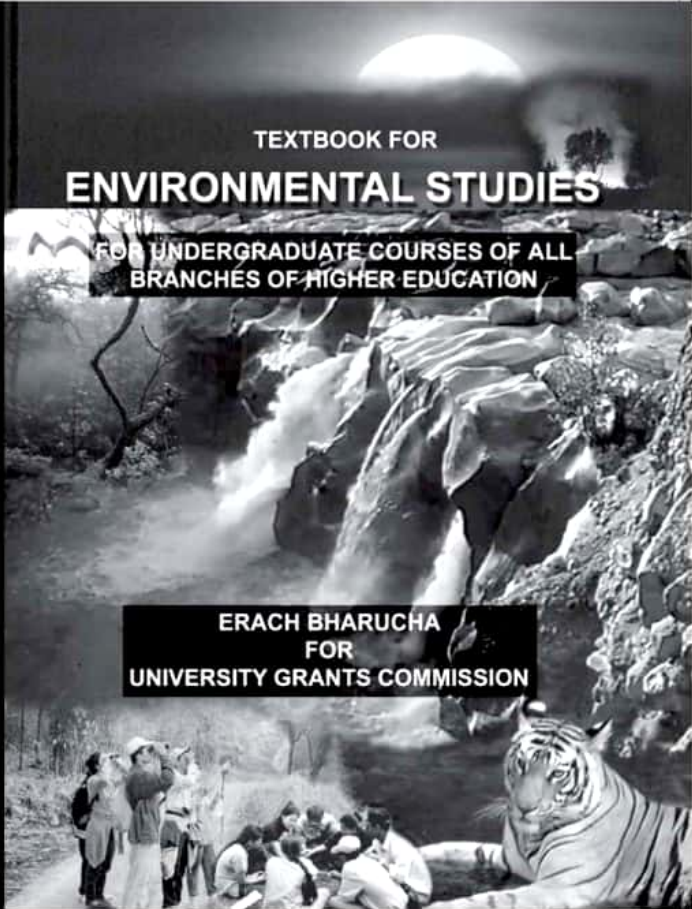




University Grants Commission, New Delhi
and
Bharati Vidyapeeth Institute of Environment Education and Research, Pune

Environmental Studies For Undergraduate Courses
Erach Bharucha



TEXTBOOK FOR
ENVIRONMENTAL STUDIES

FOR UNDERGRADUATE COURSES OF ALL
BRANCHES OF HIGHER EDUCATION

ERACH BHARUCHA
FOR
UNIVERSITY GRANTS COMMISSION

UNIT 3: Ecosystems

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3.1 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 **biogeographical 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 **biogeographic 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 landuse.

3.1.1 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 ones 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.

3.1.2 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, culminatingly 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.

3.1.3 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.

3.2 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.

Since each ecosystem has a non-living and a living part that are linked to each other, one needs to look around us and observe this closely. This is an important aspect that is a vital part of our lives.

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.

3.3 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.



Ecosystems

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

Herbivores



Nectarivores



Frugivores



Granivores

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



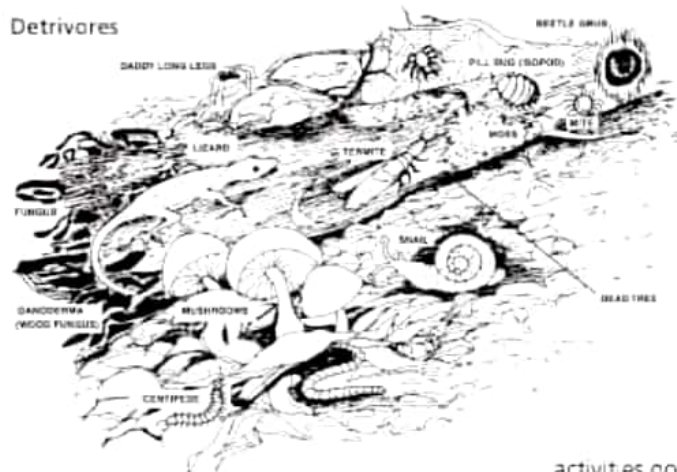
Carnivores

the sea, carnivorous fish live on other fish and marine animals. Animals that live in the sea range in size from microscopic forms to giant mammals such as the whale.

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.

Most ecosystems are highly complex and consist of an extremely large number of individuals

Detritivores



of a wide variety of species. In the species-rich tropical ecosystems (such as in our country), only a few species are very common, while most species have relatively few individuals. Some species of plants and animals are extremely rare and may occur only at a few locations. These are said to be 'endemic' to these areas.

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.

