them energy. A large part of this energy is used up for day to day functions of these animals such as breathing, digesting food, supporting growth of tissues, maintaining blood flow and body temperature. Energy is also used for activities such as looking for food, finding shelter, breeding and bringing up young ones. The carnivores in turn depend on herbivorous animals on which they feed. Thus the different plant and animal species are linked to one another through food chains. Each food chain has three or four links. However as each plant or animal can be linked to several other plants or animals through many different linkages, these inter-linked chains can be depicted as a complex food web. This is thus called the 'web of life' that shows that there are thousands of interrelationships in nature.

The energy in the ecosystem can be depicted in the form of a food pyramid or energy pyramid. The food pyramid has a large base of plants called 'producers'. The pyramid has a narrower middle section that depicts the number and biomass of herbivorous animals, which are called 'first order consumers'. The apex depicts the small biomass of carnivorous animals called 'second order consumers'. Man is one of the animals at the apex of the pyramid. Thus to support mankind, there must be a large base of herbivorous animals and an even greater quantity of plant material.

When plants and animals die, this material is returned to the soil after being broken down into simpler substances by decomposers such as insects, worms, bacteria and fungi so that plants can Energy Cycle absorb the nutrients through their roots. Animals excrete waste products after digesting food, which goes back to the soil. This links the energy cycle to the Nitrogen cycle.

Integration of cycles in Nature

These cycles are a part of global life processes. These biogeochemical cycles have specific features in each of the ecosystems. These cycles are however linked to those of adjacent ecosystems. Their characteristics are specific to the plant and animal communities in the region. This is related to the geographical features of the area, the climate and the chemical composition of the soil. Together the cycles are responsible for maintaining life on earth. If mankind disturbs these cycles beyond the limits that nature can sustain, they will eventually break down and lead to a degraded earth on which man will not be able to survive.

ECOLOGICAL SUCCESSION

Ecological succession is a process through which ecosystems tend to change over a period of time. Succession can be related to seasonal environmental changes, which create changes in the community of plants and animals living in the ecosystem. Other successional events may take much longer periods of time extending to several decades. If a forest is cleared, it is initially colonized by a certain group of species of plants and animals, which gradually change through an orderly process of community development. One can predict that an opened up area will gradually be converted into a grassland, a shrubland and finally a woodland and a forest if permitted to do so without human interference. There is a tendency for succession to produce a more or less stable state at the end of the successional stages. Developmental stages in the ecosystem thus consist of a pioneer stage, a series of changes known as seral stages, and finally a climax stage. The successive stages are related to the way in which energy flows through the biological system. The most frequent example of successional changes occur in a pond ecosystem where it fluctuates from a dry terrestrial habitat to the early colonisation stage by small aquatic species after the monsoon, which gradually passes through to a mature aquatic ecosystem, and then reverts back to its dry stage in summer where its aquatic life remains dormant.

FOOD CHAINS, FOOD WEBS AND ECOLOGICAL PYRAMIDS

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. These food chains are not isolated sequences, but are interconnected with each other. This interlocking pattern is known as the food web. Each step of the food web is called a trophic level. Hence green plants occupy the first level, herbivores the second level, carnivores the third level and secondary carnivores the fourth level. These trophic levels together form the ecological pyramid.