3.4 ENERGY FLOW IN THE ECOSYSTEM

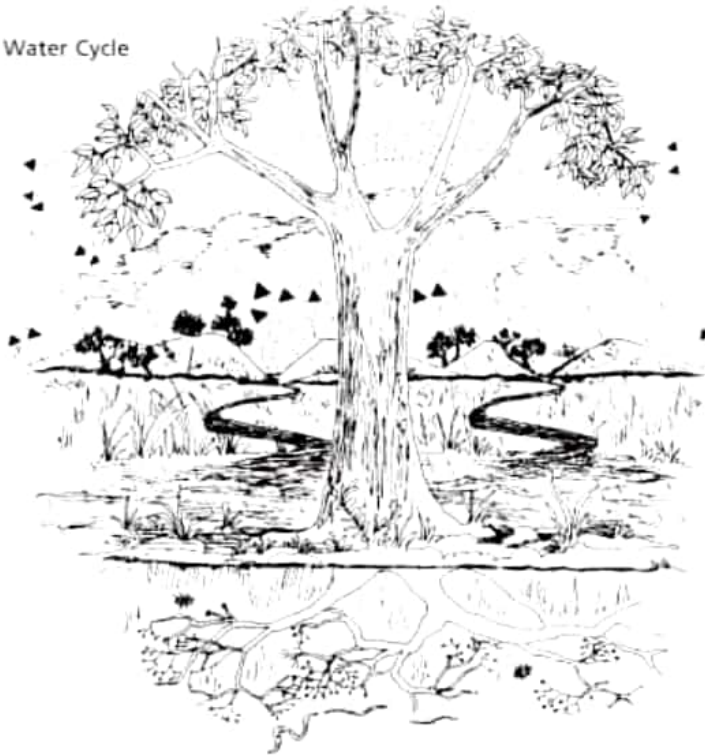
Every ecosystem has several interrelated mechanisms that affect human life. These are the water cycle, the carbon cycle, the oxygen cycle, the nitrogen cycle and the energy cycle. While every ecosystem is controlled by these cycles, in each ecosystem its abiotic and biotic features are distinct from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

3.4.1 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

Water Cycle



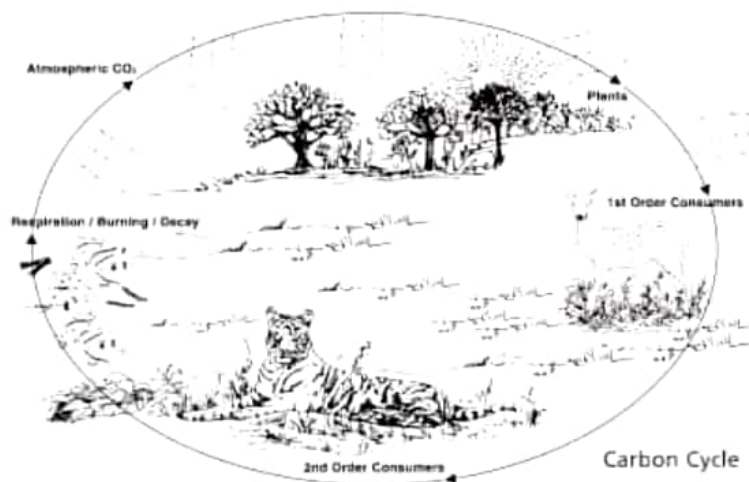
to the atmosphere. As it is lighter than air, water vapour rises and forms clouds. Winds blow the clouds for long distances and when the clouds rise higher, the vapour condenses and changes into droplets, which fall on the land as rain. Though this is an endless cycle on which life depends, man's activities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

Ecosystems

3.4.2 The Carbon cycle

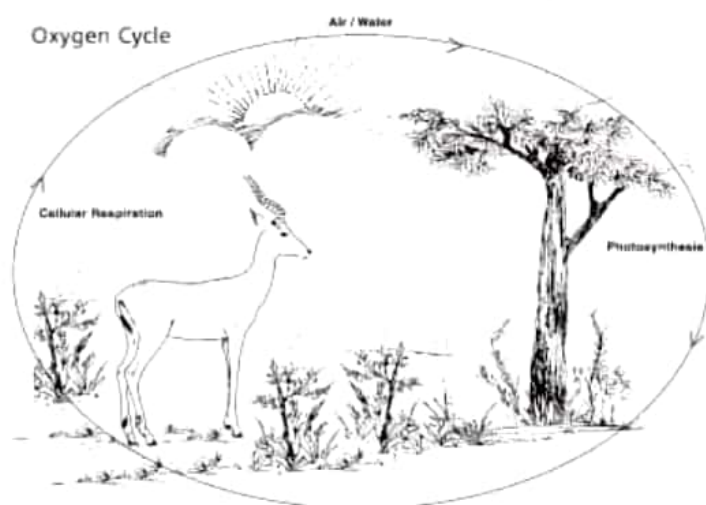
The carbon, which occurs in organic compounds, is included in both the abiotic and biotic parts of the ecosystem. Carbon is a building block of both plant and animal tissues. In the atmosphere, carbon occurs as carbon dioxide (CO_2). In the presence of sunlight, plants take up carbon dioxide from the 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



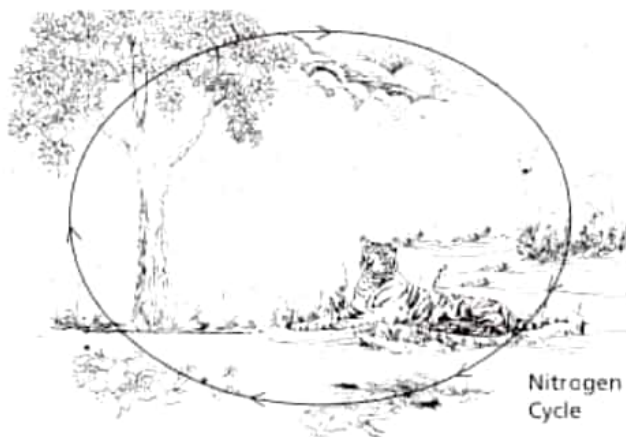
the oxygen generated through this cycle. It also keeps the CO₂ at acceptable levels.

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.



3.4.3 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.



3.4.4 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.

3.4.5 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.



Energy Cycle
Ecosystems

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 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.

3.4.6 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.

3.5 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.

3.6 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.

3.6.1 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.

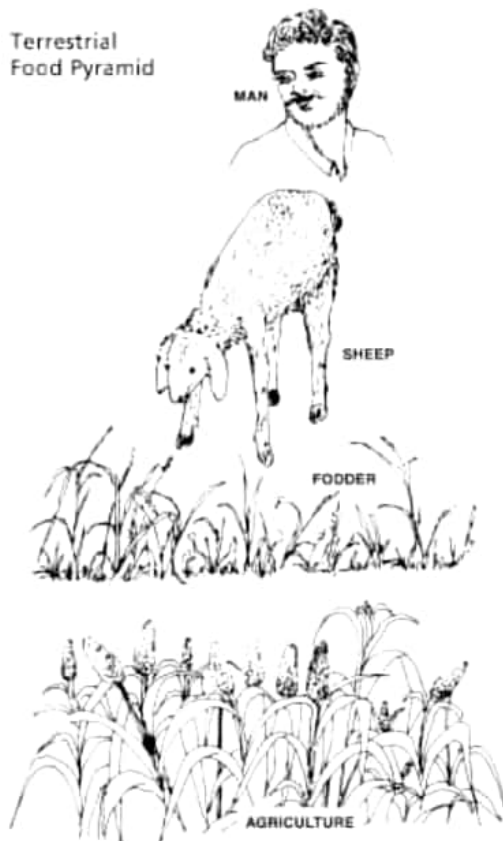
3.6.2 The food webs

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.

3.6.3 The ecological pyramids

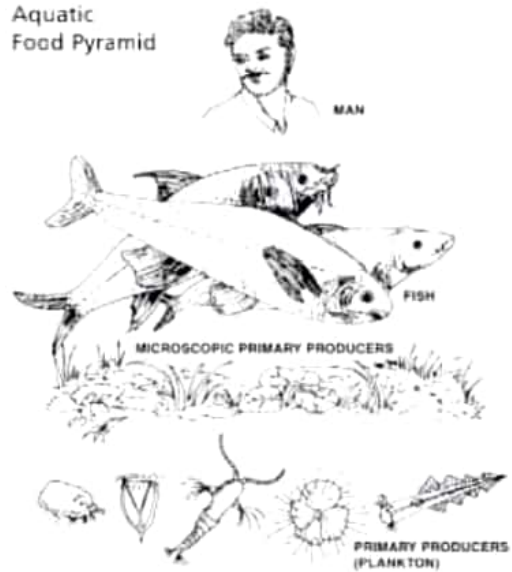
In an ecosystem, green plants – the producers, utilize energy directly from sunlight and convert it into matter. A large number of these organisms form the most basic, or first 'trophic level' of the food pyramid. The herbivorous animals that eat plants are at the second trophic level

Terrestrial Food Pyramid



Ecosystems

Aquatic Food Pyramid



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.

3.7 INTRODUCTION, TYPES, CHARACTERISTIC FEATURES, STRUCTURE AND FUNCTIONS

Types of Ecosystems

Terrestrial Ecosystems	Aquatic Ecosystems
Forest	Pond
Grassland	Lake
Semi arid areas	Wetland
Deserts	River
Mountains	Delta
Islands	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.

3.7.1 Forest ecosystem

Forests are formed by a community of plants which is predominantly structurally defined by its trees, shrubs, climbers and ground cover. Natural vegetation looks vastly different from a group of planted trees, which are in orderly rows. The most 'natural' undisturbed forests are located mainly in our National Parks and Wildlife Sanctuaries. The landscapes that make up various types of forests look very different from each other. Their distinctive appearance is a fascinating aspect of nature. Each forest type forms a habitat for a specific community of animals that are adapted to live in it.

What is a forest ecosystem?

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 and the local temperature which varies according to latitude and altitude. Forests also vary in their plant communities in response to 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. For instance coniferous trees occur in the Himalayas. Mangrove trees occur in river deltas. Thorn trees grow in arid areas. The snow leopard lives in the Himalayas while the leopard and tiger live in the forests of the rest of India. Wild sheep and goats live high up in the Himalayas. Many of the birds of the Himalayan forests are different from the rest of India. Evergreen forests of the Western Ghats and North East India are most rich in plant and animal species.

The **biotic** component includes both the large (macrophytes) and the microscopic plants and animals.

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.

The **animals** include species of mammals, birds, reptiles, amphibians, fish, insects and other invertebrates and a variety of microscopic animals.

As the plant and animal species are closely dependent on each other, together they form different types of forest communities. Man is a part of these forest ecosystems and the local people depend directly on the forest for several natural resources that act as their life support systems. People who do not live in the forest buy forest products such as wood and paper, which has been extracted from the forest. Thus they use forest produce indirectly from the market.

Forest types in India: The forest type depends upon the abiotic factors such as climate and soil characteristics of a region. 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. In many cases a forest is named after the first three or four most abundant tree species.

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



Coniferous forest



Broadleaved forest

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.