The food chains

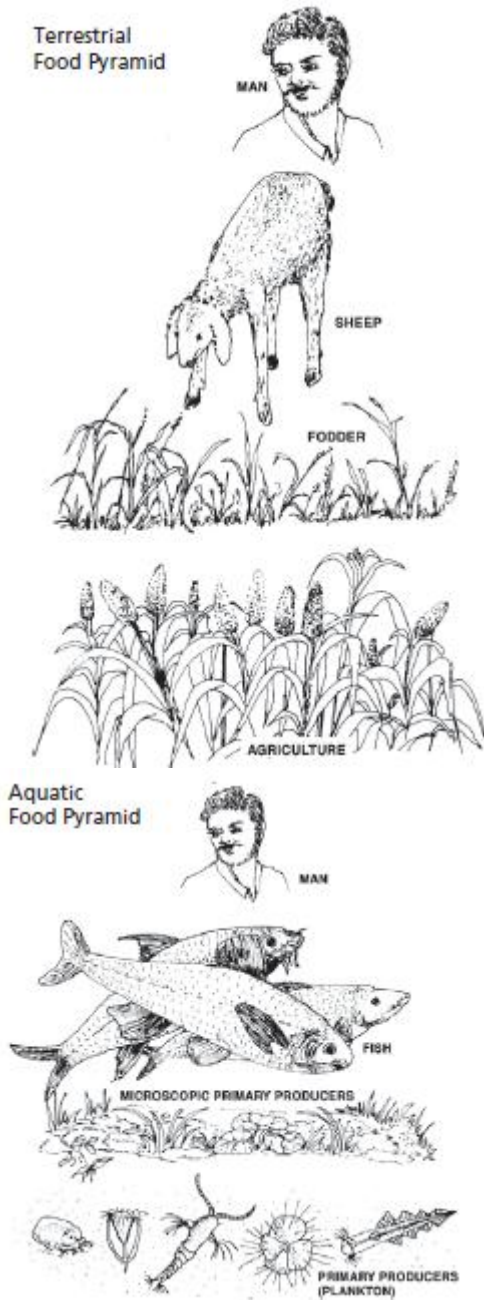
The most obvious aspect of nature is that energy must pass from one living organism to another. When herbivorous animals feed on plants, energy is transferred from plants to animals. In an ecosystem, some of the animals feed on other living organisms, while some feed on dead organic matter. The latter form the 'detritus' food chain. 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.

The food webs

In an ecosystem there are a very large number of interlinked chains. This forms a food web. 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.

The ecological pyramids

In an ecosystem, green plants – the producers, utilize energy directly from sunlight and convert it into matter. A large number of these organisms form the most basic, or first ‘trophic level’ of the food pyramid. The herbivorous animals that eat plants are at the second trophic level



and are called primary consumers. The predators that feed on them form the third trophic level and are known as secondary consumers. Only a few animals form the third trophic level consisting of carnivores at the apex of the food pyramid. This is how energy is used by living

creatures and flows through the ecosystem from its base to the apex. Much of the energy is used up in activities of each living organism.

INTRODUCTION, TYPES, CHARACTERISTIC FEATURES, STRUCTURE AND FUNCTIONS

Types of Ecosystems

Terrestrial Ecosystems

Forest

Grassland

Semi arid areas

Deserts

Mountains

Islands

Aquatic Ecosystems

Pond

Lake

Wetland

River

Delta

Marine

For each of these ecosystems we need to understand 4 basic issues:

1. What is the nature of the ecosystem? What is its structure and its functions?
2. Who uses the ecosystem and for what purpose?
3. How are these ecosystems degraded?
4. What can be done to protect it from deteriorating in the long-term? How can the ecosystem be conserved?

Ecosystem goods and services

Direct Values:

These are resources that people depend upon directly and are easy to quantify in economic terms.

- Consumptive Use Value - Non-market value of fruit, fodder, firewood, etc. that are used by people who collect them from their surrounds.]
- 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.

- Non-consumptive use value – scientific research, bird-watching, ecotourism, etc.
- Option value - maintaining options for the future, so that by preserving them one could reap economic benefits in the future.
- Existence value - ethical and emotional aspects of the existence of wildlife and nature.

Terrestrial ecosystems in their natural state are found in different types of forests, grasslands, semiarid areas, deserts and sea coasts. Where the land is intensively used, these have been gradually modified over several thousand years into agricultural and pastoral regions. In the recent past they have been rapidly converted into intensively irrigated agricultural ecosystems or into urban and industrial centers. Though this has increased production of food and provides the raw material for 'consumer' goods that we use, the overuse and misuse of land and natural ecosystems has led to a serious degradation of our environment. The unsustainable use of environmental goods such as soil, water, fuelwood,

timber from forest, grasses and herbs from grasslands for grazing and repeatedly burning the grass, degrades these natural ecosystems. Similarly, improper use of resources can destroy the services that the natural ecosystems provide. These processes of nature such as photosynthesis, climate control, prevention of soil erosion are disturbed by many human activities. When our human population was small, most ecosystems could supply all our needs. Resources were thus used 'sustainably'. As industrial 'development' led to a very great increase in consumption of resources, the short term economic gains for people became an indicator of progress, rather than long term ecological benefits. This has resulted in an 'unsustainable use' of natural resources. Forests thus disappear, rivers run dry, deserts begin to spread, and air, water and soil become increasingly polluted as by-products of development. Human well being itself is then seriously affected.

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