Evergreen forests grow in the high rainfall areas of the Western Ghats, North Eastern India and the Andaman and Nicobar Islands. These forests grow in areas where the monsoon lasts for sev-

eral months. Some even get two monsoons, such as in Southern India. Evergreen plants shed a few of their leaves throughout the year. There is no dry leafless phase as in a deciduous forest. An evergreen forest thus looks green throughout the year. The trees overlap with each other to form a continuous canopy. Thus very little light penetrates down to the forest floor. Only a few shade loving plants can grow in the ground layer in areas where some light filters down from the closed canopy. The forest is rich in orchids and ferns. The barks of the trees are covered in moss. The forest abounds in animal life and is most rich in insect life.

Evergreen forest



Environmental Studies for Undergraduate Courses

Deciduous forest



Thorn forest



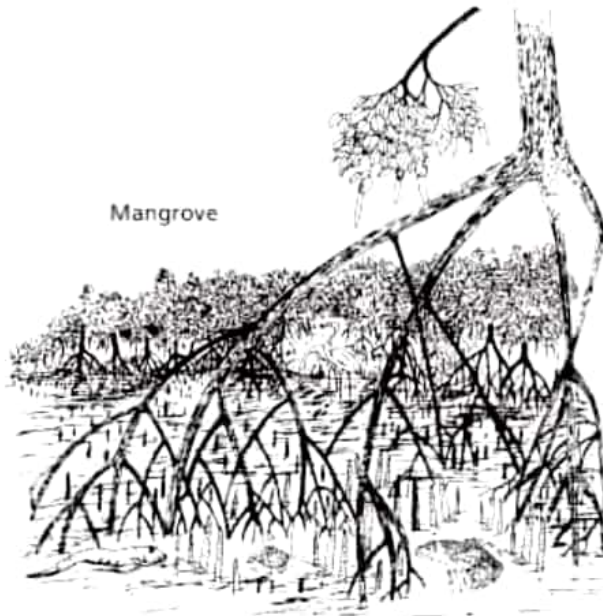
called xerophytic species and are able to conserve water. Some of these trees have small leaves, while other species have thick, waxy leaves to reduce water losses during transpiration. Thorn forest trees have long or fibrous roots to reach water at great depths. Many of these plants have thorns, which reduce water loss and protect them from herbivores.

Mangrove forests grow along the coast especially in the river deltas. These plants are able to grow

Deciduous forests are found in regions with a moderate amount of seasonal rainfall that lasts for only a few months. Most of the forests in which Teak trees grow are of this type. The *deciduous* trees shed their leaves during the winter and hot summer months. In March or April they regain their fresh leaves just before the monsoon, when they grow vigorously in response to the rains. Thus there are periods of leaf fall and canopy regrowth. The forest frequently has a thick undergrowth as light can penetrate easily onto the forest floor.

Thorn forests are found in the semi-arid regions of India. The trees, which are sparsely distributed, are surrounded by open grassy areas. Thorny plants are

Mangrove



Forest communities:

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

in a mix of saline and fresh water. They grow luxuriantly in muddy areas covered with silt that the rivers have brought down. The mangrove trees have breathing roots that emerge from the mudbanks.

Forest utilisation: Natural forests provide local people with a variety of products if the forest is used carefully. Over-exploitation for fuel wood or timber, and conversion to monoculture plantations for timber or other products, impoverishes local people as the economic benefit goes to people who live elsewhere. The entire resource base on which local people have traditionally survived for generations, is rapidly destroyed. Eventually the forest is completely degraded.

Natural forest ecosystems play an important role in controlling local climate and water regimes. It is well-known that under the canopy of a natural forest, it is cooler than outside the forest.

During the monsoon, the forest retains moisture and slowly releases it through perennial streams during the rest of the year. Plantations fail to perform this function adequately. The loss of forest cover in the catchments of a river thus leads to irreversible changes such as excessive soil erosion, large run-off of surface water during monsoons leading to flash floods, and a shortage of water once the monsoons are over.

Forest products that are collected by people include food such as fruit, roots, herbs and medicinal plants. People depend on fuelwood to cook food, collect fodder for domestic animals, cut building material for housing, collect medicinal plants that have been known for generations for several ailments and use a variety of non timber forest products such as fiber, cane, gum, to make household articles. Wood from different species of trees have special uses. For instance a soft wood is used for the yolk of a bullock cart while a very hard wood is used for its axle. These forest products are of great eco-



economic value as they are collected, sold and marketed. Forest dwellers and agricultural people use these goods directly. Other people get them indirectly from the market. Traditional types of agriculture needs forest material such as branches and leaves, which are burnt to form wood ash which acts as a fertiliser for crops such as rice.

Urban people use these forest resources indirectly as all their food and other goods come from agricultural areas that are dependent on the neighbouring forests.

Forest services include the control of the flow of water in streams and rivers. Forest cover reduces surface runoff of rainwater and allows ground water to be stored. Forests prevent erosion of soil. Once soil is lost by erosion, it can take thousands of years to reform. Forests regulate local temperature. It is cooler and more moist under the shade of the trees in the forest. Most importantly, forests absorb carbon dioxide and release oxygen that we breathe.

The wild relatives of our crop plants and fruit trees have special characteristics in their genes which are used to develop new crops and newer varieties of fruit. These newer varieties developed from wild relatives give greater yields or

are more resistant to diseases. New industrial products are being produced from the wild plants of the forest. Many of our new medicines come from wild plants.

Direct uses of forest products

- Fruits – mango, jamun, awla
- Roots – Dioscoria
- Medicine – Gloriosa, Foxglove
- Fuel wood – many species of trees and shrubs
- Small timber for building huts and houses
- Wood for farm implements
- Bamboo and cane for baskets
- Grass for grazing and stall feeding livestock

Indirect uses of forest products

- Building material for construction and furniture for the urban sector
- Medicinal products collected and processed into drugs
- Gums and resins processed into a variety of products
- Raw material for industrial products and chemicals
- Paper from bamboo and softwoods

What are the threats to the forest ecosystem?

As forests grow very slowly, we cannot use more resources than they can produce during a growing season. If timber is felled beyond a certain limit the forest cannot regenerate. The gaps in the forest change the habitat quality for its animals. The more sensitive species cannot survive under these changed conditions. Overutilizing

forest resources is an unsustainable way of misusing our limited forest resources. We are now creating more and more goods that are manufactured from raw material from the forest. This leads to forest degradation and finally changes the ecosystem into wasteland. Wood is illegally extracted from many forests leading to a highly disturbed ecosystem.

Developmental activities such as rapid population growth together with, urbanisation, industrialisation and the increasing use of consumer goods, leads to over utilisation of forest produce. Forests are shrinking as our need for agricultural land increases. It is estimated that India's forest cover has decreased from about 33% to 11% in the last century. The increasing use of wood for timber, wood pulp for paper and the extensive use of fuelwood results in continual forest loss. Forests are also lost by mining and building dams. As the forest resources are exploited beyond what they can produce the forest canopy is opened up, the ecosystem is degraded, and its wildlife is seriously threatened. As the forest is fragmented into small patches its wild plant and animal species become extinct. These can never be brought back. Extinction is forever.

What if the forests disappear?

When forests are cut down tribal people who depend directly on them for food and fuelwood and other products find it very difficult to survive. Agricultural people do not get enough fuelwood, small timber, etc. for making houses and farm implements. Urban people who depend on food from agricultural areas, which in turn depend on neighbouring forest ecosystems have to pay a higher price for food as human population grows.

Insects that live and breed in the forest such as bees, butterflies and moths decrease in abundance once forests are degraded. As their numbers decrease they are unable to effectively pol-

linate agricultural crops and fruit trees. This leads to a decrease in agricultural yields.

The rain that falls on deforested land flows directly into nearby rivers. Thus water is not retained under the ground. People thus do not get a sufficient quantity of water throughout the year. The exposed soil is rapidly washed away during the rains once the protective forest cover is removed. Thus agriculture is seriously affected in such areas. In deforested areas, the water in streams is brown in colour as soil is washed away while water in forested streams is crystal clear.

Wild animals lose their habitat. This leads to extinction of our precious species. Residual forests must be protected from being destroyed any further if all the diverse species of plants and animals are to be kept for future generations.

How can forest ecosystems be conserved?

We can conserve forests only if we use its resources carefully. This can be done by using alternate sources of energy instead of fuelwood. There is a need to grow more trees than are cut down from forests every year for timber. Afforestation needs to be done continuously from which fuelwood and timber can be judiciously used.

The natural forests with all their diverse species must be protected as National Parks and Wildlife Sanctuaries where all the plants and animals can be preserved.

3.7.2 Grassland ecosystems

A wide range of landscapes in which the vegetation is mainly formed by grasses and small annual plants are adapted to India's various climatic conditions. These form a variety of grassland ecosystems with their specific plants and animals.

What is a grassland ecosystem?

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. 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 root stock 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.

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.

Grassland Types in India: Grasslands form a variety of ecosystems that are located in different climatic conditions ranging from near desert conditions, to patches of shola grasslands that occur on hillslopes alongside the extremely moist evergreen forests in South India. In the Himalayan mountains there are the high cold Himalayan pastures. There are tracts of tall elephant grass in the low-lying Terai belt south of the Himalayan foothills. There are semi-arid grasslands in Western India, parts of Central India, and in the Deccan Plateau.

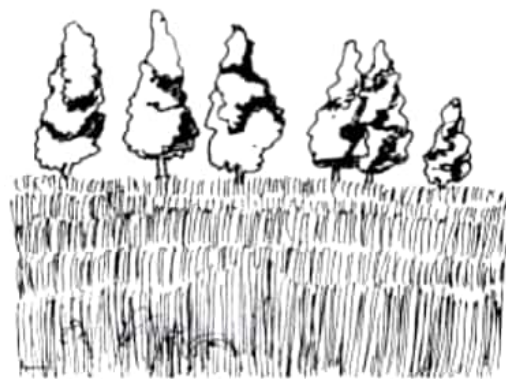
The **Himalayan pasture belt** extends upto the snowline. The grasslands at a lower level form patches along with coniferous or broadleaved forests. Himalayan wildlife require both the forest and the grassland ecosystem as important parts of their habitat. The animals migrate up

Himalayan Pastures



into the high altitude grasslands in summer and move down into the forest in winter when the snow covers the grassland. These Himalayan pastures have a large variety of grasses and herbs. Himalayan hill slopes are covered with thousands of colourful flowering plants. There are also a large number of medicinal plants.

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



Terai grassland

Semiarid grassland



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

Shola grassland



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

Grasslands are not restricted only to low rainfall areas. Certain grassland types form when clearings are made in different forest types. Some are located on the higher steep hill slopes with

patches of forest that occur along the streams and in depressions. The grasslands are related to repeated fires that do not permit the forest to grow.

The grasses are the major producers of biomass in these regions. Each grassland ecosystem has a wide variety of species of grasses and herbs. Some grass and herb species are more sensitive to excessive grazing and are suppressed if the area is over grazed. Others are destroyed by repeated fires and cannot regenerate. Thus overused or frequently burnt grasslands are degraded and are poor in plant species diversity.

How are grasslands used?

Grasslands are the grazing areas of many rural communities. Farmers who keep cattle or goats, as well as shepherds who keep sheep, are highly dependent on grasslands. Domestic animals are grazed in the 'common' land of the village. Fodder is collected and stored to feed cattle when there is no grass left for them to graze in summer. Grass is also used to thatch houses and farm sheds. The thorny bushes and branches of the few trees that are seen in grasslands are used as a major source of fuelwood.

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

What are the threats to grassland ecosystems?

In many areas grasslands have been used for centuries by pastoral communities. Overutilization and changes in landuse of the

'common grazing lands' of rural communities has led to their degradation. The grassland cover in the country in terms of permanent pastures now covers only 3.7 percent of land. A major threat to natural grasslands is the conversion of grasslands into irrigated farmlands. In the Deccan, grasslands have been altered to irrigated farms and are now mainly used to grow sugarcane. After continuous irrigation such land becomes saline and useless in a few years. More recently many of these residual grassland tracts have been converted into industrial areas. This provides short-term economic gains but results in long-term economic and ecological losses.

Grasslands have a limited ability to support domestic animals and wildlife. Increasing this pressure by increasing the number of domestic animals reduces the 'naturalness' of the grassland ecosystem leading to its degradation.

Most grassland ecosystems are highly modified by human activities. Cattle, sheep and goat grazing, and lighting repeated fires affects grasslands adversely. Changing the grasslands to other forms of land use such as agriculture, tree plantations and industrialisation forms a serious threat to this highly productive ecosystem. Thus some of the grassland patches which are in a less disturbed state and have retained their special plants and animals need to be urgently protected.

Degradation of grasslands due to over grazing by cattle, sheep and goats occurs if more than a critical number of domestic animals are present in the grasslands. When animals overgraze the area, the grasses are converted into flat stubs with very little green matter. Degraded grasslands have fewer grass species as the nutritious species are entirely used up by the large number of domestic animals. They are thus unable to regenerate.

When fires are lit in the grasslands in summer, the burnt grass gets a fresh flush of small green

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.

Why are our grassland species vanishing?

Most people feel that it is only our forests and its wildlife that is disappearing. However, other natural ecosystems such as grasslands are disappearing even more rapidly.

Many of the grassland species have disappeared from several parts of India in which they were found 50 or 60 years ago. The Cheetah is extinct in India. The Wolf is now highly threatened. Blackbuck and chinkara are poached for meat. Birds such as the beautiful Great Indian Bustards are vanishing. Unless grassland species are protected they will vanish from their shrinking habitat, as natural and undisturbed grasslands are left in very few locations. If these animals and birds are killed or their habitat is reduced further, their extinction will rapidly follow.

What if our grasslands disappear?

If our grasslands are lost we will lose a highly specialised ecosystem in which plants and animals have been adapted to these habitat conditions over millions of years. Local people will not be able to support their livestock herds.

The extinction of species is a great loss to Mankind. The genes of wild grasses are extremely useful for developing new crop varieties. New medicines could well be discovered from wild grassland plants. It is possible that genes from wild herbivores such as wild sheep, goats and antelopes may be used for developing new strains of domestic animals.

How can grassland ecosystems be conserved?

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

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

What should we do?

- There is a need to preserve the few natural grassland areas that still survive by creating National Parks and Wildlife Sanctuaries in all the different types of grasslands.
- Animals such as the wolf, blackbuck, chinkara and birds such as bustards and floricans have now become rare all over the country. They must be carefully protected in the few National Parks and Wildlife Sanctuaries that have natural grassland habitats as well as outside these Protected Areas.
- 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.

- Keeping grasslands alive is a National priority.

3.7.3 Desert ecosystem

Desert and semi arid lands are highly specialised and sensitive ecosystems that are easily destroyed by human activities. The species of these dry areas can live only in this specialised habitat.

What is a desert or a semi-arid ecosystem?

Deserts and semi arid areas are located in Western India and the Deccan Plateau. The climate in these vast tracts is extremely dry. There are also cold deserts such as in Ladakh, which are located in the high plateaus of the Himalayas. The most typical desert landscape that is seen in Rajasthan is in the Thar Desert. This has sand dunes. There are also areas covered with sparse grasses and a few shrubs, which grow if it rains. In most areas of the Thar the rainfall is scanty and sporadic. In an area it may rain only once every few years. In the adjoining semi arid tract the vegetation consists of a few shrubs and thorny trees such as kher and babul.

The Great and Little Rann of Kutch are highly specialised arid ecosystems. In the summers they are similar to a desert landscape. However as



Desert and Semi arid eco systems

Environmental Studies for Undergraduate Courses

these are low-lying areas near the sea, they get converted to salt marshes during the monsoons. During this period they attract an enormous number of aquatic birds such as ducks, geese, cranes, storks, etc. The Great Rann is famous, as it is the only known breeding colony of the Greater and Lesser Flamingos in our country. The Little Rann of Kutch is the only home of the wild ass in India.

Desert and semi-arid regions have a number of highly specialized insects and reptiles. The rare animals include the Indian wolf, desert cat, desert fox and birds such as the Great Indian Bustard and the Florican. Some of the commoner birds include partridges, quails and sandgrouse.

How are desert and semi-arid ecosystems used?

Areas of scanty vegetation with semi-arid scrubland have been used for camel, cattle and goat grazing in Rajasthan and Gujarat, and for sheep grazing in the Deccan Plateau.

Areas that have a little moisture, such as along the watercourses, have been used for growing crops such as jowar, and bajra. The natural grasses and local varieties of crops have adapted to growing at very low moisture levels. These can be used for genetic engineering and developing arid land crops for the future.

What are the threats to desert ecosystems?

Several types of development strategies as well as human population growth have begun to affect the natural ecosystem of the desert and semi-arid land. Conversion of these lands through extensive irrigation systems has changed several of the natural characteristics of this region. The canal water evaporates rapidly bringing the salts to the surface. The region becomes highly unproductive as it becomes saline. Pulling excessive groundwater from tube

wells lowers the water table creating an even drier environment. Thus human activities destroy the naturalness of this unique ecosystem. The special species that evolved here over millions of years may soon become extinct.

How can desert ecosystems be conserved?

Desert ecosystems are extremely sensitive. Their ecological balance that forms a habitat for their plants and animals is easily disturbed. Desert people have traditionally protected their meagre water resources. The Bishnois in Rajasthan are known to have protected their Khejdi trees and the blackbuck antelope for several generations. The tradition began when the ruler of their region ordered his army to cut down trees for his own use. Several Bishnois were said to have been killed while trying to protect their trees.

There is an urgent need to protect residual patches of this ecosystem within National Parks and Wildlife Sanctuaries in desert and semi-arid areas. The Indra Gandhi Canal in Rajasthan is destroying this important natural arid ecosystem, as it will convert the region into intensive agriculture. In Kutch, areas of the little Rann, which is the only home of the Wild Ass, will be destroyed by the spread of salt works.

Development Projects alter the desert and arid landscape. There is a sharp reduction in the habitat available for its specialised species bringing them to the verge of extinction. We need a sustainable form of development that takes the special needs of the desert into account.

3.7.4 Aquatic ecosystems

The aquatic ecosystems constitute the marine environments of the seas and the fresh water systems in lakes, rivers, ponds and wetlands. These ecosystems provide human beings with a wealth of natural resources. They provide goods that people collect for food such as fish and



crustaceans. Natural aquatic systems such as rivers and seas break down chemical and organic wastes created by man. However, this function has limitations, as the aquatic ecosystem cannot handle great quantities of waste. Beyond a certain limit, pollution destroys this natural function.

If aquatic ecosystems are misused or over utilized, their ability to provide resources suffers in the long term. Over-fishing leads to a fall in the fish catch. River courses that are changed by dams to provide electricity affect thousands of people who do not get a continuous supply of water downstream for their daily use. When wetlands are drained, their connected rivers tend to cause floods. These are all examples of unsustainable changes in the use of natural resources and nature's ecosystems that are dependent on hydrological regimes.

Water is an important factor in all our ecosystems. Several ecosystems exist in freshwater and

marine salt water. There is very little fresh water on earth, which is a key resource for people all over the world.

What is an aquatic ecosystem?

In aquatic ecosystems, plants and animals live in water. These species are adapted to live in different types of aquatic habitats. The special abiotic features are its physical aspects such as the quality of the water, which includes its clarity, salinity, oxygen content and rate of flow. Aquatic ecosystems may be classified as being **stagnant** ecosystems, or **running water** ecosystems. The mud gravel or rocks that form the bed of the aquatic ecosystem alter its characteristics and influence its plant and animal species composition. The aquatic ecosystems are classified into **freshwater**, **brackish** and **marine** ecosystems, which are based on the salinity levels.

The fresh water ecosystems that have running water are streams and rivers. Ponds, tanks and lakes are ecosystems where water does not flow. *Wetlands* are special ecosystems in which the water level fluctuates dramatically in different seasons. They have expanses of shallow water with aquatic vegetation, which forms an ideal habitat for fish, crustacea and water birds.

Marine ecosystems are highly saline, while brackish areas have less saline water such as in river deltas. *Coral reefs* are very rich in species and

Types of Aquatic ecosystems

Fresh water ecosystems			Marine ecosystems		
Flowing water		Still water	Brackish water	Saline water	
Streams	Rivers	Ponds, wetlands, lakes	Deltas	Coastal shallows, Coral reefs	Deep ocean

are found in only a few shallow tropical seas. The richest coral reefs in India are around the Andaman and Nicobar islands and in the gulf of Kutch.

Brackish water ecosystems in river deltas are covered by mangrove forests and are among the world's most productive ecosystems in terms of biomass production. The largest mangrove swamps are in the Sunderbans in the delta of the Ganges.

The Pond ecosystem

The pond is the simplest aquatic ecosystem to observe.

There are differences in a pond that is temporary and has water only in the monsoon, and a larger tank or lake that is an aquatic ecosystem throughout the year. Most ponds become dry after the rains are over and are covered by terrestrial plants for the rest of the year.

When a pond begins to fill during the rains, its life forms such as the algae and microscopic animals, aquatic insects, snails, and worms come out of the floor of the pond where they have remained dormant in the dry phase. Gradually more complex animals such as crabs, frogs and fish return to the pond. The vegetation in the



Ecosystems

water consists of floating weeds and rooted vegetation on the periphery which grow on the muddy floor under water and emerge out of the surface of the water.

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

Lake ecosystem

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

Energy cycles through the lake ecosystem from the sunlight that penetrates the water surface to the plants. From plants energy is transferred to herbivorous animals and carnivores. Animals excrete waste products, which settle on the bottom of the lake. This is broken down by small ani-

mals that live in the mud in the floor of the lake. This acts as the nutrient material that is used by aquatic plants for their growth. During this process plants use Carbon from CO_2 for their growth and in the process release Oxygen. This Oxygen is then used by aquatic animals, which filter water through their respiratory system.

Stream and River ecosystems

Streams and rivers are flowing water ecosystems in which all the living forms are specially adapted to different rates of flow. Some plants and animals such as snails and other burrowing animals can withstand the rapid flow of the hill streams. Other species of plants and animals such as water beetles and skaters can live only in slower moving water. Some species of fish, such as Mahseer, go upstream from rivers to hill streams for breeding. They need crystal clear water to be able to breed. They lay eggs only in clear water so that their young can grow successfully.

As deforestation occurs in the hills the water in the streams that once flowed throughout the year become seasonal. This leads to flash floods in the rains and a shortage of water once the streams dry up after the monsoon.

The community of flora and fauna of streams and rivers depends on the clarity, flow and oxygen content as well as the nature of their beds. The stream or river can have a sandy, rocky or muddy bed, each type having its own species of plants and animals.

Marine ecosystems

The Indian Ocean, the Arabian Sea and the Bay of Bengal constitute the marine ecosystems around peninsular India. In the coastal area the sea is shallow while further away, it is deep. Both these are different ecosystems. The producers

in this ecosystem vary from microscopic algae to large seaweeds. There are millions of zooplankton and a large variety of invertebrates on which live fish, turtles and marine mammals.

The shallow areas near Kutch and around the Andaman and Nicobar Islands are some of the most incredible coral reefs in the world. Coral reefs are only second to tropical evergreen forests in their richness of species. Fish, crustacea, starfish, jellyfish and the polyps that deposit the coral are a few of the thousands of species that form this incredible world under the shallow sea.

Deforestation of adjacent mangroves leads to silt being carried out to sea where it is deposited on the coral which then dies. There are many different types of coastal ecosystems which are highly dependent on the tide.

The marine ecosystem is used by coastal fisherfolk for fishing which forms their livelihood. In the past, fishing was done at a sustainable level. The marine ecosystem continued to maintain its abundant supply of fish over many generations. Now with intensive fishing by using giant nets and mechanised boats, fish catch in the Indian Ocean has dropped significantly.

Seashore ecosystems

Beaches can be sandy, rocky, shell covered or muddy. On each of these different types, there are several specific species which have evolved to occupy a separate niche. There are different crustacea such as crabs that make holes in the sand.

Various shore birds feed on their prey by probing into the sand or mud on the sea shore.

Several different species of fish are caught by fishermen. In many areas the fish catch has decreased during the last decade or two.

How are aquatic ecosystems used?

Man uses aquatic ecosystems for the clean fresh-water on which his life is completely dependent. We need clean water to drink and for other domestic uses. Water is essential for agriculture. Fisherfolk use the aquatic ecosystems to earn a livelihood. People catch fish and crabs. They also collect edible plants. This is used locally as food or for sale in the market. Over fishing leads to a serious decline in the catch and a long-term loss of income for fisherfolk.

Marshes and wetlands are of great economic importance for people who live on their fish, crustacea, reeds, grasses and other produce.

Modern man impounds water in dams to be able to store it throughout the year. Agriculture and industry are highly dependent on large quantities of water. However this leads to problems for tribal people who have lived there before the dams were built as they are displaced to build large dams. These dams make rich people richer in the farmland and supports people in large urban centres that use enormous quantities of water. The poor tribal folk become even poorer as the natural resources they depend on are taken away as their lands are submerged under the water of the dam.

Dams are built across rivers to generate electricity. A large proportion of this energy is used by urban people, by agriculturists in irrigated farmlands and in enormous quantities for industry. Large dams have serious ill effects on natural river ecosystems. While water from dams used for irrigation has led to economic prosperity in some areas, in semi-arid areas that are artificially irrigated the high level of evaporation leads to severe salinisation as salts are brought up into the surface layers of the soil. This makes such lands gradually more and more saline and unproductive.

What are the threats to aquatic ecosystems?

Water pollution occurs from sewage and poorly managed solid waste in urban areas when it enters the aquatic ecosystem of lakes and rivers. Sewage leads to a process called eutrophication, which destroys life in the water as the oxygen content is severely reduced. Fish and crustacea cannot breathe and are killed. A foul odour is produced. Gradually the natural flora and fauna of the aquatic ecosystem is destroyed.

In rural areas the excessive use of fertilisers causes an increase in nutrients, which leads to eutrophication. Pesticides used in adjacent fields pollute water and kills off its aquatic animals. Chemical pollution from industry kills a large number of life forms in adjacent aquatic ecosystems. Contamination by heavy metals and other toxic chemicals affects the health of people who live near these areas as they depend on this water.

CASE STUDY

Threats to wetlands in Assam

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

How can aquatic ecosystems be conserved?

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

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

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